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U7, floor IV, room 4064

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Window Selection and Averaging for Probabilistic Day-Ahead Electricity Price Forecasting

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Most day-ahead electricity price forecasting (EPF) studies focus on developing models that better represent the inter-variable dependencies or implementing faster and more efficient estimation algorithms. However, somewhat surprisingly, authors have almost completely ignored the problem of finding the optimal length of the calibration window. The typical approach is to select ad-hoc, a 'long enough' window. The problem is that there is no consensus in the literature as to the length of this window – training samples as short as two weeks and as long as six years have been used.

In this study we build on a recently introduced concept for point forecasting [1, 2], that averaging day-ahead electricity price predictions over calibration windows of various lengths produces better results than selecting, even ex-post, only one 'optimal' window length. Here, we extend this approach to probabilistic forecasts.

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Understanding Intraday Electricity Markets: Variable Selection and Very Short-Term Price Forecasting Using Lasso

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Since the deregulation of government-controlled power sectors in the 1990s and 2000s and the introduction of competitive markets in many countries worldwide, electricity is traded under market rules as any other. In Europe, the workhorse of power trading has been the uniform price auction conducted a day before delivery, and a vast majority of research and applications has concerned day-ahead (DA) electricity prices. However, the expansion of renewable generation (mostly wind and solar), power grid modernization (including increase of interconnector capacity) and active demand side management (smart meters, smart appliances) have made the electricity demand/supply and prices more volatile and less predictable than ever before. This has amplified the importance of intraday markets, which can be used to balance deviations resulting from positions in day-ahead contracts and the actual demand. As a result, during the last few years we have observed a shifting of volume from the DA to intraday markets across Europe.

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Equilibrium Price of Carbon Certificates and the Electricity Sector

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The price of emission certificates, in particular carbon certificates, has been the object of several theoretical and econometric papers (e.g. Hintermann, 2011, Mansanet and Kopler, 2010). The two types of contributions happened not to converge to a common understanding. Empirical contributions have identified quite successfully which factors drive carbon price. However, theoretical papers have kept quite distant from econometrical findings. Theoretical models have focused particularly on the probability that the emissions cumulated by the industrial sectors included in an ETS will exceed the maximum limit fixed by the authority before a given final date. Keeping the aim of providing a general framework, theoretical contributions (e.g. Carmona et al. 2010) have neglected the features of different kind of emissions and of different industrial sectors. However, turning to the major example of emission market (i.e. the EUETS), the electricity sector dominates the percentage of the CO2 emissions. It turns out that facts like the high pass-through coefficient of variable generation costs to the final electricity price, the (two) most influent technologies driving the price of electricity have a relevant impact on the equilibrium price of carbon certificates.

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Econometric Modelling and Forecasting of Intraday Electricity Prices

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Constant development of weather-dependent renewable energy production in Germany requires flexible market, in which power plants can balance their production forecast errors that may be caused by changing, unpredicted weather conditions. Introduction of intraday electricity markets faces these problems and lets market participants trade the energy continuously until 30 minutes before delivery begins on the whole market and until 5 minutes before delivery begins within respective control zones. In the paper we analyse the ID3-Price on German Intraday Continuous Electricity Market using an econometric time series model.

A multivariate approach is conducted for hourly and quarter-hourly products separately. We estimate the model using lasso and elastic net techniques and perform an outof-sample very short-term forecasting study. The model's performance is compared with benchmark models and is discussed in detail. Forecasting results provide new insights to the German Intraday Continuous Electricity Market regarding its efficiency and to the ID3-Price behaviour.

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Forward or Backward Simulation? Application to the Pricing of Energy Facilities

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The aim of this study is to present algorithms for the backward simulation of several common stochastic processes and compare their computational effort to the standard sequential construction. The traditional Monte Carlo (MC) approach is based on the generation of trajectories forward in time over a time grid of d points t1,t2,...,td = T. The computational cost of a such strategy depends on the particular stochastic process and the number of MC simulations. On the other hand, we are not restricted to generate the random points of the trajectory in sequence, the only strict requirement is to generate points with the correct transition density.

For a moment let us consider the simple case of a Brownian motion (BM); in the sequential generation the points are obtained forward in time, while for instance, the standard Brownian bridge construction fills the time grid simulating the last point first and then iteratively proceeding as shown in Figure (1a). The standard BB construction is not the only

possible bridge construction, one can hook the left point to t0 = 0 and obtain the backward simulation as shown in Figure (1b). As far as we are aware of, an explicit backward algorithm has been only presented for a few processes: see Dutt and Welke [2], Pellegrino and Sabino [6] Hu and Zhou [3] for the backward construction of the standard Poisson, the Ornstein-Uhlenbeck (OU) and the CIR/Heston processes. As first contribution of this study we extend the works of Ribeiro and Webber [7] and Avramidis and L'Ecuyer [1] on gamma bridge and obtain the backward construction of a Gamma process. Moreover, we are able to write a novel acceptance-rejection algorithm to simulate Inverse Gaussian (IG) backward in time therefore, using the time-change approach, we can easily obtain the backward generation of the Compound Poisson, the Variance Gamma (VG), the Normal Inverse Gaussian (NIG) processes and then the time-changed version of the OU process (SubOU) introduced by Li and Linetsky [4].

In principle the forward and backward constructions should have the same computational cost because they are based on the simulation of the same number of random points and rv's; the main difference is actually driven by the cost of generating the rv needed in the sequential or backward.

We conclude our study conducting numerical experiments with the aim of pricing gas storages using a VG and IG time-changed OU process in a setting similar to the one published by Li and Linetsky [4].

We show how the advantage of using the backward simulation becomes therefore evident if the pricing solution is based on backward dynamic programming. The improvement becomes even more remarkable for longer maturities which makes the backward construction the native strategy for the implementation of the LSMC method.

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Options on Futures in Electricity Markets: an Affine Seasonal Stochastic Volatility Model

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Futures contracts cover one of the most important types of derivatives in the electricity market. However, compared to other commodities, power has special characteristics that lead to specific requirements. In particular, one has to handle the non-storability of electricity. Hence, the commodity will be typically delivered over a period of time in- stead of a one-time delivery by use of electricity futures. As a consequence, a weight function has to be introduced.

In addition, we consider European options on monthly delivering electricity futures at the EEX. We calculate the accumulated implied volatilities and observe the well-known smile effect in the related volatility surfaces. This motivates a stochastic volatility model as proposed by Heston [4]. Recently, [1] applied the model directly to one-time delivering commodity futures. We want to extend this approach to be applicable for the electricity market. Besides a weight function, we add seasonalities in the delivery period which play an important role enforced by the non-storability of the commodity. Moreover, the Samuelson

effect will be included to cover the volatility term-structure as done by [5] for one-time delivering commodity futures.

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Investing in Electricity Production Under a Reliability Options scheme

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In many electricity markets worldwide there are capacity remuneration mechanisms that explicitly remunerate power capacity. Among them, Reliability Options (ROs) have been implemented in Colombia (Cramton and Stoft, 2007), New England (FERC, 2014) and Ireland (SEM, 2015, 2016a, and 2016b) and are about to be implemented in Italy (TERNA, 2018, Mastropietro et al. 2018).

ROs give to their holder, the System Operator (SO), the right to ask the issuers, the power producers, to produce power when there is need for remuneration of power capacity, and to receive the (positive) difference between the market price of electricity and a predetermined price level. This price level is the strike price of the RO and is set in order to represent the value of the power at that specific level for which load is not shed. The issuer of the RO has the obligation to supply the SO with electricity when asked. It receives in exchange a predetermined payment for issuing the RO.

Andreis et al. (2018) discuss how the strike price and the stochastic parameters of the electricity price affect the price of the RO. They assume that a given power producer already exists and has to decide whether it wants to sell ROs to the SO or not. The difference in the value of the power plant with and without ROs determines the equilibrium price of the latter.

In this work, we discuss the case of a potential investor who is contemplating investing in a power plant when an RO scheme is in place. Our aim is to discuss how the implementation of an RO scheme affects the timing and the value of investments in power production.

Smile Modelling in Commodity Markets

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An increasing number of derivatives written on Commodity Futures are traded on the market or are embedded within structured notes. Examples of these contracts are Autocallable, Accumulator or Swing Options. These derivatives are, due to their digital clauses, sensitive to smile effects. The most liquid hedging instruments in the Commodity

markets are, in addition to the Futures contracts themselves, the Plain Vanilla Options on Futures and sometimes some exotics like Calendar Spread or Mid Curve Options. Therefore, we need to develop a pricing model for Futures able to reproduce the market smile that can be calibrated in a fast and robust way to market quotes. Moreover, for some underlyings, the market quotes Futures on different delivery periods. Therefore, we need a model that is flexible enough to link instruments indexed on different delivery periods.

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Activity Based Modelling of Commodity Futures Markets

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Commodity markets exhibit seasonal behavior, which can be traced back to characteristics of supply and demand. For example, the demand of energy is depending on the outside air temperature, which itself shows a seasonal behavior. If it is very warm energy is used to cool down houses, if the temperature is low for heating. On the other hand, renewable energy sources as solar energy, hydropower and wind energy rely on natural quantities as sunshine, wind and rain. Thus, we have periods of high activity in the market that alternate with those of low activity. Here the degree of activity is triggered by temperature, wind or sunshine. Consequently, these natural factors should be included into a stochastic model for commodity prices.

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Short-Term Forecasting of Italian Gas Demand

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Natural gas is one of the most important energy sources in Italy: it feeds thermoelectric power plants, industrial facilities and domestic heating. Energy companies need to predict gas demand (GD) to reserve pipe capacity, plan stocks, and avoid financial penalties due to network unbalance. Moreover, GD is one of the most relevant inputs to draw scenarios for natural gas price. An extensive literature, reviewed in [3] and [4], covers the topic; however, to the best of our knowledge, no study has been carried out about Italian GD. Herein, one-day-ahead forecasting of daily Italian GD is addressed. In particular, the attention is focused on industrial and thermoelectric demand, as the residential component is studied in [1]. We address the GD forecasting problem in the framework of statistical learning, developing and comparing several two-step models, i.e. forecasters obtained by the suitable aggregation of

first-level forecasts. The out-of-sample Mean Absolute Error (MAE) achieved on 2017 is 5.16 Millions of Standard Cubic Meters (MSCM), definitely lower than 9.57 MSCM obtained by the forecasts issued by SNAM, the Italian Transmission System Operator (TSO).

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New trends in applied research in the Energy Sector

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Renewables, Finance, and Growth: Causality Relationships

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The global commitment to drastically curb greenhouse gas emissions towards a sustainable development is strongly connected to the development and usage of renewable energy (RE), such as solar and wind. Between 2006 and 2016, world's total RE consumption, excluding hydro-electricity, increased by almost 350% (from 93 to 420 million tonnes of oil equivalent), and RE investment grew from 47 US$ billion in 2004 to 279.8 billion in 2017 (BP 2017, FS 2018).
The effects of renewables on economic growth are examined by a growing body of empirical research which leads to the general result that increasing RE consumption or production leads to higher real GDP per-capita growth rates (see, among all, Sadorsky 2009, Tugcu et al. 2012, Aflaki et al. 2014, Omri 2014, Bhattacharya et al. 2016, Inglesi-Lotz 2016).
While there exists a well-established literature investigating the finance and growth nexus (the long-lasting strand shows the existence of a positive relationship between financial development and economic growth - among all, King and Levine 1993, Levine 2002, Levine 2005 - while recent contributions, that take on board lessons from the recent great recession, show that also financial structure matters - Demirgüç-Kunt et al. 2011, Gambacorta et al. 2014, Morganti and Garofalo 2018), the potential effects of the financial system on energy consumption, production or investment, are yet to be fully examined. It is reasonable to

suppose that the financial system plays a crucial role in the RE and growth nexus, since either the overall financial development or the financial structure (bank- or market-based) of a country might influence the pace of its environmental development, to the extent that they can affect the financing of renewables investment (Mazzucato and Semieniuk 2018).
The aim of this paper is to empirically investigate the relationship between economic growth (measured by the real GDP per-capita growth rate) and renewable energy, by taking into account the role of financial development and financial structure. In particular, we will investigate the relationship between economic growth and renewables on the one hand, and renewables and financial structure and development on the other hand. The main questions addressed by the paper will be: i) Does exist a statistically significant relationship between RE and economic growth? ii) What are the effects across-countries and over-time in the long- or medium-run? iii) Does the financial system matter, and does its potential contribution to RE variables, mostly investment, vary according to the country's degree of economic and financial development? iv) What policy lessons can be learned?

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Life Cycle Costing for Financial and Environmental Assessments: a Renewable Energy Project

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The objective of Life-Cycle Costing is a multi-dimensional assessment of the financial and environmental impact of engines, plants and eco-systems according to different scenarios and different methodologies.

For the success of companies, the insertion of environmental concerns into innovation processes is an important step and LCC can help to basic technological changes in green innovations economies. In this paper, the LCC assessment is applied to a renewable energy project located in the Maldives Islands. A water desalination plant will be powered by a photovoltaic plant. The small economy and the fragile environment of the Maldives need local and clean resources for electricity generation. Renewable energyfed desalination is an excellent solution for areas lacking electrical grid connection or any other source of energy. However, the economic feasibility of renewable energy-fed desalination compared to desalination using grid energy must be carefully analyzed as well as alternative ways of providing the atolls of drinkable water.

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A Deterministic Model for Generation and Transmission Expansion Planning with High Shares of Renewables

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This contribution presents a deterministic model for the joint generation and transmission expansion planning of energy systems with high penetrations of intermittent renewable energy sources. Given forecasts of future values of load, fossil fuel prices and investment costs, the proposed model defines how the capacity mix should evolve in order to meet the demand for electricity and fulfill policy targets at minimal cost.

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Determining the Demand Elasticity in a Wholesale Electricity Market

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The main focus of researchers in energy markets is typically placed on the analysis of the supply side. The demand side, despite its critical importance, is a subject which still deserves a more profound academic investigation. In particular, the number of studies on the demand elasticity in a wholesale market is limited to merely several pieces. In this paper we extend this field of study and propose a new method for determining the demand elasticity. More specifically, we decompose the data observed in the wholesale market into individual supply and demand schedules of the market participants. This allows us to better understand their bidding behavior and thus make more precise inferences about the functioning of an electricity market.

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Efficient Representation of Supply and Demand Curves on Day-Ahead Electricity Markets

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Supply and demand curves on day-ahead electricity markets are the results of thousands of bid/ask entries in the day-ahead auction, this for all the 24 hours. In principle, it would be possible to represent, and forecast, these curves by taking into account each production/consumption unit as a separate time series, and then joining these together to construct the final curves, and thus the resulting price. However, the huge number of these units (from several hundreds to thousands) makes this naive strategy infeasible, unless one has extremely high computing capacity with complex machine learning algorithms available.

In this talk, we present a much more parsimonious approach. In fact, the idea is to represent each curve using non-parametric mesh-free interpolation techniques, so that we can obtain an approximation of the original curve with far less parameters than the original one.

We consider the Italian electricity market (IPEX). IPEX consists of different markets, including a dayahead market. The day-ahead market is managed by Gestore del Mercato Elettrico (GME) where prices and demand are determined the day before the delivery by means of hourly concurrent auctions. For each delivery day the market session starts at 8 a.m. of the ninth day before the day of physical delivery and closes at mid-day (12 p.m.) of the day before delivery.

The producers submit offers where they specify the quantities and the minimum price at which they are willing to sell. The demanders submit bids where they specify the quantities and the maximum price at which they are willing to buy. They are then aggregated by an independent system operator (ISO) in order to construct the supply and demand curves.

Accurate modeling and forecasting electricity demand and prices are very important issues for decision making in deregulated electricity markets. Different techniques were developed to describe and forecast the dynamics of electricity load. Short term forecast proved to be very challenging task due to these specific features. Functional data analysis is extensively used in other fields of science, but it has been little explored in the electricity market setting.

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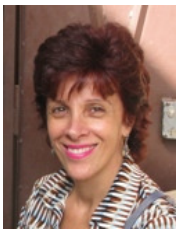
How to Guarantee the General Charges of electricity in the Liberalized Energy Value Chain



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The Italian liberalized power sector has been designed as a linear chain composed of manifold actors, from energy generation to consumption by the end-client, each of which playing a different role within the chain. In analogy with other principal public utility network services in Italy, the power sector is characterized by a system in which payment for a good or service occurs subsequently to the actual consumption/use of the former; it is hence evident that an inherent weak point of such a system design is represented by the possibility that part of the good or service may be consumed/used even if the subsequent payment does not occur.

With reference to the energy sector, the total amount due for consumption/use of service is composed of the following two components: costs directly connected to electricity, such as the cost of the commodity, the costs of marketing, or the cost of transport and the cost of balancing on one hand, and of costs called “general charges” on the other; general charges, as identified by the legislator, are a cost component of the electricity bill and are used to finance objectives of general interest. The collection of general charges, as provided by law (aca "decreto Bersani"), is managed within the electric chain, as an increase of the cost of transportation. General charges are set in proportion both with the type of end-client, and with the consumption of power withdrawn from the network.

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Efficiency Valuation of Stocks and Green Portfolio Construction: a Two Stage Approach

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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.

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A First Attempt to Bridge the Gap Between Derivative and Insurance Contracts: Hedging Meteorological Risk

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This contribution presents some preliminary results of a wider research project whose aim is to propose a range of hybrid contracts for hedging meteorological risk. Those contracts are structured in such a way that they may benefit of positive characteristics carried by both standard financial derivatives and insurance contracts without incurring in their drawbacks.

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Some Examples of High Frequency Trading in Crude Oil Markets during Times of High Volatility

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