

Quantile Regression for Peak Demand Forecasting

Charlie Gibbons
Ahmad Faruqui

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THE **Brattle** GROUP

Outline

Approaches to forecasting peak demand

Our empirical approach

OLS versus QR

Results

Forecasting peak demand

In this presentation, we discuss methodologies for forecasting peak demand.

Any proposed methodology should be evaluated by its accuracy.

An *accurate* model is just as likely to over-forecast as it is to under-forecast peak demand in a given year.

Motivation for the study

Annual peak demand is anomalous and the forecasting methodology must take this into account.

Current approaches largely rely on OLS, which is best suited to forecasting average consumption and not peak demand:

- OLS with one data point for each annual peak
- OLS on a subset of relatively extreme days

We propose Quantile Regression (QR) as a superior solution.

We compare QR and OLS methods of the same functional form using 32 “utilities” in a meta-study.

Data (1999—2013)

We model

- Daily maximum hourly demand using all summer (May-September) days

Using

- Monthly energy
- Maximum daily temperature (contemporaneous and lag)
- Minimum daily temperature (contemporaneous and lag)
- Month fixed effects
- Day of week fixed effects
- Dummy variable for weekday holiday
- Quarterly index of economic activity*
- Daily humidity*
- Monthly CDD and HDD*

* when available

Approach

Daily maximum demand is predicted separately by utility and the same functional form is used for all utilities.

We estimate QR and OLS using data from 1999-2008 (the “in sample” or “estimation” period).

We evaluate the methods using the 2009-2013 data (the “out of sample” period).

Decomposing maximum demand

We can decompose maximum demand into two parts:

- **Predictable demand**

We can use weather, sales, and other variables to predict maximum demand.

- **Unpredictable shock**

There are idiosyncratic components of demand that are not predictable.

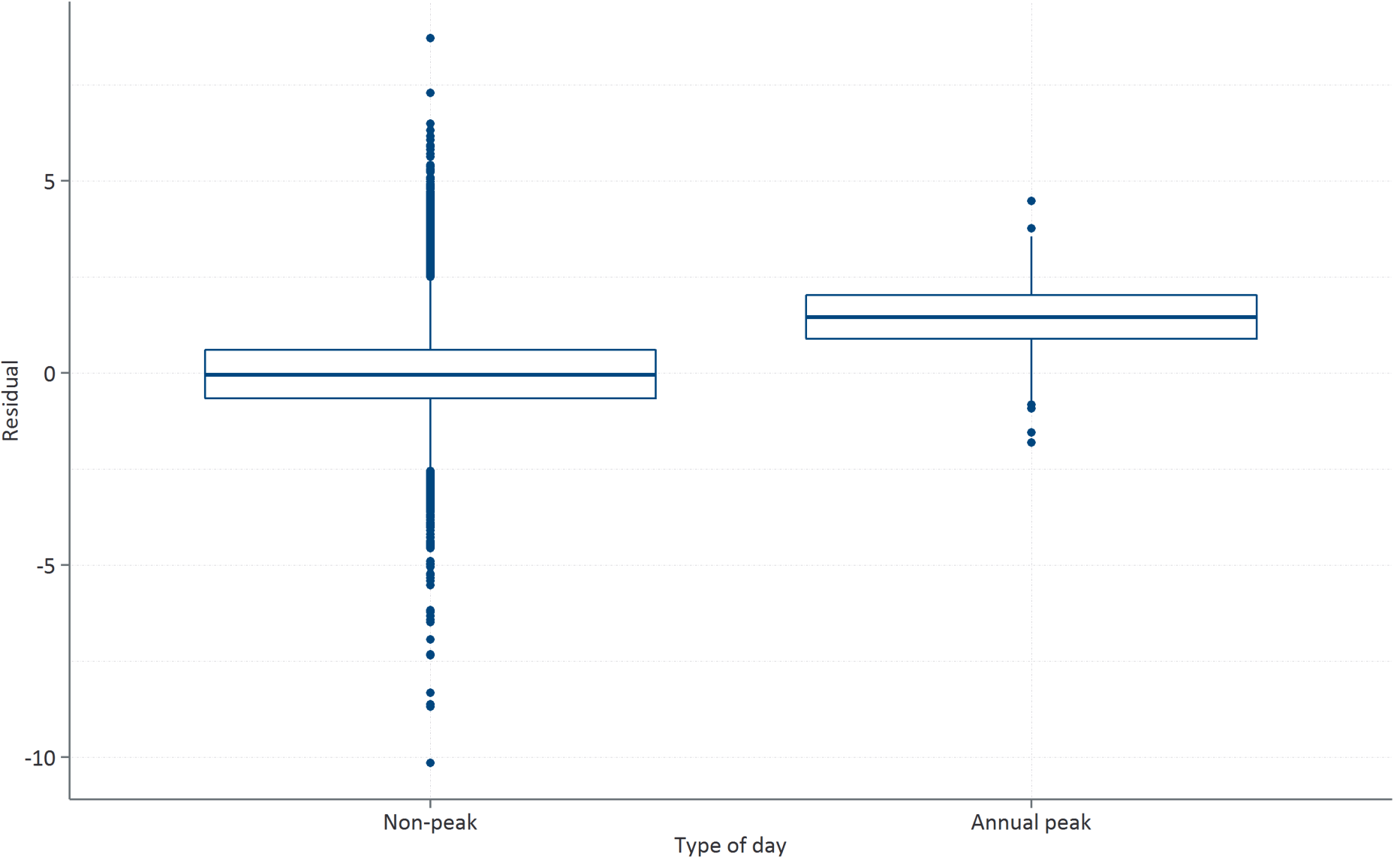
OLS versus QR

The day establishing peak demand likely has large values for both of these components.

- Many days in the summer exhibit severe weather; the one with the highest demand will be the one with the highest demand shock.
- OLS can be used to create forecasts for days with large predictable demand.
- OLS **cannot** be used to create forecasts for days with large shocks.
- QR can be used to create forecasts for days with both large predictable demand and large shocks.

An accurate peak demand model must incorporate both components.

Standardized residuals from OLS models



The questions that OLS and QR answer

OLS

- For a given level of the predictors, what is the average level of demand that is to be expected?
- This model incorporates a shock of size 0 (the average).

QR

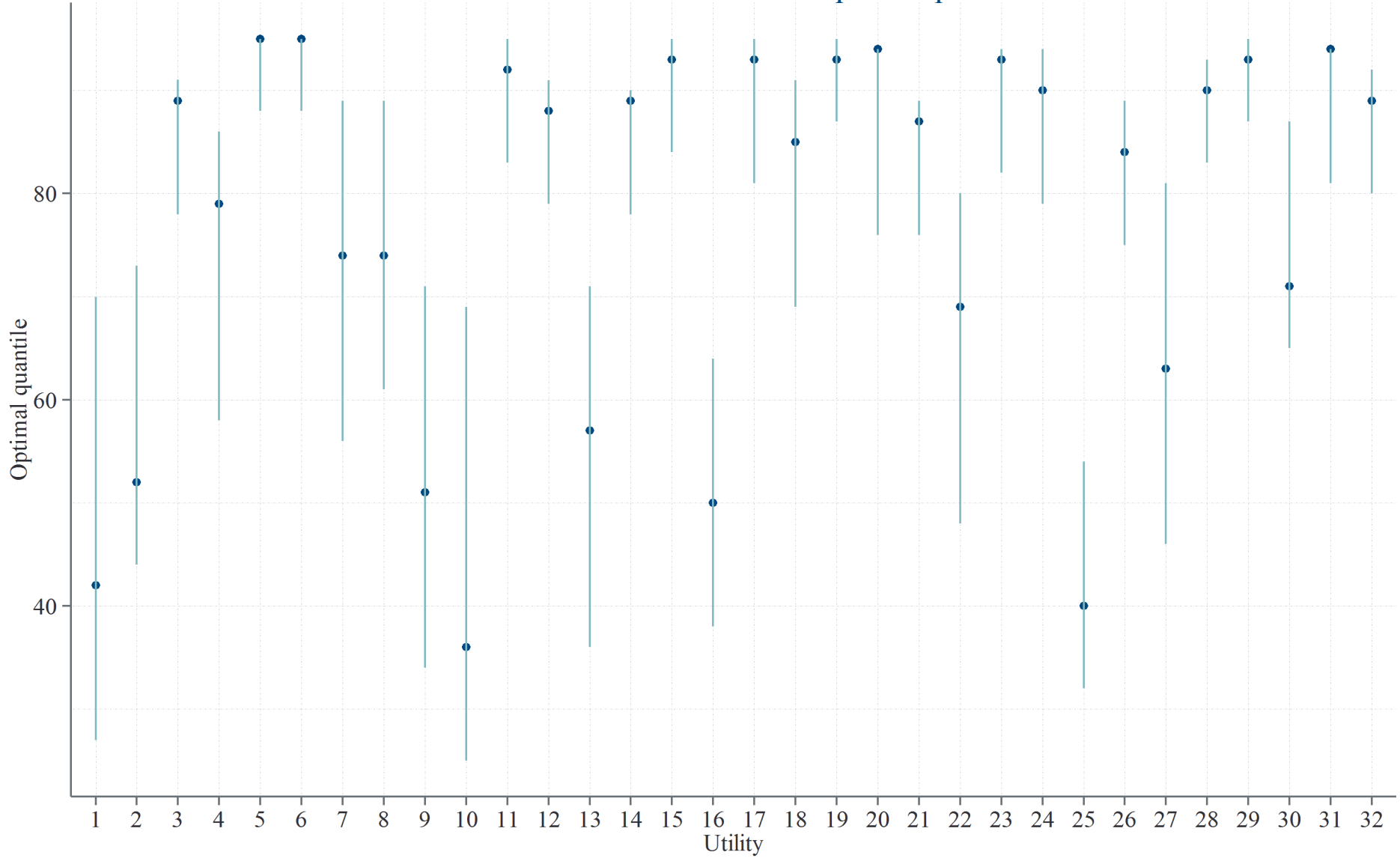
- QR requires specifying a percentile of interest; 90%, say.
- For a given level of the predictors, what is the 90th percentile of demand that is to be expected?
- This model incorporates a 90th percentile shock.

Quantiles

The quantile is estimated to provide accurate in-sample predictions of peak demand.

The further the estimated quantile is from 50, the greater the difference between the QR and OLS models.

95% confidence intervals for optimal quantile



Evaluation

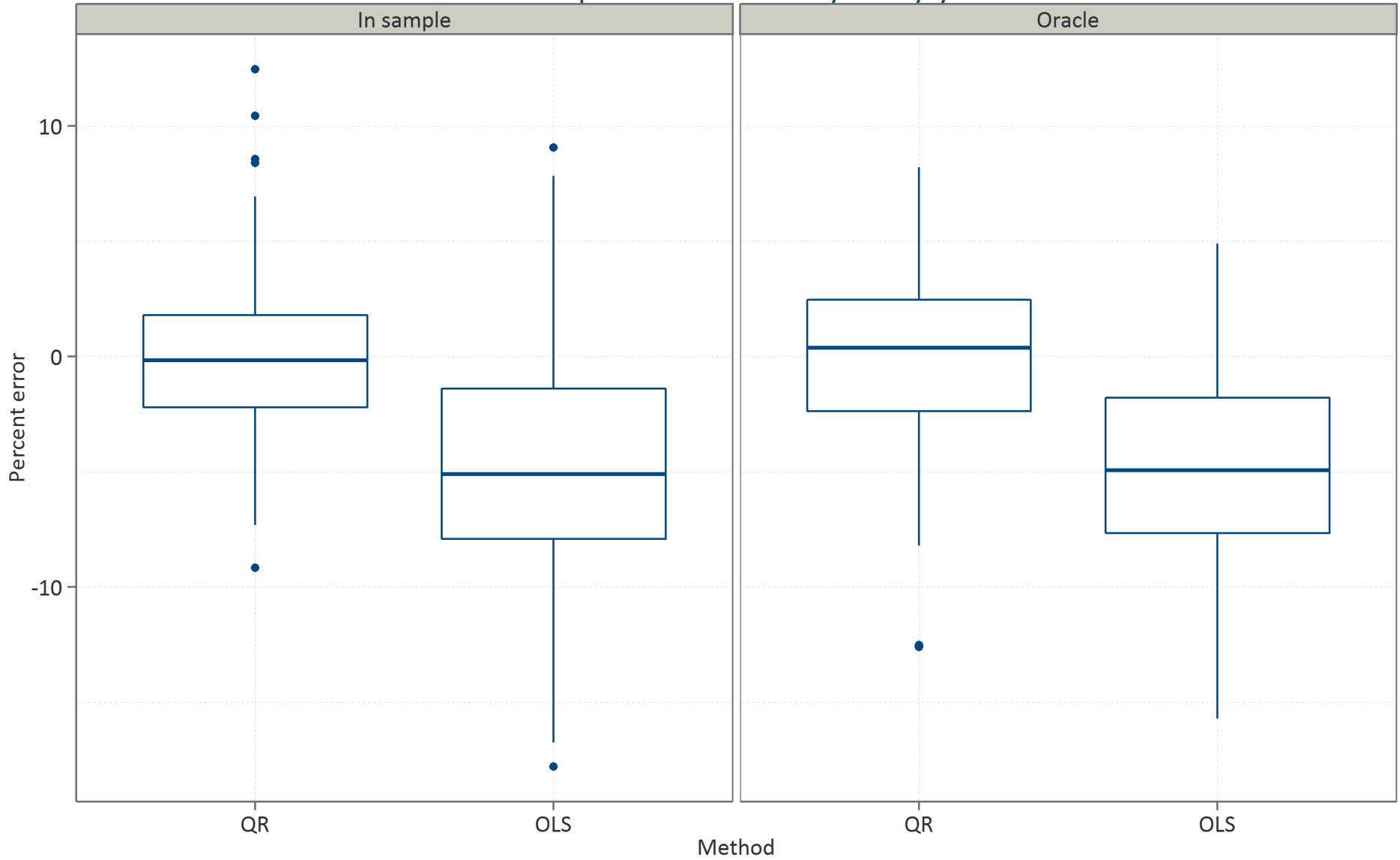
For each year and each utility, we compare:

- Highest level of hourly demand predicted by the model
- Highest level of hourly demand actually witnessed (non-coincident)

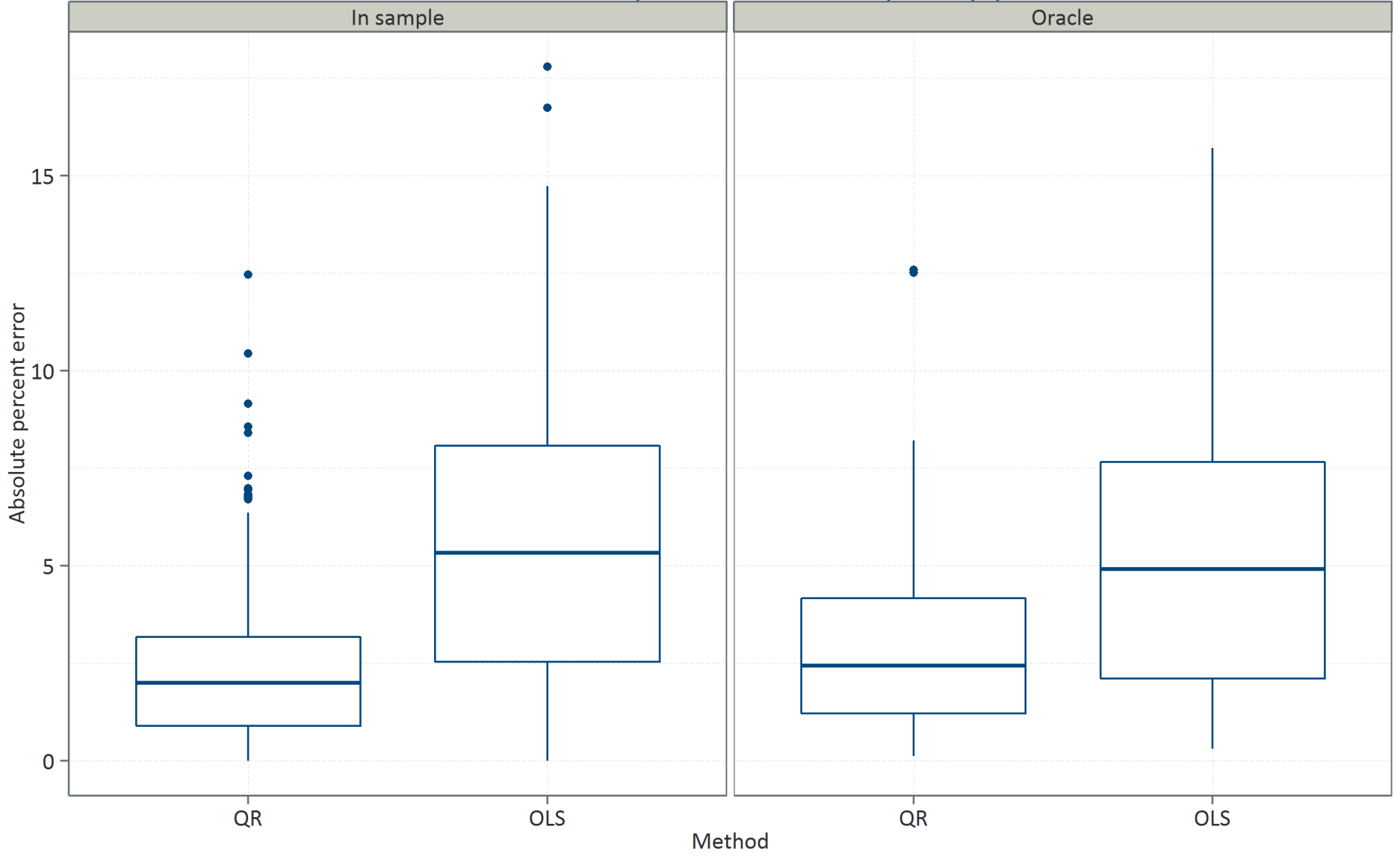
We provide errors for two sets of predictions:

- In sample prediction
- Oracle forecasts
These out-of-sample forecasts use the true values of the predictors.

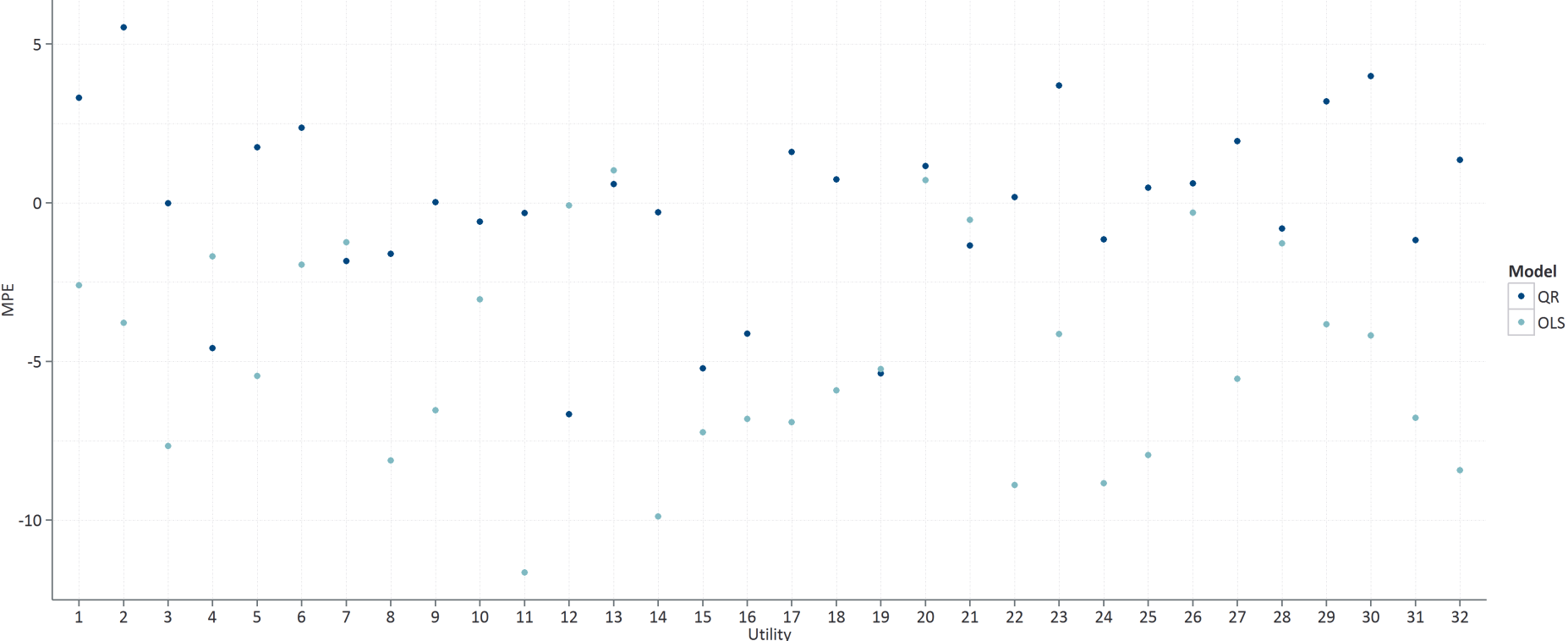
Annual prediction errors by utility-year



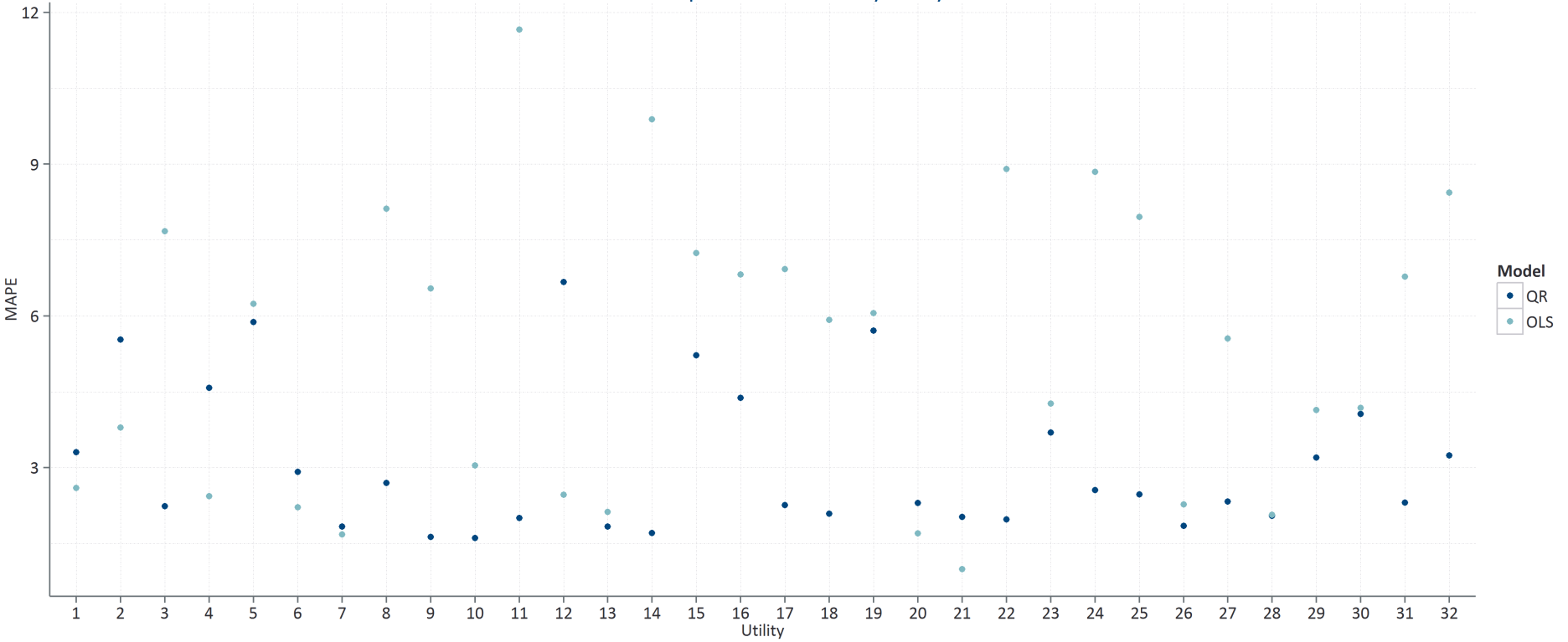
Annual absolute prediction errors by utility-year



Out of sample Oracle MPE by utility



Out of sample Oracle MAPE by utility



Performance summary

Across utilities, QR:

- Has a mean out-of-sample prediction error of 0.05% compared to -4.82% for OLS
- Has a mean out-of-sample absolute prediction error of 3.05% compared to 5.28% for OLS, a reduction of 42%

By utility, QR:

- Has a negative MPE for 15 of 32 utilities, while OLS has a negative MPE for 30 of 32 utilities
- Has a smaller MAPE than OLS for 24 out of 32 utilities
- Has a median MAPE that is 25% smaller than that for OLS

Results

Peak demand is a function of predictable demand and unpredictable shocks.

- OLS only considers the predictable component of demand.
- Shocks are larger on annual peak days compared to non-peak days.
- QR incorporates the size of the shock term in addition to the predictable component.

We see that

- The OLS model generally under-predicts peak demand.
- The QR model generally provides an accurate estimate of peak demand.

These results generally hold across utilities.

Forecast intervals

We also develop a bootstrapping method to produce forecast intervals for peak demand.

	95% interval coverage
In sample	95.1
Oracle	88.1

Conclusions

Peak demand days are differentiated from other high demand days by the presence of extreme shocks to demand.

OLS does not account for this distinguishing feature of these days and the approach's predictions are biased downward.

Focusing on days with high levels of predictors (rather than high levels of shocks) does not counteract this bias.

Quantile regression can incorporate extreme shocks to better predict peak demand.

Presenter information



CHARLIE GIBBONS

Associate | San Francisco, CA
Charlie.Gibbons@brattle.com
+1.415.217.1055

Dr. Charles Gibbons is an associate with The Brattle Group who specializes in applying sophisticated econometric and statistical models to legal, regulatory, and policy issues. He has produced analysis for a variety of litigation matters, including models of mortgage delinquencies, forensic analysis of product defects, and local impacts of environmental damages. His work has been used for class certification, liability determination, and damage calculations. He has also developed models for forecasting electricity sales and peak demand for an international utility.

Additionally, Dr. Gibbons is a lecturer at the University of California, Berkeley and last taught a graduate-level course in probability and statistics. He received a Ph.D. in economics and an M.A. in statistics from the University of California, Berkeley. His dissertation proposed new methods in applied econometrics and a theory of competition for online advertising platforms.

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Presenter information



AHMAD FARUQUI

Principal | San Francisco, CA

Ahmad.Faruqui@brattle.com

+1.415.217.1026

Dr. Ahmad Faruqui has advised utilities, ISOs/RTOs and government agencies on the design and evaluation of demand forecasting models since the inception of his career at the California Energy Commission. At the Electric Power Research Institute, he directed the research program on end-use analysis and forecasting which pioneered the use of a variety of new forecasting models that are still in widespread use in the electricity utility industry. He has consulted with more than 50 utilities and transmission system operators around the globe and testified or appeared before a dozen state and provincial commissions and legislative bodies in the United States and Canada.

He has developed models for forecasting monthly and hourly loads for clients using a variety of econometric and time series methods. He helped develop an hourly load forecasting model to assist a competitive wholesaler in bidding for default service. For a utility, he diagnosed why energy sales were below forecasts even after adjusting for the effects of the economy. He assisted a transmission system operator understand why peak demand was being under-forecast by a large amount. And he assisted a regulated provider of steam analyze the customer's decision to switch from purchasing steam to self-generating of steam and also to analyze the response of steam usage to rising steam prices. The analysis was carried out on a customer-by-customer basis and involved the use of discrete choice methods and conventional regression analysis.

He holds a doctorate in economics from the University of California at Davis and undergraduate and graduate degrees from the University of Karachi, Pakistan.

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