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Managing electricity price modeling risk via ensemble forecasting: The case of Turkey☆

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ABSTRACT

There are two ways of managing market price risk in electricity day ahead markets, forecasting and hedging. In emerging markets, since hedging possibilities are limited, forecasting becomes the foremost important tool to manage spot price risk. Despite the existence of great diversity of spot price forecasting methods, due to the unique characteristics of electricity as a commodity, there are still three key forecasting challenges that a market participant has to take into account: risk of selection of an inadequate forecasting method and transparency level of the market (availability level of public data) and country-specific multi-seasonality factors. We address these challenges by using a detailed market-level data from the Turkish electricity day-ahead auctions, which is an interesting research setting in that it presents a number of challenges for forecasting. We reveal the key distinguishing features of this market quantitatively which then allow us to propose individual and ensemble forecasting models that are particularly well suited to it. This forecasting study is pioneering for Turkey as it is the very first to focus specifically on electricity spot prices since the country's day-ahead market was established in 2012. We also suggested applicable policy and managerial implications for both regulatory bodies, market makers and participants.

1. Introduction

Electricity day-ahead auctions play a central role for the sustainability of electricity markets since they reveal the *reference price* for all market participants. In emerging markets, since the number and variety of hedging tools are limited, for market participants accurate forecasting becomes the most essential tool for managing spot price risk. On the other hand designing a market with a proper transparency level is one of main responsibilities of the policy makers to let market participants generate reasonable forecasts using public information.

Especially after the well-known California crisis in the 2000s, the number of studies on day-ahead price forecasting increased substantially, as the need for such studies became apparent (e.g., Borenstein, 2001). Since the storability of electricity is limited, electricity prices reveal characteristics that differ from other commodities and present specific forecasting challenges. Studies focus first on the basic characteristics of electricity, namely non-storability and inelasticity of supply/demand (Geman and Roncoroni, 2006; Lucia and Schwartz, 2002), and then examine spikes, nonstationarity and mean reversion (Haugom and Ullrich, 2012; Knittel and Roberts, 2005). However there are still three challenges that needs to be dealt with in electricity price forecasting (Weron, 2014).

The first one is a methodological issue, the *risk of selection of an inappropriate forecasting model*. Although various individual forecasting methods are suggested in the literature, none of them has been proven to be superior (Chen and Bunn, 2010; Weron, 2014), and the

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performance of individual models depends on the periods being considered and the characteristics of market (Aggarwal et al., 2009). To compensate for the weaknesses of each individual method, the combined forecasting approach was developed (Crane and Crotty, 1967; Bates and Granger, 1969). The main advantage of combining forecasts is not that the ex-post performance of best ensembles are better than that of best individuals, but that it is less risky to ensemble forecasts than to select ex-ante one individual forecasting method (Hibon and Evgeniou, 2005). Although ensemble approach has been well-studied in other contexts (Stock and Watson, 2004; Timmermann, 2006), the number of combined forecasting studies relating to electricity markets is limited (Weron, 2014). The existing studies are mostly on electricity load forecasting (e.g. Bunn, 1975, 1977; Taylor, 2010). In the context of day-ahead price forecasting, leading point forecasting studies are, Bordignon et al. (2013) and Nowotarski et al. (2014), both of which are from mature electricity markets (the UK and NordPool). The recent few studies (e.g. Maciejowska et al., 2016; Gaillard et al., 2016, Maciejowska and Nowotarski, 2016) focus on probabilistic forecasting and are from the results of the Global Energy Forecasting (GEF) Competition-2014 in which US zonal prices are used. One of the main findings of these papers is that analysis of different market conditions can provide important insights in terms of comparing individual and ensemble models.

Second challenge is a more market-specific one which is the *appropriate selection of exogenous variables* (e.g., Keles et al., 2016), since the quality and availability of public data (transparency level of the market) and their influence on price may differ depending on the market studied (Aggarwal et al., 2009; Von der Fehr, 2013). Including exogenous variables (e.g., demand) generally increases the accuracy of price forecasts. However, when the number of exogenous variables is increased, the probability of data quality issues and access problems can increase, and may lead to even worse price forecasts. Therefore, in devising a sound process for selecting variables the features of the market need to be taken into account.

The last challenge is catching market-specific *multi-seasonality* (e.g., Janczura et al., 2013) characteristics of the spot price. Multi-seasonality is defined as having simultaneously daily, weekly and annual components. The *annual seasonality* is more difficult to detect, as it is masked by more irregular patterns, and it is often ignored in studies as it is generally believed to add complexity to already parsimonious models (Weron, 2014; Nowotarski and Weron, 2016). The problem of *daily seasonality* is solved by either taking daily averages or modeling each hour separately (Misiorek et al., 2006; Karakatsani and Bunn, 2008, 2010). Since predictability level (and thus market efficiency) of electricity prices can change over the course of the day, choosing forecasting models by considering fractal properties is very important (Avci-Surucu et al., 2016). The *dual-calendar effect* is another factor that influences prices in countries which follow both the Hijri and Gregorian calendars for holidays (De Livera et al., 2011).

In this paper our aim is to examine the performance of carefully selected individual and ensemble models in an emerging EDA market, Turkey, which is an interesting research setting in that it presents several challenges for forecasters. First, since it is an emerging market, hedging possibilities are limited, forecasting becomes the foremost important tool to manage spot price risk for power agents. As stated in Hong (2015), even one percent decrease in short term price forecasting error could result in a hundred thousands of profit per year for a medium sized utility. Even worse, as in most of the emerging markets, there is no information transparency platform from which market participants can obtain relevant data easily and use them in order to decrease their forecast errors. This makes the Turkey day ahead market (DAM) a *semi-transparent* one in terms of information dissemination.[1] Secondly, there is no nuclear power plant which eases the horizontal shift of the base load in the hourly merit order curve (MOC). Third, there is no gas forward market as gas prices are regulated by the government, therefore it is more difficult to catch the trend seasonality by calculating the marginal costs of bidders. Fourth, the observance of multiple religious holidays in Turkey means that dual-calendar seasonal effects can be found and this situation complicates modeling seasonality component. Lastly, bids by the state-owned hydro power plants (PP) have a crucial impact on the shape of the MOC, therefore appropriate selection of the exogenous variables relating to supply stack characteristics becomes vital. Thus, our main research question is '*How to manage price modeling risk via ensemble forecasting in the Turkish electricity day ahead auctions*'. In sum, we aim to develop well-performing ensemble forecast models for an emerging market and compare their performance with alternative individual models. This will enable us to address some of the shortcomings of existing ensemble modeling studies, specifically the inadequate handling of trend seasonality component, the inappropriate selection of exogenous variables when one considers the relationships that exist between price and system constraints, and the methodological similarity of the individual models they have considered. We contribute to the energy economics literature on both theoretical and practical dimensions. Firstly, regarding the variety and type of individual models, ours is one of the first studies to include a long-term seasonality component for ensemble forecasts and to provide evidence of their performance. Secondly, since all of the previous ensemble forecasting studies of electricity price are from well-developed markets (such as the UK and Nord Pool) and ours is the first to look at a developing market with a semi-transparent structure, our findings may be informative for market participants and policymakers in other developing markets with similar transparency features. Lastly, this forecasting study is also pioneering in terms of the Turkish electricity market since it is the very first to examine electricity day-ahead auction prices after the establishment of the DAM in 2012.

The remainder of the paper is organized as follows. In Section 2, we briefly explain the theoretical framework of the individual and ensemble models that we adopt for this study. Section 3 illustrates the conceptual background related to general processes and fundamental drivers of the clearing price in day ahead auctions. Section 4 describes the data and its temporal properties, Section 5 explains the theoretical framework and presents the results, and Section 6 concludes the paper with a summary of the findings and suggestions for future research.

2. Theoretical framework

We consider three classes of individual models; econometric time series, artificial neural networks and seasonality models; which are chosen by virtue of their suitability for catching the specific features of the price dynamics of electricity day ahead auctions and also for minimizing the methodological similarities between them guided by the previous literature. We aim to understand how their forecasting performance changes according to the particular electricity market. We derive our ensemble models by using *equally weighted means* which has been highly advocated (Makridakis et al., 1998; Stock and Watson, 2004). All the models (both individual and ensemble) are executed with a set of explanatory variables which are carefully selected from the literature due to their fundamental relation with auction mechanism of the day ahead markets and their correlation with the clearing price (Karakatsani and Bunn, 2008; Nan, 2009).

2.1. Exogenous variables affecting electricity day ahead auction prices

The selection of exogenous variables is a crucial step for developing forecasting models. Market characteristics, nonstrategic uncertainties, other stochastic uncertainties, behavioral indices, and temporal effects are main classes of input variables effecting electricity prices (Karakatsani and Bunn, 2008). *Historical electricity prices* (e.g., price lags of 1–7, 14, 21, 28 or 364 days) are the most extensively used variable.

[1] Details about the *transparency level* is given in Section 3.