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Electricity derivatives pricing with forward-looking information ☆

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ABSTRACT

In order to increase overall transparency on key operational information, power transmission system operators publish an increasing amount of fundamental data, including forecasts of electricity demand and available capacity. We employ a fundamental model for electricity prices which lends itself well to integrating such forecasts, while retaining ease of implementation and tractability to allow for analytic derivatives pricing formulae. In an extensive futures pricing study, the pricing performance of our model is shown to further improve based on the inclusion of electricity demand and capacity forecasts, thus confirming the general importance of forward-looking information for electricity derivatives pricing. However, we also find that the usefulness of integrating forecast data into the pricing approach is primarily limited to those periods during which electricity prices are highly sensitive to demand or available capacity, whereas the impact is less visible when fuel prices are the primary underlying driver to prices instead.

1. Introduction

Following the liberalization of electricity markets in many countries, utility companies and other market participants have been facing an increasing need for new pricing models in order to accurately and efficiently evaluate spot and derivative electricity contracts. In addition, the end of cost-based pricing and the transition towards *deregulated* markets also gave rise to new financial risks, threatening to impose substantial losses especially for sellers of electricity forward contracts. As such, the necessity to now optimize against the market for both standard electricity products and tailored contingent claims additionally required effective and integrated risk management strategies to be developed.

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These developments have to be seen in the context of the unique behavior of electricity (spot) prices, which is primarily induced by the non-storability of this commodity: apart from hydropower with limited storage capabilities, an exact matching of flow supply and flow demand for electricity is required at every point in time. The resulting price dynamics with their well-known *stylized facts* such as spikiness, mean-reversion, and seasonality, have extensively been analyzed in the literature,[1] yet still pose a challenge to both practitioners and researchers in terms of adequately modeling their trajectories.

However, the non-storability of electricity has further implications for the price formation mechanism. First, unlike in a classic storage economy, it is the instantaneous nature of electricity that causes the intertemporal linkages between economic agents' decisions today and tomorrow to break down. In fact, this forms the basis for electricity markets usually being characterized as very transparent with respect to their underlying economic factors, including electricity demand, available levels of generation capacity, as well as the costs for generating fuels and emissions allowances. Against this background, structural approaches taking this information explicitly into account appear especially appealing to electricity price modeling (see, e.g., Pirrong, 2012). Second, and as the above implies, the classic assumption that the evolution of all relevant pricing information, i.e., the information filtration, is fully determined by the price process of the commodity itself, does not hold for non-storable assets such as electricity. In other words, today's electricity prices do not necessarily reflect forward-looking information that is publicly available to all market participants.[2] At the same time, legal requirements and voluntary initiatives to increase data transparency have had power transmission system operators (TSOs) publish an increasing amount of data regarding the condition of their network, including, e.g., forecasts about expected electricity demand or updated schedules of planned short-term outages.[3] Pricing electricity spot and derivatives contracts based on models that make use of historical information only, may hence result in substantial errors since the model leaves aside important, forward-looking information, although it is publicly available and likely to play a key role for individual trading decisions.

In this paper, we contribute to the literature by focusing on the prominent role of forward-looking information in electricity markets and investigating its impact on the pricing of electricity derivatives contracts. Based on an empirical analysis of 1-month and 2-months ahead forward contracts traded in the British market, we show that the integration of forecast data on fundamental variables, such as electricity demand or available capacity, significantly improves the performance of our electricity derivatives pricing model during those times when prices are highly sensitive to these drivers. By means of an enlargement-of-filtration approach, we demonstrate how to properly integrate forecasts of demand and capacity into our setting, and thus account for the apparent asymmetry between the historical filtration and the (enlarged) market filtration in electricity markets.

In general, existing literature on electricity *spot* price modeling can be grouped into two categories: on the one hand, often allowing for analytic derivatives pricing formulae, considerable attention has been devoted to reduced-form models that either directly specify dynamics for the electricity spot price process itself or, alternatively model the term structure of forward contracts, where spot dynamics are derived from a forward contract with immediate delivery (see, e.g., Clewlow and Strickland, 2000; Koekebakker and Ollmar, 2005; or Benth and Koekebakker, 2008). Starting with traditional commodity modeling approaches via mean-reverting one- or two-factor models (Lucia and Schwartz, 2002), the goal of reflecting the stylized facts of electricity spot price dynamics even more adequately has led to more elaborate settings including: regime-switching approaches (Janczura and Weron, 2010); affine jump diffusion processes (Bierbrauer et al., 2007); and settings with non-constant deterministic or stochastic jump intensities (Seifert and Uhrig-Homburg, 2007). However, for the purposes of our analysis, it will be important to employ a model that is capable, at least in some form, of reflecting the dependence structure between prices and the electricity markets' underlying drivers, which then allows us to also relate forward-looking information on these drivers to electricity prices. Hence, by their nature, classic reduced-form models appear unsuited in this context and will not be pursued in this paper.[4]

On the other hand, the class of structural/fundamental electricity price models subsumes a wide spectrum of more diverse modeling approaches; starting with equilibrium-based models (Bessembinder and Lemmon, 2002; Buehler and Mueller-Mehrbach, 2007; Aïd et al., 2011) or even more richly parameterized full production cost models (Eydeland and Wolyniec,

[1] See, e.g., Johnson and Barz (1999), Burger et al. (2004) or Fanone et al. (2013).

[2] Benth and Meyer-Brandis (2009) provide several examples in support of this argument, such as the case of planned maintenance for a major generating unit, which is likely to be public information available to all market participants. Assuming a stylized setting, this outage will necessarily affect electricity spot prices expected to prevail during the time the unit is offline. Likewise, the outage will also affect today's prices of derivative contracts such as forward and futures contracts if their delivery periods overlap with the period of scheduled maintenance. However, in the absence of any means to economically store electricity bought at (cheaper) spot prices today and to sell it at higher prices during the time of the outage, there is no opportunity for arbitrage in such situation. This consequently implies that today's electricity *spot* prices will remain virtually unaffected by the announcement of the outage.

[3] In Europe, Regulations (EC) no. 1228/2003, its follow-up no. 714/2009, and annexed "Congestion Management Guidelines" (CMG) may serve as the most prominent example, requiring, e.g., that "*the TSO shall publish the relevant information on forecast demand and on generation (…)*" (CMG, article 5.7). In the US, similar standards are in place, e.g., as issued by the Federal Energy Regulatory Commission (FERC).

[4] Note that it is still possible to integrate information about the dynamics of fundamental state variables (such as demand or, e.g., also temperature) into reduced-form models by means of correlated processes. For an example, see Benth and Meyer-Brandis (2009). However, even though such models may bridge the gap between classic reduced-form and fundamental approaches, it is still questionable whether a single correlation parameter may be sufficient to reflect the rich dependence structures between electricity prices and a fundamental state variable – all the more if the dynamics of several underlying variables are to be taken into account at the same time.