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Electricity market equilibrium model with seasonal volatilities

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Abstract

In this paper we propose and implement an electricity market equilibrium model. The model, originally conceived by Hinz [8], is now set up by making use as input of the spot price pattern obtained with the term structure Heath Jarrow Morton [6] model, but we assume that price volatility is seasonal. The chosen volatility functional form captures the price return seasonality and consequently allows to support the production scheduling. We show as seasonality and electricity demand forecasting techniques make the study of energy forward price dynamics related to the demand and the provisional capacity of the agents.

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1. Introduction

The electricity market deregulation, started in the United States and then diffused in the main western countries, has determined new price dynamics development. The electricity market, once monopolistic, becomes a competitive market, where energy prices derive from the demand/supply match. This new context, along with the physical characteristics of the electricity, has generated new price dynamics, never seen before, nor on the financial markets or commodities markets. The fundamental characteristics of such good is not to be stored: with the exception of

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hydropower, electricity should be generated exactly at the time of its request for consumption. The offer turns out to be completely inelastic to price changes, and also prices show very high volatilities and sudden changes of price levels, called spikes.

Market operators, both producers and consumers, suffer therefore the exposure to energy price uncertainty and risk management techniques become fundamental tools to quantify and cope with price risk generated from such uncertainty.

For this reason both researchers and practitioners have concentrated on the electricity price evolution study, by setting up models able to catch the main characteristics of price evolution in order to price derivative products and manage price risk.

Electricity is a flow commodity: all contracts guarantee the delivery of a certain amount of energy (1 MWh) continuously over a time interval (1 hour, 1 month, 1 quarter, 1 year). Electricity is traded on an auction system with standardized contracts, which can be settled both with physical delivery and financially.

In the last few years the electricity market and other flow commodities stochastic models literature has rapidly developed. In particular two research lines have been created: the traditional methodology is build up on the spot price stochastic process modelling, by adapting the original approach already used with other flow commodities.

Lucia and Schwarz [11] model the natural logarithm of the spot price by assuming a mean reverting process estimated by using the spot price data in the Nordic market. The price evolution of a future contract is than determined by applying expected value under an appropriate martingale measure equivalent to the objective one.

Other authors ([13] e [4]) suggest a two factor model, in order to take into account the influence on the spot price given both by a short term and a long term source of randomness. The introduction of a jump diffusion process appears the natural way to account for spikes ([4] e [2]), even if market incompleteness is introduced. Huisman [9], Deng [3] and Mari [12] among others, suggested Markovian regime switching models characterized by the occurrence of stable and turbolent periods.

The major disadvantage of the spot price models is that forward prices are given endogenously from the spot price dynamics. Therefore, the obtained dynamics of forward prices is most of the times not consistent with the market observed prices.

The second research line refers to the modeling framework of Heath Jarrow and Morton [6] that, using only few stochastic factors and the initial price curve as given, models futures prices under some equivalent martingale measure in a no-arbitrage environment. Clewlow and Strickland [2] have been the first researchers to introduce this approach to the energy market. Bjerksund et al. [1] and Koekebakker et al. [10] model a continuum of instantaneous-delivery forward contracts under risk neutral probability measure.

To tell the truth it has never been explicitly made clear how it is possible to apply the term structure classical models to an anomalous market such the electricity one: the non storability of electrical power cannot be neglected using a price methodology in which the underlying is assumed storable. Besides, hedging is impossible if short position are not allowed and the electricity market is far away from being complete, so it is not guaranteed the existence of a risk neutral measure.

Hinz [8] gives an interesting interpretation of the electricity market and demonstrates that it is possible to create a market framework where it is guaranteed the existence of a risk neutral measure: the energy cannot be stored, but it can be produced. And the producer can put himself in the condition of having the ability to produce electricity, creating a sort of “electricity storability”. According to this perspective, the electricity market becomes more complex and has to be considered as composed of both power electricity and agreements on power production capacities. The market reaches the equilibrium and determines the price process for all tradable assets both physical (production capacity agreements) and financial (future electricity prices). The equilibrium existence gives and economic interpretation of the martingale measure Q: it is equivalent to the market measure P, such that equilibrium asset prices under P are given by their future revenues, expected with respect to Q. Price dynamics can be, therefore, described directly under the equivalent martingale measure Q and it becomes possible to price all contracts by using classical no arbitrage