ANALYSIS OF DEMAND AND SUPPLY CURVES IN THE ITALIAN NATURAL GAS MARKET THROUGH FUNCTIONAL TIME SERIES.

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ABSTRACT. Motivated by price prediction in Italian natural gas balancing market, we propose a model to forecast supply and demand curves evolving through time. Differently from the previous literature, where supply and demand curves are described as static objects, here we consider them as dynamic objects. Assuming that the future curve depends on the previous curves and on some quantities available at prediction time, we looked for a suitable functional autoregressive model with scalar covariates which maintains the monotonicity constraints. The results are satisfactory and coherent with standard time series analysis but with much richer information about the market dynamic.

1 INTRODUCTION

In Italy we have assisted to the recent introduction of the natural gas balancing platform, a system in which gas operators virtually sell and buy natural gas in order to balance the common pipelines network. Basically, the operators daily submit demand bids and supply offers which are eventually sorted according to price. Demand and supply curves are hence obtained by cumulating the corresponding quantities. The selection of bids/offers accepted on the platform is based on the auction mechanism so that every offer to the left of the intersection of the two curves is accepted and exchanged at the resulting intersection price. In this work, we propose a model to forecast supply and demand curves evolving day by day. Differently from the previous literature, where supply and demand curves are described as static objects, here they are analyzed in a dynamical perspective. Moreover, the prediction of the entire demand and supply curves allows - at least in markets with a moderate number of traders - the evaluation of the effect of a single non-standard bid or offer on the resulting price and thus on the accepted bids and offers, opening to development of strategic and speculative policies based on what-if simulations.

2 METHODOLOGY

Demands and supply curves observed across time provide a time series of bounded and monotonic functions. Firstly we built a bijective map associating each possible bounded and mono-

tonic function to an unconstrained one and mapping the entire constrained functional time series to an unconstrained one. Then, assuming that the future transformed curve linearly depends on the previous transformed curves and on some quantities available at prediction time, we looked for a suitable functional autoregressive model with scalar covariates.

In particular, we investigated two kinds of model: concurrent models - in which an infinite number of scalar-to-scalar autoregressive models are used to predict pointwise evaluations of the demand/supply function - :

$$f_t(s) = \alpha(s) + \sum_{k=r}^{p} x_k(s)\beta_k(s) + \sum_{j=1}^{p} f_{t-j}(s)\psi_j(s) + \varepsilon_t(s) \; ; \tag{1}$$

and non-concurrent models - in which a unique functional-to-functional autoregressive model is used to predict the entire demand/supply function - :

$$f_t(s) = \alpha(s) + \sum_{k=r}^{p} x_{kt}(s)\beta_k(s) + \sum_{j=1}^{p} \int f_{t-j}(u)\psi_j(u,s)du + \varepsilon_t(s) \; . \tag{2}$$

In both models, $\{f_t\}$ is the functional time series of the transformed functions to be predicted, $\{\varepsilon_t\}$ are a sequence of iid mean zero error functions, α is the intercept term, β_k are the regressive parameters pertaining the scalar covariates, and ψ_j are the autoregressive parameters.

We estimated the parameters α, β_k, and ψ_j by means of a penalized L^2-based least square optimization with penalties proportional to the squared L^2-norm of the parameters. Finally, once detected a good model for prediction, we anti-transformed the model output obtaining a non-linear functional predictor providing the trader a prediction of the future demand/supply curve satisfying all required constraints.

3 RESULTS

We apply the previous models to predict both the demand and supply curves of the Italian natural gas balancing platform (PB-GAS) which are daily released by the Italian energy regulatory *Gestore Mercati Energetici* (GME) since December 1st, 2011. We tested different models relying on different covariates and different lags, and try to predict either the requested/offered quantity as a function of the exchanging price or, contrariwise, the price as a function of requested/offered quantity. In terms of the squared prediction errors of the exchanged quantity and corresponding price the best performances are achieved by a non-concurrent second order autoregressive model without covariates. In detail, an excellent matching between the predicted curves and the actual ones are obtained.

Focusing on the intersection between the demand and the supply curves, which defines the exchanged quantity and price, we obtain a price prediction with mean squared error equal to 0.013. As a benchmark, a classical time series approach has been adopted to analyze the series of price. See Canale (2013) for further details. The final model includes exogenous covariates and a second order autoregressive component for the mean level of the series and leads to a mean squared error of 0.012. Hence, our approach, while leading to comparable predictive results for pointwise prediction of price, gives deeper and reacher insights on the market dynamics. The prediction of the entire demand and supply curves allows the evaluation of the effect of a single bid or offer and results to be a tool with dramatic impact for gas traders.

4 DISCUSSION

In this work we discussed a model for time series of functions that are constrained to be monotone, positive or bounded. The approach has been applied to the Italian natural gas balancing platform data, showing that the supply and demand curves of this market evolves through time according to a second order autoregressive model. The approach is of general interest and can be generalized in any situation in which one has to deal with constrained monotonic functions which evolve through time.

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