Energy Finance Italia III

Pescara (Italy), February 15 – 16, 2018
complesso AURUM, Largo Gardone Riviera

Scientific Committee

- Federico BOFFA (University of Bolzano)
- Rita Laura D'ECCLESIA (University of Roma 'La Sapienza')
- Stefano FIORENZANI (Phinergy Srls)
- Fulvio FONTINI (University of Padova)
- Hlyette GEMAN (Birkbeck - University of London and Johns Hopkins University)
- Michele GOVERNATORI (Axpo Italia)
- Carlo LUCHERONI (University of Camerino)
- Carlo MARI (University of Chieti-Pescara)
- Carlo MENCHINI (ENI S.p.A.)
- Alessandro SAPIO (University of Napoli 'Parthenope')
- Elisa SCARPA (Edison S.p.A.)
- Stefan TRUECK (Macquarie University)
- Tiziano VARGIOLU (University of Padova)
- Rafał WERON (Wroclaw University of Science and Technology)

Organizing committee

- Carlo MARI, University of Chieti - Pescara, chair
- Carlo LUCHERONI, University of Camerino, co-chair

Local organizing Committee

- Cristina CAROLI COSTANTINI (University of Chieti-Pescara)
- Claudia CECI (University of Chieti-Pescara)
- Guglielmo D'AMICO (University of Chieti-Pescara)
- Cristina DI GIROLAMI (University of Chieti-Pescara)
- Marcella MARRA (University of Chieti-Pescara)

Program

Thursday, February 15

morning	**Sala Tosti**
09.00 - 09.45	Registration
09.45 - 10.00	Welcome
10.00 - 11.00	**Energy markets** Chair: Carlo Lucheroni
10.00	Carlo Sala
10.25	Discussant: Tiziano Vargiolu
10.30	Marco Piccirilli
10.55	Discussant: Carlo Sala
11.00 - 11.30	Coffee Break
11.30 - 13.00	**Energy derivatives** Chair: Alessandro Sapio
11.30	Emanuele Fabbiani
11.55	Discussant: Marco Piccirilli
12.00	Maren Schmeck
12.25	Discussant: Emanuele Fabbiani
12.30	Piergiacomo Sabino
12.55	Discussant: Maren Schmeck
12.30 - 14.00	Lunch
afternoon	**Sala Tosti**
14.30 - 16.00	**Econometrics of energy markets** Chair: Guglielmo D'Amico
14.30	Pierluigi Vellucci
14.55	Discussant: Alessandro Sapio
15.00	Alessandro Sapio
15.25	Discussant: Pierluigi Vellucci
15.30 - 16.00	Coffee Break
16.00 - 17.00	**Renewables** Chair: Paolo Falbo
16.00	Filippo Petroni
16.25	Discussant: Carlo Lucheroni
16.30	Tiziano Vargiolu
16.55	Discussant: Filippo Petroni
17.00	**Riunione scientifica**
20.30	Social dinner at the restaurant **Alcyione** viale della Riviera 24

Friday, February 16

morning	**Sala Tosti**
09.30 - 11.00	**Electricity pricing models** Chair: Tiziano Vargiolu
09.30	Fulvio Fontini
09.55	Discussant: Mauro Rosestolato
10.00	Luca Maria Giordano
10.25	Discussant: Fulvio Fontini
10.30	Mauro Rosestolato
10.55	Discussant: Luca Maria Giordano
11.00 - 11.30	Coffee Break
11.30 - 13.00	**Environmental markets** Chair: Fulvio Fontini
11.30	Paolo Falbo
11.55	Discussant: Maria Flora
12.00	Patrizio Morganti
12.25	Discussant: Paolo Falbo
12.30	Maria Flora
12.55	Discussant: Patrizio Morganti
13.00 - 14.30	Lunch
afternoon	**Sala Tosti**
14.30 - 16.00	**Environmental and energy risk management** Chair: Carlo Mari
14.30	Cristian Pelizzari
14.55	Discussant: Emmanuel Fiano
15.00	Hyeri Yu
15.25	Discussant: Cristian Pelizzari
15.30	Emmanuel Fianu
15.55	Discussant: Hyeri Yu
16.00 - 16.30	Coffee Break
16.30	**Closing**

Abstracts

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

Emanuele Fabbiani, (emanuele.fabbiani01@universitadipavia.it), *Andrea Marziali, Giuseppe De Nicolao*

Fast calibration of two-factor model for energy option pricing

During the last two decades, the liberalization of energy markets boosted the interest in energy derivates, among which European vanilla options are widely represented. Pricing and option is critical for any energy company, both as a stand-alone task and as a calibration of stochastic models of the underlying. Monte Carlo simulations can then be run with calibrated models to price more complex derivatives, like Virtual Power Plants (VVP). The Black-Sholes formulae provide a closed-form solution for the price of a European vanilla option, assuming a Geometric Brownian Motion (GBM) model for underlying. Differently from most equities, however, energy commodities exhibit a mean-reverting behaviour, not captured by GBM. Thus the need of more appropriate models to describe the volatility of the underlying as a function of maturity, a key factor in the pricing formula. We considered both single- and two factor mean-reverting linear stochastic models. In both cases, the time evolution of the covariance matrix of the state of the linear stochastic system obeys a Lyapunov differential equation, whose direct solution may therefore represent an effective alternative to computationally approaches to solve the differential Lyapunov equation. In both cases, the key point is the computation of a Gramian integral - a well-known problem in matrix algebra, whose solution can be obtained via a proper matrix exponential. A comparison between the numerical and the analytical approaches is then carried out in terms of computational speed. We found the analytical solution to be 30 to 40 times faster.

Paolo Falbo, (paolo.falbo@unibs.it), *Cristian Pelizzari, Luca Taschini*

Renewables, Allowances Markets, and Capacity Expansion in Energy-Only Markets

We investigate the combined effect of an Emissions Trading System (ETS) and renewable energy sources on electricity generation investments in energy-only markets. We propose a simple representation of the long-term capacity expansion decision involving fossil fuel and renewable production, where electricity demand is uncertain. Increasing renewable capacity creates a tradeoff for large fossil fuel and renewables plants owners: a higher share of renewable production can be priced at the higher marginal cost of fossil fuel production, yet the likelihood of achieving higher profits is reduced because more electricity demand is met by cheaper renewable production. This work analyses how an ETS affects the profits resulting from long-term capacity expansion decisions. This line of analysis adds to the growing literature that stresses the need to account for the full effects of co-existing emission con- straints and renewable energy policies due to the sometimes conflicting incentives of the stakeholders involved. Acknowledging these effects is critically important for the design of long-term electricity markets, as conflicting incentives can often lead to suboptimal outcomes, or even outcomes contradictory to the compelling goals of the environmental policy. Contributions in the literature have investigated the incentives of fossil fuel energy producers to increase the share of renewables in their energy portfolios. It has been shown that in an oligopolistic setup, installations of renewable capacity can actually decrease net welfare as a result of reductions in energy production when the supply of renewables is high. Because we focus on the long-term capacity expansion decision, we also assume a cooperative oligopolistic setup

to examine the interplay between the essorts of the regulatory authority, the incentives of electricity producers, and the prices of electricity and allowances. The choice of an oligopoly aligns with the observed dominance of large electricity players and the presence of industry associations affecting the long-term developments in electricity markets. Our formulation is probably the simplest allowing one to examine the long- term capacity expansion decision in energy-only markets1 operating under an ETS. Specifically, we propose an optimisation of expected profits in the electricity sector, where the decision variables are the installation levels of the generation capacities. This energy-mix decision is uncertain, because the future electricity demand is unknown. Our approach is positive: we do not undertake a full-fledged welfare analysis. Rather, we focus our attention on key socio-economic variables, such as the percentages of renewable generation and fossil fuel generation, the level of electricity prices, and the level of profits accruing to the electricity sector associated with an ETS. Considering three market settings, representing stylised stages of an ETS, a quantitative illustration of our model shows that the higher the share of electricity demand satisfied with renewables, the greater the incentive to re- strain from investing in them. Moreover, depending on the level of pass-through of allowance costs into electricity prices, agents even prefer to reduce green capacity (by disconnecting green technologies from the grid, or dismantling them). As our model predicts, we observe that there is a general incentive to maintain a substantial fossil fuel generation. In fact, the only market setting where renew- able capacity increases is when the initial renewable capacity is limited and the emissions cap is rather generous. These results provide insights into the observed decline of new investments in renewables in Europe,2 where the flagship ETS is entering its fourth (more stringent) Phase and the existing share of renewable capacity is relatively large. As such, our analysis also contributes to the discussion on the current reform of energy and environmental policies. We demonstrate our theoretical results using a quantitative example and show that producers prefer withholding investments in renewable energy sources, call- ing into question the long-term effectiveness of an ETS. The sensitivity analysis confirms these conclusions.

Emmanuel Senyo Fianu, (emmanuelsenyo.fianu@gmail.com), *Daniel Felix Ahelegbey, Luigi Grossi*

A Network Framework of Investigating Systemic Risk in Zonal Energy Markets

Deregulation of energy markets has led to increase volatilities in energy prices. Cost of investments are therefore quite huge for market participants, and thus require prudent investment decisions. This paper therefore employs the recently proposed state of the art network modelling techniques known as the Bayesian graphical vector autoregressive (BG-VAR) model to examine the complex network dynamics in zonal power market movements. In addition, it accommodates the statistical and computational challenges associated with inference of interdependence (or temporal dependence) from observed multivariate time series. Our findings show the relevance of this methodology in studying interconnectedness, extracting useful hidden spatial information. In particular, various network measures have been explored in view of systemic risk spread, which therefore provide a benchmark for proper energy risk management as well as ensuring energy supply reliability and security.

Maria Flora (maria.flora@phd.unipd.it*, Tiziano Vargiolu*

Price dynamics in the EU ETS and evaluation of its ability to boost emssion-related investment decisions

We assess the effects of the European Union emission trading scheme $EUETS$ in delivering low-carbon investments at the firm level, by modeling a price taker electricity producer

subject to the EU ETS jurisdiction. We compute, via Monte Carlo methods and dynamic programming, the value of the real option the greenhouse gas emitter has, consisting in the opportunity to switch from its current high-carbon technology to a cleaner one. We evaluate this real option by proposing an extension to the model presented by introducing a different stochastic process, both for fuel and carbon prices, in place of the geometric brownian motion (GBM). Specifically, we propose a Brennan-Schwarz model, which exhibits positive mean-reverting prices, for fuel and a Variance Gamma (VG) specification for carbon prices. Moreover, we further analyze the investment decision problem, in case of CO_2 price stabilization mechanism, by explicitly computing the expected value of the investment project by means of Fourier methods. Our results show that the introduction of a price stabilization mechanisms, in this case a carbon floor price, significantly affects the timing of the investment decision, supporting emission related investments.

Fulvio Fontini (fulvio.fontini@unipd.it*, Massimiliano Caporin, Paolo Santucci de Magistris*

Price convergence within and between the Italian electricity day-ahead and dispatching services markets

In the paper we study the convergence of prices in the electricity markets, both at the day- ahead level and for the dispatching services (such as balancing and reserves). We introduce two concepts of price convergence, the convergence of zonal prices within each market, convergence within, and the converge of prices in a given zone between the two markets, convergence between. We provide an extensive analysis based on Italian data of within and between convergence. The zonal time-series of the prices are evaluated, seasonally adjusted and tested to assess their long-run properties. This evaluation induces us to focus on the behavior of the three largest and most interconnected continental Italian zones (North, Center-North and Center-South). The fractional cointegration methodology used in the analyses shows the existence of long-run relationship among the series used in our study. This signals the existence of price convergence within markets, even though for the dispatching services market the evidence is less robust. The analysis shows also the existence of price convergence between markets in each zone, even though the evidence is more clearly armed for the North zone (the larger Italian zone), less so for the other two zones. Results are interpreted on the basis of the characteristics of the markets and the zones.

Luca Maria Giordano (luca.giordano@unimi.it), *Daniele Morale*

A Fractional Jump-Diffusion Model for the Daily Italian Electricity Spot Price

The electricity spot prices have many specific features, which are not always shared by the other commodities markets. For example, they exhibit sharp price spikes, have a strong weekly periodicity, and often also a yearly periodicity, among others. Among the different features of the spot price Y_t, one that is not often taken into account is the presence of self-correlations in the price increments $Y_t - Y_{t-1}$. The presence of this feature suggests, when trying to model these kind of markets, to modify the structure of the existing models to include the self-correlations. One of the possible choices that have been used in literature so far is to consider a fractionally integrated ARFIMA model, a generalisation of the classical ARIMA model, as it has been done in [1], and in other cases reported in the review. In particular, in [1] this has been done for the Italian electricity market. From the point of view of reduced- form models, the natural adaptation might be to consider a fractional Brownian motion (fBm), instead of the standard Brownian motion, as the driving noise. This is the direction of this work. We consider as a study case the time series of the hourly day-ahead electricity price determined on a national basis (Prezzo unico d?acquisto, PUN),

from January, 1st 2009 to December, 31st 2016. In particular we average along the day, obtaining a signal $\{Y_t\}_{t21,...,n}$ of dimension n = 2922. The choice of averaging over the entire day has been made since the reduced-form models, due to their simple structure, usually have a poor performance on hourly prices, while they perform better from the daily to monthly scale [2].

Patrizio Morganti (morganti@unitus.it), *Giuseppe Garofalo*

Electricity white certificates in Italy: market and regulatory determinants

The path towards low-carbon economies using renewable energy also includes energy efficiency targets. Improving energy efficiency is one of the most cost-effective way to reduce greenhouse gas emissions and improve energy security. The EU Energy Efficiency Directive (EED) sets a 20% energy-saving target by 2020, and energy efficiency is one of main goal of the EU's Energy Union Strategy (EC 2015). Energy efficiency is usually achieved through market-based, tradable, energy efficiency obligations (EEO) also known as white certificate (WC) schemes. In Europe several countries, such as the United Kingdom, Italy, France, Denmark and the Flemish region of Belgium, have already implemented a white certificate scheme on some categories of energy market operators, mostly electricity and gas distributors or suppliers (Bertoldi et al. 2010, Stede 2017). The Italian WC scheme is one of the most successful and relevant example of implementing EEO in the EU, and thus it is attracting a lot of interest from researchers, academics, experts and institutions.1 The Italian white certificates scheme was introduced in January 2005, after the implementation of the EU Directive on the liberalization of the electricity and natural gas markets. Since then, the annual primary energy-saving targets have grown steadily, up to 7.6 Mtoe in 2016, with 9.7 Mtoe expected for 2020 (approximately 6.4% of Italy's 2015 primary energy consumption - BP 2016, MiSE 2014). The regulatory framework plays a crucial role in achieving energy-saving targets. The changes introduced by the ministerial decree DM 28/12/12, in particular the ?tau? coefficient, have significantly influenced certificate emissions during 2013-2016 (GSE 2017). Prior to 2012, target compliance decreased continuously until its low of 64% in 2011, reflecting the inability of the system to implement effective energy efficiency measures in the industrial sector (ENEA 2017, Stede 2017). In recent years, Italy has succeeded to shift the majority of energy efficiency measures from the residential and tertiary sectors to industry, which is the sector estimated to provide nearly 25% of total EU final energy consumption (Eurostat 2017a). In 2013 and 2014 target compliance reached 100%, and nowadays the Italian industrial sector is expected to deliver 94% of the energy savings under the white certificate scheme up to 2020 (ENEA 2017, ENSPOL 2016). However, Italy has the highest electricity prices among the major European economies and an energy dependency rate of more than 75%, well above European average (Eurostat 2017b,c). The goal of this paper is to provide a comprehensive economic analysis of the electricity white certificate scheme in Italy by i) investigating the relative contribution to Type I WC price from market and regulatory determinants, and by ii) shedding light on the misalignments that has arisen between the dynamics of the WC prices and the wholesale electricity prices. The starting point of our analysis will be the theoretical framework developed by Sorrell et al. (2009), which shows that there is no necessary link between the price of white certificates and the marginal cost of energy efficiency investment, or the price of electricity. This outcome contradicts the Italian experience and thus it is an important issue that will be addressed by our work. The authors also show that a WC scheme focused solely on electricity efficiency and operating in conjunction with the EU ETS, makes no contribution to reducing EU or global carbon emissions unless, and until, it leads to a tightening of the EU ETS cap. The main

questions addressed by this paper are: i) How do market and regulatory variables impact on WC prices? ii) How does a WC scheme affect wholesale electricity prices? And what are the consequences of interacting with the EU ETS scheme? iii) Does the market price of WC properly reflect the economic value of energy savings? iv) Since supply and demand of electricity apply for a fixed capital stock in the short-run, what happens to the medium- and long-run? v) Does the heavy reliance on over-the-counter (OTC) trading impact on WC prices or wholesale electricity prices? vi) How do economic and regulatory barriers impact on WC prices? Using granular data provided by GME (Energy Market Operator), GSE (Energy Services Operator), and ENEA we will analyze the dynamics and the interactions between demand and supply of Type I white certificates and wholesale electricity, in order to provide some stylized facts related to the Italian experience that may, or may not, confirm the outcomes by Sorrell et al. (2009). We will focus on the main market determinants of the WC price, such as the energy-saving target, the price elasticity of WC supply and demand, the WC-market liquidity, the role of OTC (bilateral) trading, and on regulatory determinants, particularly in relation to ex-post changes in WC prices and electricity prices. The analysis will be conducted during the period 2004-2017, i.e. since the introduction of the WC scheme in Italy, by paying particular attention to the most relevant regulatory interventions and to the coexistence between white certificates and the EU ETS. We will address issues on existing economic and regulatory barriers in energy efficiency investments (mostly limited access to capital for SMEs and a heavily-bureaucratized regulatory framework), and how Italy has overcome some of them during the recent years. We will also take into account the role that Energy Service Companies (ESCO) are currently playing in achieving the majority of energy savings in the Italian white certificates mechanism.

Cristian Pelizzari (cristian.pelizzari@unibs.it), *Paolo Falbo, Juri Hinz*

Optimal Energy Supply Shift with Battery Energy Storage Systems

This work is concerned with the optimal management of battery energy storage systems. Saving energy during periods of low demand in order to match periods of higher load is known as energy supply shift. Despite an increasing interest towards this technology, the implementation of battery energy storage systems is not straightforward from both a technical and an economical perspective. The high battery costs, the sensitivity of battery life expectancy to deep discharge, and high uncertainty in electricity load, supply, and prices make optimal battery operation a sophisticated mathematical problem, whose precise solution seems to become a decisive factor in the deployment of battery storage technologies. This work responds to the increasing demand for sound algorithmic solutions to optimal storage control problems arising in the dispatch optimization of power supply under uncertainty. In particular, we apply a novel approach to solve discrete-time control problems arising in this context and to show how duality-based techniques can be used to assess the quality of numerical solutions.

Filippo Petroni (fpetroni@unica.it), *Guglielmo D'Amico, Robert Adam Sobolewski*

A probabilistic model of wind farm power generation via Copulas and indexed semi-Markov models

In this paper we consider the problem of modelling the wind power production of a wind farm composed of a given number of wind turbines. As it is well known, the comprehension of stochastic properties of the total produced energy cannot be obtained simply considering the produced power of a single turbine with the total number of turbines. The reasons are mainly due to the so-called shear effect and to the morphological nature of the territory

where the wind farm has been installed. For these reasons, it is interesting and crucial the development of a complete model that is able to correctly reproduce and forecast the power production of the whole wind farm. To this end we describe the stochastic production of energy of each turbine using an indexed semi-Markov chains (ISMC). This choice is motivated by recent research articles where the authors have demonstrated that ISMC model is able to reproduce the statistical properties of power production of a single wind turbine, see [2-6]. The ISMC model provides a very general approach that encompasses both semi-Markov processes and Markov chain based models. The superiority of the ISMC model resides in its accurate probabilistic description of the wind power evolution which accounts for the serial dependence of the wind power time series by incorporating past events (times and sizes of past power production) through an index process that increases the memory of the process. The modelling of the whole wind farm is executed by introducing a dependence structure among the considered ISMC that describe the wind power of each single wind turbine. The dependence structure is described by introducing copula functions. The advanced model is a modification of that presented in [1] where weighted-indexed semi-Markov chain model with copulas was applied to the description of financial performance of a portfolio of financial assets varying on a high frequency scale. A real application of the proposed multivariate model is performed on real data of energy produced have been analysed and compare with synthetic data obtained by implementing Monte Carlo simulation and the multivariate ISMC model.

Marco Piccirilli (mpicciri@math.unipd.it), *Luca Latini, Tiziano Vargiolu*

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

Standard models for energy markets usually incorporate mean-reversion in the dynamics of spot and forward prices. Less standard is the requirement that these markets are arbitrage free. This can be relevant especially in natural gas and power markets, which cannot be delivered at a given instant but is rather delivered over a certain time period, e.g. a month (M), a quarter (Q) or a whole calendar year (Cal). In these situations, one must seek models which avoid the possibility of arbitrages. Since forward contracts are the most liquid products traded in energy markets, in organized markets usually forward prices are quoted and traded continuously. In this situation, one must also avoid models which allow for dynamic arbitrages. This latter (dynamic) no-arbitrage assumption is ensured by the Heath-Jarrow- Morton (HJM) paradigm, which prescribes that in diffusion models the drift and the diffusion coeffcients of forward prices satisfy certain relations. However, it is di cult to achieve this with multiplicative models. For these reasons, we choose to work with an arithmetic model, i.e. we model directly the forward prices as Gaussian mean-reverting processes, in line with a growing recent literature [1, 2, 3, 5]. In principle, we expose ourself to the possibility of negative prices, which would seem in contrast with economic intuition. However we argue that, given the increasing presence of negative spot prices in current power markets, there is the theoretical possibility of observing a negative price also in some forward contract, though with a very small probability. The final result is that, in general, a forward contract is mean-reverting with respect to an infinite linear combination of instantaneous forward contracts, thus making the model infinite-dimensional. To solve this conundrum, we make the key assumptions that instantaneous (non-traded) forward prices (and, as a consequence, also the traded ones) depend linearly on a finite number of (hidden) state variables, and that the mean-reversion speed is at each given time the same for all contracts in the market. We also show that this class is not void, since the well known Lucia-Schwartz model [7], if we compute the forwards? dynamics, turns out to be of this kind. It is quite flexible

in mean price levels, by incorporating the spot?s seasonal component, but the volatility succeeds only in reproducing the Samuelson effect as an exponential decay, without being able to reproduce more complex term structures. To overcome this rigidity, we propose a modification of the Lucia-Schwartz model which is free of arbitrages in the way discussed above, where the prices of forward contracts are mean-reverting and where both price level and volatility are allowed to have a non-trivial term structure. We then present a technique for estimating the parameters of this model based on market time series of forward prices, which are the most liquid market quotes. After having estimated the volatility coeffcients, we pass to the mean-reversion speed and levels in a non-parametric way, so that we can replicate any functional behavior of the forward long-term mean, which takes into account the no-arbitrage requirements among forwards covering the same time period. We apply this estimation technique on a time series for the Phelix Base forward market from January 4, 2016 to May 23, 2017, considering each monthly, quarterly and calendar forward contract traded in that time window.

Mauro Rosestolato (mauro.rosestolato@polytechnique.edu), *Salvatore Federico, Elisa Tacconi*

Irreversible investment with fixed adjustment costs: a stochastic impulse control approach

We consider an optimal stochastic impulse control problem over an infinite time horizon motivated by a model of irreversible investment choices with fixed adjustment costs. By employing techniques of viscosity solutions and relying on semiconvexity arguments, we prove that the value function is a classical solution to the associated quasi-variational inequality. This enables us to characterize the structure of the continuation and action regions and construct an optimal control. Finally, we focus on the linear case, discussing, by a numerical analysis, the sensitivity of the solution with respect to the relevant parameters of the problem.

Piegiacomo Sabino(piergiacomo.sabino@gmail.com), *Nicola Cufaro Petroni*

Pricing Exchange Options with Correlated Jump-diffusion Processes

Several research studies have shown that the spot dynamics of commodity markets display mean reversion, seasonality and jumps (see for example Cartea and Figueroa [2]). Some methodologies have also been proposed to take dependency into account based on correlation and co-integration. However, these approaches can become mathematically complex and non-treatable when leaving the Gaussian-Ito? world. In this research we consider 2-dimensional jump diffusion processes with a 2-dimensional Gaussian and a 2- dimensional compound Poisson component. We then present an intuitive approach to model the dependency of 2-dimensional Poisson processes based on the self-decomposability of the exponential random variables used for its construction.

Carlo Sala (carlo.sala@esade.edu), *Giovanni Barone-Adesi, Chiara Legnazzi*

WTI Crude Oil Option Implied VaR and CVaR: an Empirical Application

Using option market prices we derive naturally forward-looking, non-parametric and model-free risk estimates, three desired characteristics hardly obtainable using historical returns. The option-implied measures are based only on the first derivative of the option price with respect to the strike price, bypassing the di cult task of estimating the tail of the return distribution. Moreover, the model-free nature of the proposed methodology enables one to overcome the elicitability issue linked to the CVaR. We estimate and backtest the 1%, 2.5%

and 5% WTI crude oil futures option-implied VaR and CVaR for the years 2011-2016 and for both tails of the distribution. Compared with other classical risk estimations including the Gaussian model, the Historical Simulation, the Expected Weighted Moving Average (EWMA) and the Filtered Historical Simulation (FHS) methodologies, results show that the option-implied risk metrics are valid alternatives to the statistically historical-based models.

Alessandro Sapio (sandrosapio78@gmail.com)

Quantile merit order effects and network upgrades

Italian islands are rich reservoirs of renewable energy sources, such as wind power and photovoltaics. Yet, their interconnection with the Italian mainland has historically been poor. The Sicilian and Sardinian wholesale prices have been above the average national price, signalling a chronic supply shortage in a region characterised by scarcity of hydropower sources. In a highly symbolic move, the Sardinian electricity system was fully integrated with the Italian grid on March 17, 2011, as part of the celebrations for the 150th anniversary of the Italian unification. A new HVDC interconnection, named SAPEI (SArdinia-Italian Peninsula), was added to the previously existing, and smaller, Sardinia-Corse-Italy (SACOI) cable. On May 28, 2016, the long awaited doubling of the Sorgente-Rizziconi cable, connecting Sicily with the Italian peninsula, has been activated, aiming to curb a congestion problem that in some years caused zonal separation in about 80% of the hours. The new cables in the Italian grid offer a highly interesting case study to assess how the additional energy production from renewables, heavily subsidised until few years ago, affected the Italian wholesale electricity prices across the new interconnections. In policy terms, this is an essential analytical step, since the expected fall in Sicilian wholesale prices do not seem to materialise yet, and concerns of increasing volatility are associated to blossoming renewables. The chosen methodology overcomes the limitations of most previous works, wherein merit order effects were estimated on the average price without taking care of zonal spillovers. In this paper, quantile regression models of the day-ahead electricity price are estimated in order to grasp how the shape of the price distribution changed, as the production of renewables increased while the new cables became operational. An additional aim is to understand volatility transmission patterns across market zones. The paper thus contributes to two strands of literature. One is about the merit order effect (from Sensfuss et al. 2008 to Paraschiv et al. 2014) and volatility effects of renewables. The other is on market integration, related to valuation anomalies (Bunn and Zachmann 2010, McInerney and Bunn 2013) and market power export effects (see Boffa and Scarpa 2009, de Villemeur and Pineau 2012). Electricity prices in Sicily and Sardinia were already explored in Sapio and Spagnolo (2015) and Sapio and Spanolo (2016), respectively. The analysis is based on day-ahead electricity prices in the Italian market zones in the 2011-2017 time window, regressed on intermittent renewable generation, on volatility estimates (in the zone and from neighbouring zones) and on fundamentals.

Maren Diane Schmeck (maren.schmeck@uni-bielefeld.de)

The seasonality in the Implied Accumulated Volatility of Electricity Options

Seasonality is an important topic in electricity markets, as both supply and demand are dependent on the time of the year. Clearly the level of prices shows seasonal behaviour, and it is to expect that also the fluctuations are seasonal. We investigate empirically the seasonality in implied volatility of options on electricity futures. The implied volatil- ity can be described very well with a combination of a linear and an exponential term, corresponding to a classical long term - short term two factor model. Moreover, we find clear seasonal

patterns in the level of the volatility depending on the delivery month of the futures, and compare the performance of several implementations of seasonality in the theoretical two factor framework.

Tiziano Vargiolu (vargiolu@math.unipd.it), *Luisa Andreis, Maria Flora, Fulvio Fontini*

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 paper 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.

Pierluigi Vellucci (pierluigi.vellucci@uniroma3.it), *Loretta Mastroeni, Maurizio Naldi*

The Nature of Energy Commodity Price Time Series: Stochastic, Chaotic, or Both?

Energy commodities have a great importance in the energy market, both for their presence in everydays life and their use in a number of industrial applications. The fluctuation of their prices, which can be observed even on very short timescales, has several important consequences, as it reflects in end price changes and interferes with a correct planning of industrial activities, in addition to spur financial speculation and the possible formation of bubbles. Forecasting the behaviour of such prices has therefore been the subject of many research efforts. Though the large mainstream of activities has revolved around the use of statistical tools, an alternative approach emerged at the end of the eighties, which adopted a nonlinear deterministic paradigm (called chaos) instead of a stochastic one. Adopting either has strong implications on the degree of predictability of future prices. In this paper, we try to overcome the conflict and incompatibility of the two paradigms, by recognizing the presence of features of both in observed price time series. We focus on four major commodities (crude oil, heating oil, natural gas, and copper), whose prices are major business driver for many industries. We consider an observation period longer than those considered in the literature so far and apply recent results in chaotic parameter estimation, which incorporate the presence of noise in an otherwise perfectly chaotic time series. In this framework, we show that the time series exhibits chaotic behaviour though in the presence of noise, whose level is here estimated, so that we actually observe the presence of both stochastic and chaotic features. In particular, we observe an intermittency behaviour, in which the state of the phenomenon alternates between steady (the state does not change or changes very slowly) and chaotic behaviour in an irregular fashion.

Hyeri Yu (ec0072ih@gmail.com), *Jiro Akahori, Luca Taschini*

Macro-Finance Approach to Option Pricing and an Application to Environmental Risk Management

In finance, the state-price density, the pricing kernel and the stochastic dis- count factor describe the arbitrage-free inter-temporal relationship between as- set cash flows; see, among others, [1], [3] and [5]. The relevance of this relation- ship to the description of macroeconomics dynamics has been explored recently by the nascent macro-finance literature; [4]

offers an excellent review of recent advances in macro-finance. Building on the framework proposed by [2], we con- tribute to this literature exploring the relation between real economy variables and the state price density. The tractability that the proposed model offers allows us to study a host of new properties of fully solved equilibria. Also, our framework opens up an avenue for new models in quantitative finance thereby reviving the field of pricing and hedging of financial derivatives. An application to an environmental problem illustrates the potential of the approach.