Energy Policy 36 (2008) 2601–2609

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Modeling the return and volatility of the Greek electricity marginal system price

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ARTICLE INFO

Article history:
Received 24 January 2008
Accepted 5 March 2008
Available online 6 May 2008

Keywords:
Energy markets
Volatility and return modeling

ABSTRACT

Traditional cost based optimization models (WASP) for expansion planning do not allow for mark-to-market valuation and cannot satisfy arbitrage free requirements. This work will fill this gap by developing and estimating models for mark-to-market valuation. Furthermore the present paper examines the return and volatility of the newly born Greek's electricity market's marginal system price. A detailed description of the market mechanism and regulation is used to describe how prices are determined in order to proceed with return and volatility modeling. Continuous time mean reverting and time varying mean reverting stochastic processes have been solved in discrete time processes and estimated econometrically along with ARMAX and GARCH models. It was found that GARCH model gave much better estimation and forecasting ability. Strong persistence in mean has been found giving suspicions of market inefficiency and strong incentives for arbitrage opportunities. Finally, the change in the regulatory framework has been controlled and found to have significant impact.

1. Introduction

Modeling of the electricity spot price used the following options: the lognormal price model, the mean reverting model, and the cost based models. Among those the most common are the cost based models which minimize a cost function for optimal electricity system expansion planning (WASP is the most commonly referred). But those models nowadays have important disadvantages if used alone. They do not take into account the market data and the premium determined by the market, they cannot satisfy the arbitrage free requirements, and do not allow for mark-to-market valuation. Thus in our work we will try to solve these problems by presenting mark-to-market models which are mainly based on market data and utilize final prices derived by the market. The ARMAX model, described below, per se cannot be used for mark-to-market; we do not use the mark-to-market term in the strict accounting and back office terminology. Forecasting price with an ARMAX is different from forecasted price derived by a model like WASP or WeatherDelta or any other model based on fundamentals; the difference among the two prices helps us to mark the market. In any case, the data used in ARMAX are derived by the market, compared to models which use only fundamentals and based on assumptions about the market trends.

Electricity trading in organized markets started globally (the UK, the USA, Scandinavia, Australia) in the 1990s along with the change in the production model (lean production, mass customization and scope vs. scale economies) (Theodorou, 1996a, b, 2001, 2003) and the will of the state to restrict its production in favor of "free" market mechanisms. New technologies in production (like combined cycle gas turbines (CCGTs)) enabled production flexibility with low cost just-in-time response to high load peaks. Also metering technologies enabled pricing according to specific demand needs (mass customization). The will of the state to restrict its production character takes flesh and blood through a top-down institutional reform process based on legislation for market opening and integration (which will be explained further in this paper).

Trading of electricity on the spot started in wholesale markets which are much similar to other organized financial markets for energy products like oil, natural gas, metals and generally, Nymex Softs. In these "free markets" the system's price is determined by demand and supply under the hope that in the near future this process will lead to decreased prices due to competition. Today electricity tariffs in many countries are still regulated by the government and their difference from the wholesale (marginal system) price lead to an arbitrage opportunity for the independent power producer (IPP) with a cost which in most cases is fully absorbed by the incumbent. The experience until now shows that

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doi:10.1016/j.enpol.2008.03.009

the liberalization process and the trading of electricity introduced much more uncertainty than before. This uncertainty partly can be managed with risk transfer techniques like hedging or using instruments like derivatives and bilateral contracts. The absence of such instruments is an important problem for the Greek market as it increases the exposure of market participants to high volatility of prices.

Thus one of the most important characteristics of the "free" electricity wholesale market price, or marginal system price (MSP), is its high volatility. The volatility of the electricity spot price or MSP is completely different than the price volatility of other commodities and equities (Weron et al., 2004; Theodorou, 2000; Janicki and Weron, 1994). Most studies to our knowledge, attribute this extreme volatility behavior to factors like the lack of storability (Barz and Johnson, 1998), demand elasticity (Ethier and Mount, 1998), transportation capacity and limited inter-connectivity (Bernard et al., 1998; Rudkevich et al., 1998), steeply sloped supply stuck curve (Wolak and Patrick, 1997; Mount, 1999), and load seasonality (Bhanot, 2000; Schwartz and Lucia, 2002). But in our view another important volatility factor of the electricity spot market price is the type of auctioning system in relation to the portfolio of producing units. Specifically, in periods of high demand (load peaks), the marginal unit (which determines the MSP) may be a CCGT or a gas turbine (GT) with higher variable cost than the base units which burn lignite and coal. If we add upon this cost a speculation margin we lead to the extreme spikes usually observed in those markets. Completely different results may be obtained by a different auctioning system where the price is not determined exclusively by the marginal unit (auctioning literature).

Contrary to the regulated tariff system electricity spot price, volatility can alter the value of peaking and mid-merit generating assets. Usually, base load assets, such as coal, lignite and nuclear, realize a price close to the period's average contrary to the peaking and mid merit units which are often out of money (without taking into account investment and CO_2 cost). However, in times of market tightness dramatic increase in volatility and price flyup recoup not only the variable cost of peak and mid-merit stations but also the capacity cost as well as a return above risk. Generally, as reserve margins are decreasing and capacity investments are delayed, volatility increases and price spikes.

Thus, it is important to be able to predict the rate at which volatility will increase taking into account the markets' fundamentals. Volatility estimation is very important in evaluating the liberalization process, in forecasting future spot price, in pricing energy futures and derivatives necessary for risk transfer and in valuing energy assets (stations, etc.). In this research an attempt will be made to determine future change in volatility and estimate how the Greek units' portfolio was managed and how regulatory changes in the calculation of MSP has affected volatility along with seasonal aspects. We will try to determine what change we expect and how wrong this expectation is.

Generally, existing literature is more focused on electricity spot prices rather than on their volatility estimation. Relevant literature can be found for the USA, British, Scandinavian, and Australian markets while for Greece to our knowledge nothing has been done until now (Bailey, 1998; Blumslein et al., 2002; Borenstein, 2002; Borenstein et al., 2002; Joskow, 2001; Joskow and Kahn, 2002; Barnett et al., 2002; Michaels and Ellig, 1999; Klitgaard and Reddy, 2000; Green and Newbery, 1992; Wolfram, 1999; Bystrom, 2000). This gap of volatility study for electricity prices in Greece is what this research paper is going to fill.

Volatility can be calculated as market implied or model implied using asset pricing models or as historical/actual volatility using time series methods. As the Greek market is in its infancy and options are not used, the time series models are selected. Estimation of volatility and movement of electricity prices is attempted based on the family of ARCH–GARCH models. Observed electricity prices are strongly mean reverting and infrequently followed by large jumps which quickly drop toward the mean price level. Thus, mean reverting Ornstein Uhlenbeck stochastic processes, time varying mean and ARMAX models are also employed. Conditional maximum likelihood technique is employed for parameter estimation using the Newton-type algorithm of BHHH (Berndt et al., 1974). It is worth mentioning that prices in Greece like Scandinavia and New Zealand are not so volatile as in other countries and not so strictly competitive (Theodorou, 2000; Wolak, 1997). That is why high jumps are not observed. Our research was based on the empirical examination of prices by Knittel and Roberts (2005).

The rest of the present paper is organized as follows. Section 2 describes the market structure and its mechanisms which determine the observed prices. Section 3 presents the data characteristics and their statistical analysis. Section 4 focuses on the models that are applied so as to model the price and the volatility of the Greek electricity market and Section 5 contains the conclusions.

2. Wholesale market structure—price mechanics

The economic development model which was based on mass production and scale economies (Theodorou, 1996a, b, 2001, 2003) leaded globally to vertically integrated electric utilities and to monopolistic markets operating under governmental authority and control. In the decade of 1990s procedures for deregulation and electricity market liberalization took place in a top-down process based on certain regulations. Specifically, the liberalization of the European electricity market started in 1996 with the adoption of directive 96/92/EC which was modified by the directive 2003/54/EC. Concerns about safeguarding the security of supply and infrastructure investment were adopted with directive 2005/89/EC and European market integration with cross-border trade regulation based on directive 1228/2003/EC.

The wholesale electricity market in Greece started to operate around November 2001, a time when first wholesale prices (thereafter MSPs) were published in the official site of Greek system operator (thereafter DESMIE or HTSO). The operation of the Greek wholesale electricity market is still in its infancy while its operation until 2006 was based on 623/01 Power Exchange Code (Government Gazette 623/B/25.5.2001) and 654/01 Grid Control Code (Government Gazette 654/B/30.5.2001) which were both prepared in accordance with the provisions of Law 2773/1999 on the liberalization of the electricity market. In 2006, those codes changed and accordingly changed the operation of the market. Generally, after 2006 a new code appeared, the 655/05 Grid Control and Power Exchange Code (GCPEC) published in Government Gazette 655/B/17.05.2005 which was based on the amendments of Law 2773/99 (2837/2000, 2941/2001, 2992/2002), with the most important being the provisions of Law 3175/2003 on the development of geothermal potential. Those changes will be discussed after presenting market structure.

Law 2773/99 was first issued within the framework of Hellenic law harmonization to the provisions of directive 96/92/EC for the liberalization of the electricity market. Upon this regulation, which constituted the legal backbone, two organizations emerged: The Regulatory Authority of Energy (RAE) and the Hellenic Transmission System Operator (HTSO). RAE is a financially and administrative independent authority which accesses tariffs, the terms and conditions for balancing services and security in electricity and gas market and serves as a dispute settlement authority. RAE has an advisory and consultatory role