Supplementary Material for: Probabilistic Forecasting of Regional Net-load with Conditional Extremes and Gridded NWP

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1 Overview

This document provides additional materials that accompany "Probabilistic Forecasting of Regional Net-load with Conditional Extremes and Gridded NWP" by Browell and Fasiolo [1]. It provides descriptions of the R scripts and data files. The data includes Case Study dataset comprising net-load for the 14 regions of the GB electricity transmission system from 2014–2018, forecasts and evaluation results, and the code used to produce them. In addition, we provide an extended set of results to supplement and support those presented in the main paper.

2 Description of Code

The code used in this study is shared along with this document. Brief descriptions of the relevant files are provided here. Please also see comments in the scripts themselves. In addition to R packages available on CRAN, we have used `ProbCast`, a package developed by Jethro Browell and Ciaran Gilbert for probabilistic forecasting [2].

2.1 forecasting.R

Main script which reads in and prepares the dataset of net-load and weather forecasts, fits forecast models (including cross-validation and testing with rolling updates), calculates evaluation metrics and saves results. This script fits many models and as a result takes several days to run on a high performance laptop (Intel i7-7500U quad-core processor, 16GM RAM). Various speed-ups are possible, e.g. only fitting 'test' models, estimating models for fewer quantiles, and not calculating the PIT transformation of residuals. The data output by this script is provided so that forecasts can be examined without the need to run it and wait.

2.2 NodeForecasting_funcs.R

Additional functions called in `forecasting.R`. See comments in script.

2.3 evaluation.R

This scrips loads the forecasts and evaluation metrics calculated and saved by `forecasting.R`. It reproduces all of the figures and tables presented in the main paper and supplementary material.

3 Description of Data

The following data are provided to support reproduction of this research. Unfortunately, due to legal restrictions, is is not possible to share the raw components of net-load, i.e. the metered net-load at each Grid Supply Point. Following some basic leaning, we have aggregated the GSPs withing each Group, which we share here. Weather forecasts from ECWMF have been pre-processed as described in the main paper.

3.1 GSPGroup_NetD_v3_2.Rda

Table 1: List of columns/data fields in `GSPGroup_NetD_v3_2.Rda`. Additional features are created in `forecasting.R`, including lagged and interaction variables. Not all features were ultimately used in net-load forecasting models. For more details on NWP parameters, see the ECMWF Parameter Database

Column Name	Description
issueTime	Base time for NWP, [posixct]
targetTime	Time stamp for forecast, [posixct]
var246_max_2	100 metre U wind component, maximum value in +/-2° of GSP Group centre
var246_min_2	100 metre U wind component, minimum value in +/-2° of GSP Group centre
var246_mean_2	100 metre U wind component, mean value in +/-2° of GSP Group centre
var246_sd_2	100 metre U wind component, standard deviation in +/-2° of GSP Group centre
var247_max_2	100 metre V wind component, maximum value in +/-2° of GSP Group centre
var247_min_2	100 metre V wind component, minimum value in +/-2° of GSP Group centre
var247_mean_2	100 metre V wind component, mean value in +/-2° of GSP Group centre

var247_sd_2	100 metre V wind component, standard deviation in +/-2° of GSP Group centre
x10U_max_2	10 metre U wind component...
x10U_min_2	...
x10U_mean_2	...
x10U_sd_2	...
x10V_max_2	10 metre V wind component...
x10V_min_2	...
x10V_mean_2	...
x10V_sd_2	....
SSRD_max_2	Surface solar radiation downwards...
SSRD_min_2	...
SSRD_mean_2	...
SSRD_sd_2	...
LCC_max_2	Low cloud cover...
LCC_min_2	...
LCC_mean_2	...
LCC_sd_2	...
MCC_max_2	Medium cloud cover
MCC_min_2	...
MCC_mean_2	...
MCC_sd_2	...
HCC_max_2	High cloud cover...
HCC_min_2	...
HCC_mean_2	...
HCC_sd_2	...
x2T_weighted.mean_cell	2 meter temperature, mean over precise GSP Group region
x2T_weighted.sd_cell	2 meter temperature, standard deviation over precise GSP Group region
WindSpd100_weighted.mean_cell	100 meter wind speed...
WindSpd100_weighted.sd_cell	...
WindSpd10_weighted.mean_cell	10 meter wind speed...
WindSpd10_weighted.sd_cell	...
TP_weighted.mean_cell	Total precipitation...
TP_weighted.sd_cell	...
SSRD_weighted.mean_cell	Surface solar radiatoin downwards...
SSRD_weighted.sd_cell	...
LCC_weighted.mean_cell	Low cloud cover...
LCC_weighted.sd_cell	...
MCC_weighted.mean_cell	Medium cloud cover...
MCC_weighted.sd_cell	...
HCC_weighted.mean_cell	High cloud cover...
HCC_weighted.sd_cell	...
x2T_weighted.mean_pcell	2 meter temperature, mean weighted by population density in GSP Group region

TP_weighted.mean_pcell	Total precipitation...
settlement_date	Settlement data (corresponding to GB Balancing Mechanism)
settlement_period	Settlement period (corresponding to GB Balancing Mechanism)
node	Net-load, agregation of GSP meters in a given GSP Group [MWh]
targetTimeLondon	Local time
t	Time since 2014-01-01T00:00:00Z
dow	Day of the week [factor]
doy	Day of the year [numeric]
clock_hour	Hour of the day [numeric]
Date	Date [date]
type	Day type [factor]
hol_EW	Holiday in England and Wales [factor]
hol_Sc	Holiday in Scotland [factor]
type_simple	Day type grouped [factor]
node_sm	Smoothed net-load, 8 week rolling mean
kfold	Cross-validation fold
SolarCap	Embedded solar capacity in GSP Group
n2ex	Day-ahead electricity price from n2ex acution
EMBEDDED_WIND_CAPACITY	National (GB) embedded wind capacity
x2T_weighted.mean_p_max_point	2 meter temperature at point of maximum population density in GSP Group
TP_weighted.mean_p_max_point	Total precipitation at point of maximum population density in GSP Group

3.2 Forecast data

A file is provided with forecast data for each of the five models named `[model name].Rda`. Each file loads an R `list` object called `NodeData_temp` with entries detailed in the following table.

Table 2: Caption. *See `ProbCast` documentation for details.

Element	Description
model_formula	Formula for deterministic model [formula]
model_formula_qr	Formula for linear quantile regression [formula]
gam_models	List of estimated models [list]
$\tilde{}$[GSPG]	Main modelling table, detailed in Table 3 [data.table]
$\tilde{}$[GSPG]_norm	Mean and standard deviation used to calculate node_n (z-score of net-load) [list]
$\tilde{}$[GSPG]_qr	Table of predictive quantiles from quantile regression, rows correspond to those in [GSPG] [MultiQR]*
$\tilde{}$[GSPG]_u	PIT transformed node_n using cGPD tails [numeric]
$\tilde{}$[GSPG]_u_sGPD	PIT transformed node_n using sGPD tails [numeric]
$\tilde{}$[GSPG]_u_QR	PIT transformed node_n using quantile regression and interpolation
$\tilde{}$[GSPG]_evtails	Specification* of α_L and α_R [list]
tail_parama_$\tilde{}$[GSPG]	Parameters* for interpolating quantile regression to form full predictive CDF [list]

Table 3: List of columns/data fields in main modelling table for each GSP Group.

Column Name	Description
issueTime	Base time for NWP, [posixct]
targetTime	Time stamp for forecast, [posixct]
node	Net-load [numeric, MWh]
node_n	Net-load [numeric, standardised/z-score]
WindSpd100_weighted.mean_cell	Wind speed 100m above ground, spatial mean over region [numeric, m/s]
SSRD_weighted.mean_cell	Surface Solar Radiation Downwards, spatial mean over region [numeric, w/m^2]
clock_hour	hour of the day in local time, i.e. Europe/London [numeric]
kfold	Indicator for cross-validation fold (1, 2, 3, or Test) [factor]
BadData	Flag for bad data which is excluded from all analysis [Boolean]
gam_pred	Deterministic forecast of node_n, out-of-sample by virtue of either cross-validation or being in Test data [numeric]
tail_l_resid	Residuals for peaks-over-threshold fitting of left tail GPDs, i.e. q_{α_L} − node_n [numeric]
tail_r_resid	Residuals for peaks-over-threshold fitting of right tail GPDs, i.e. node_n − q_{α_R} [numeric]
gpd_scale_l0	Scale parameter for left tail static GPD, out-of-sample (OOS) by virtue of either cross-validation or being in Test data [numeric]
gpd_shape_l0	Shape parameter for left tail static GPD, OOS as above [numeric]
gpd_scale_r0	Scale parameter for right tail static GPD, OOS as above [numeric]
gpd_shape_r0	Shape parameter for right tail static GPD, OOS as above [numeric]
gpd_scale_l	Scale parameter for left tail conditional GPD, OOS as above [numeric]
gpd_shape_l	Shape parameter for left tail conditional GPD, OOS as above [numeric]
gpd_scale_r	Scale parameter for right tail conditional GPD, OOS as above [numeric]
gpd_shape_r	Shape parameter for right tail conditional GPD, OOS as above [numeric]

3.3 Evaluation.Rda

A file containing a `data.table` of forecast evaluation results. Metrics are provided by quantile, model (Vanilla-Point, GAM-Grid etc) and tail model (QR, sGPD, CGP) where appropriate.

3.4 School_Hols_v1.Rda

A file containing estimates of school holidays in Great Britain 2014–2018. These can vary between local authority and are only estimated here based on those which provide machine-readable tables and manual entry for regions with little or no data.

4 Additional Results

An expanded set of results is presented here covering all metrics and visualisations of which only a subset fit in the main paper.

4.1 Deterministic Forecasts Error

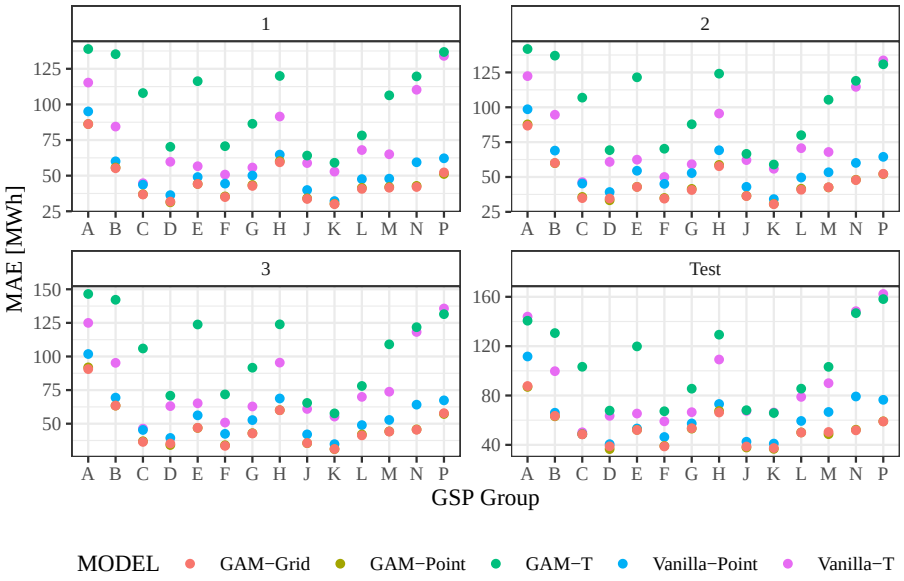

Figure 1: Mean Absolute Error (MAE) for each model, GSP Group, and cross-validation fold (1, 2, 3 and Test) in original units of MWh per half-hour settlement period. GAM-Point is not always visible because it is covered by GAM-Grid.

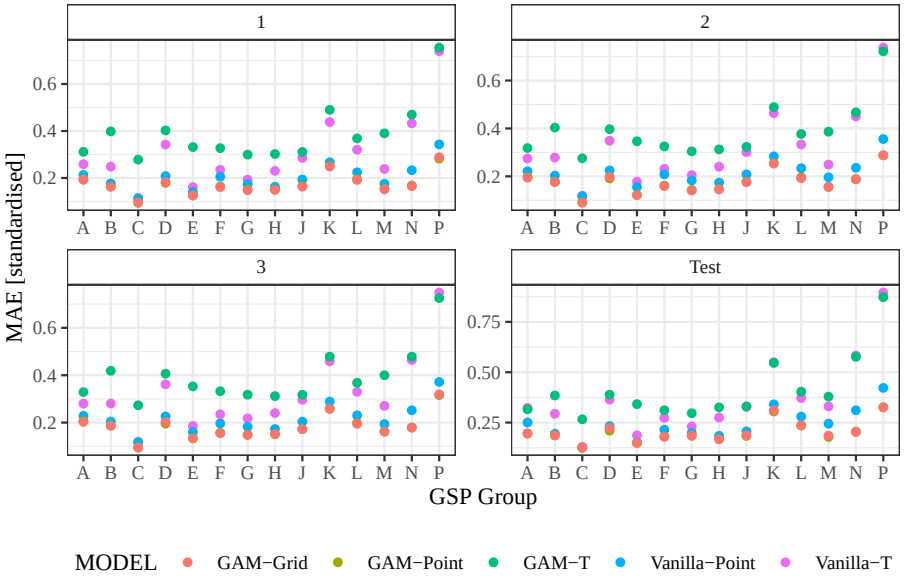

Figure 2: Mean Absolute Error (MAE) for each model, GSP Group and cross-validation fold (1, 2, 3 and Test) in standardised units (data transformed to z-score).

4.2 Pinball Loss

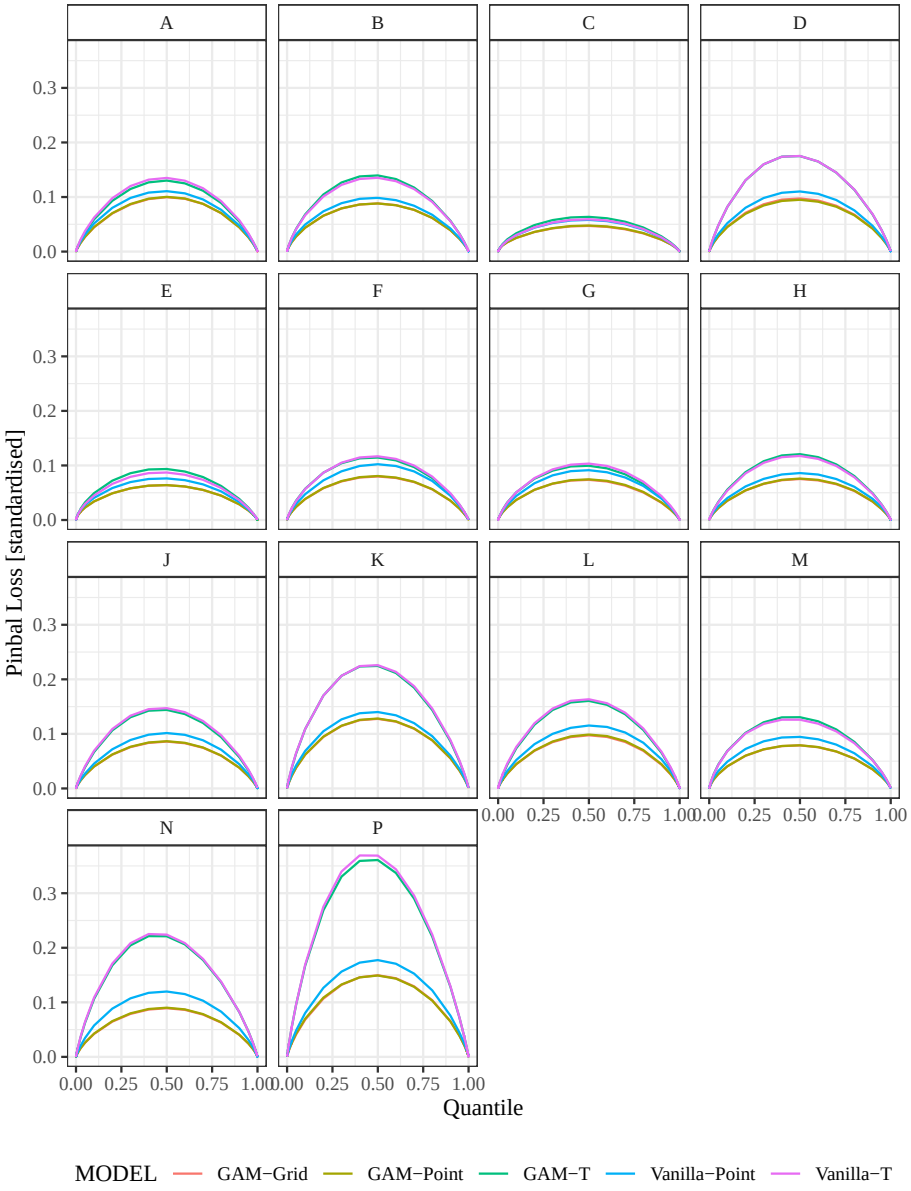

Figure 3: Pinball Loss for each model, GSP Group, and quantile in standardised units (data transformed to z-score). Average across all cross-validation folds.

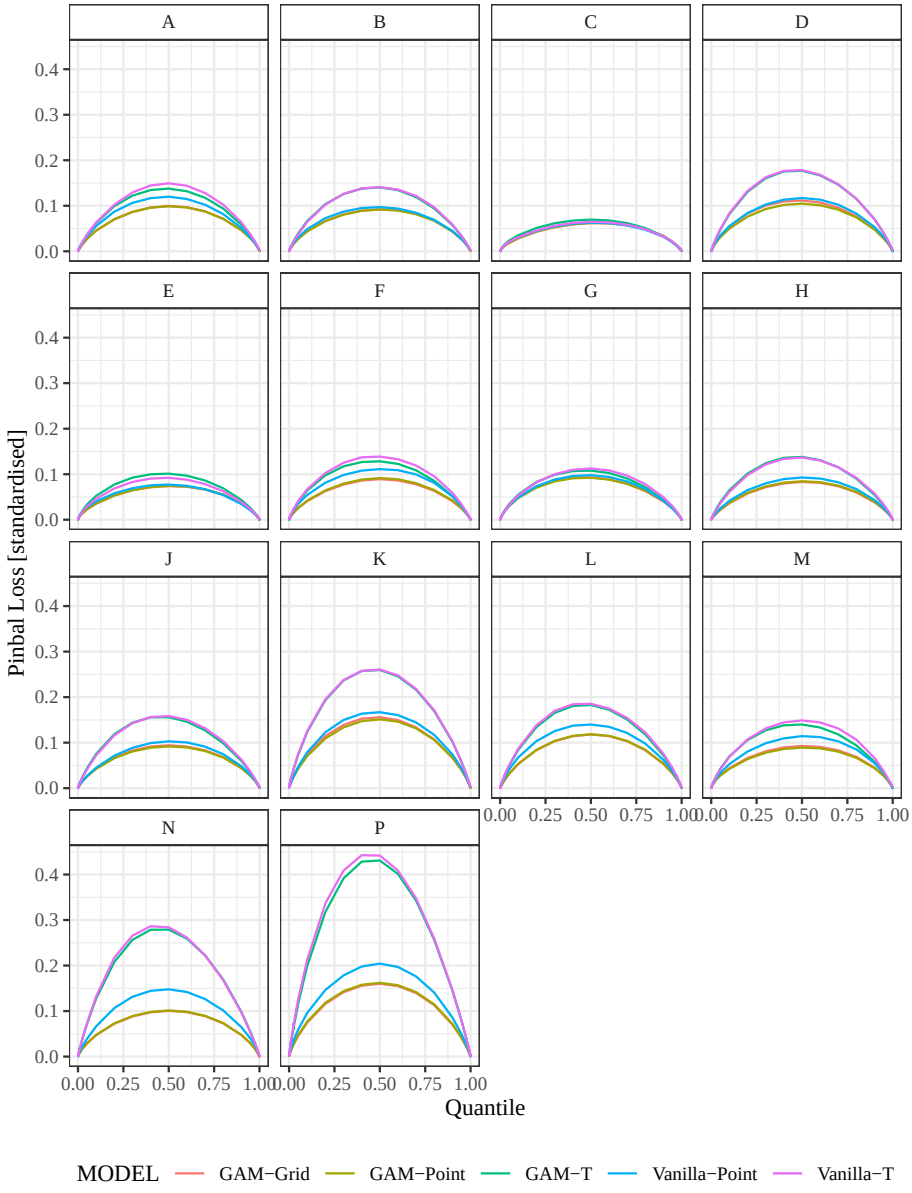

Figure 4: Pinball Loss for each model, GSP Group, and quantile in standardised units (data transformed to z-score). Test period.

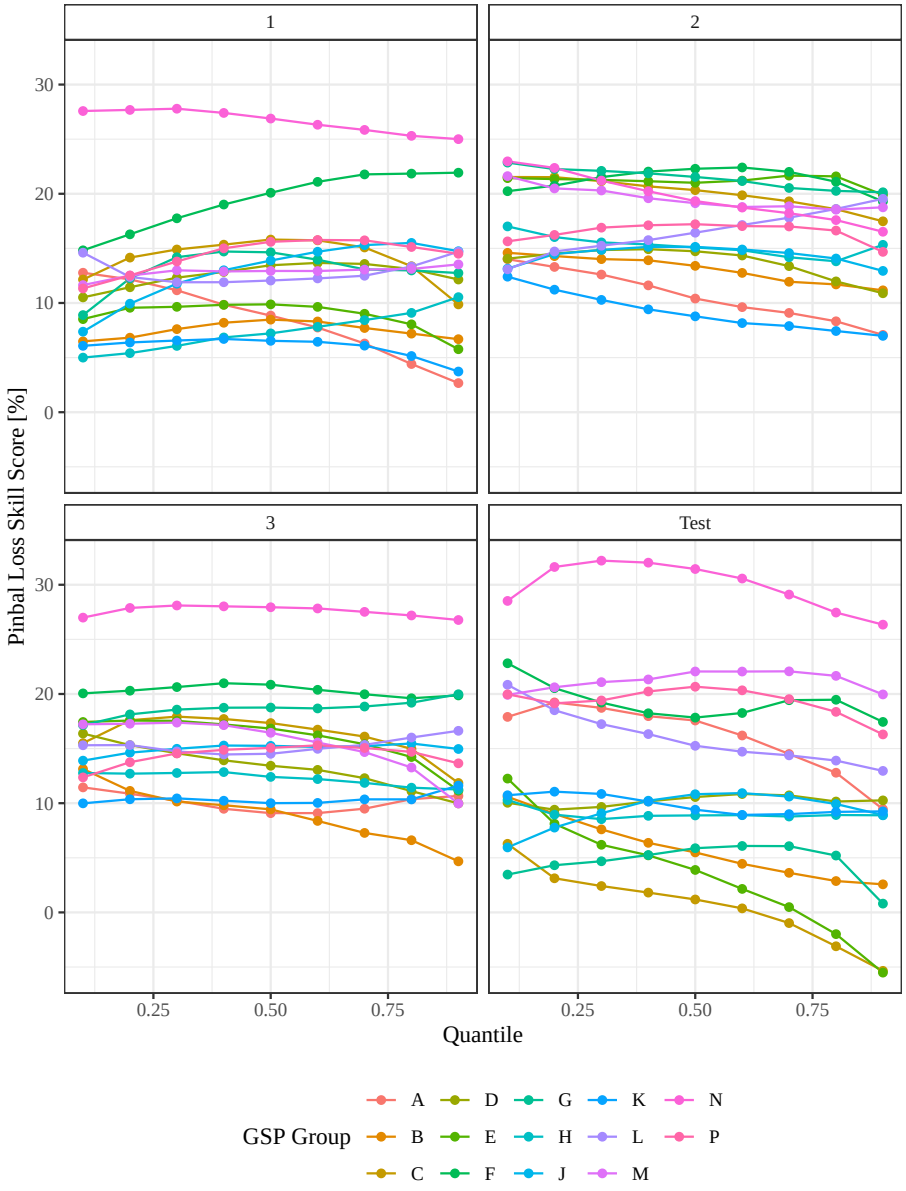

Figure 5: Pinball Loss Skill Score for GAM-Point relative to Vanilla-Point for each GSP Group, quantile and cross-validation fold (1, 2, 3 and Test).

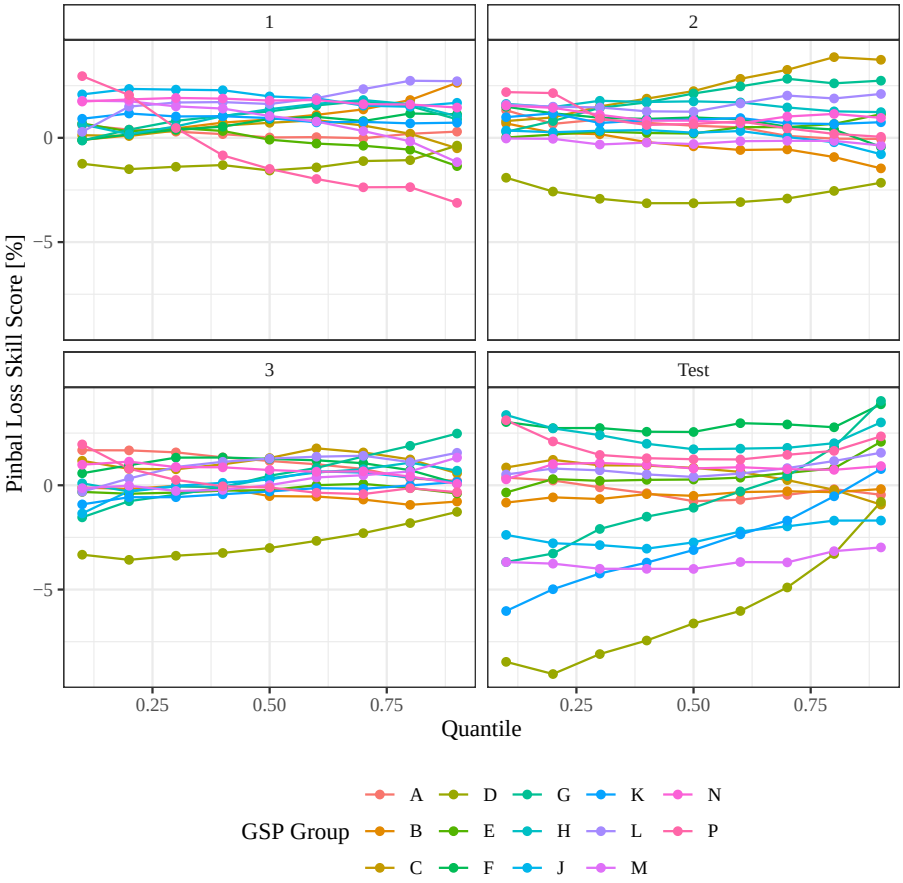

Figure 6: Pinball Loss Skill Score for GAM-Grid relative to GAM-Point for each GSP Group, quantile and cross-validation fold (1, 2, 3 and Test).

4.3 Reliability/Calibration

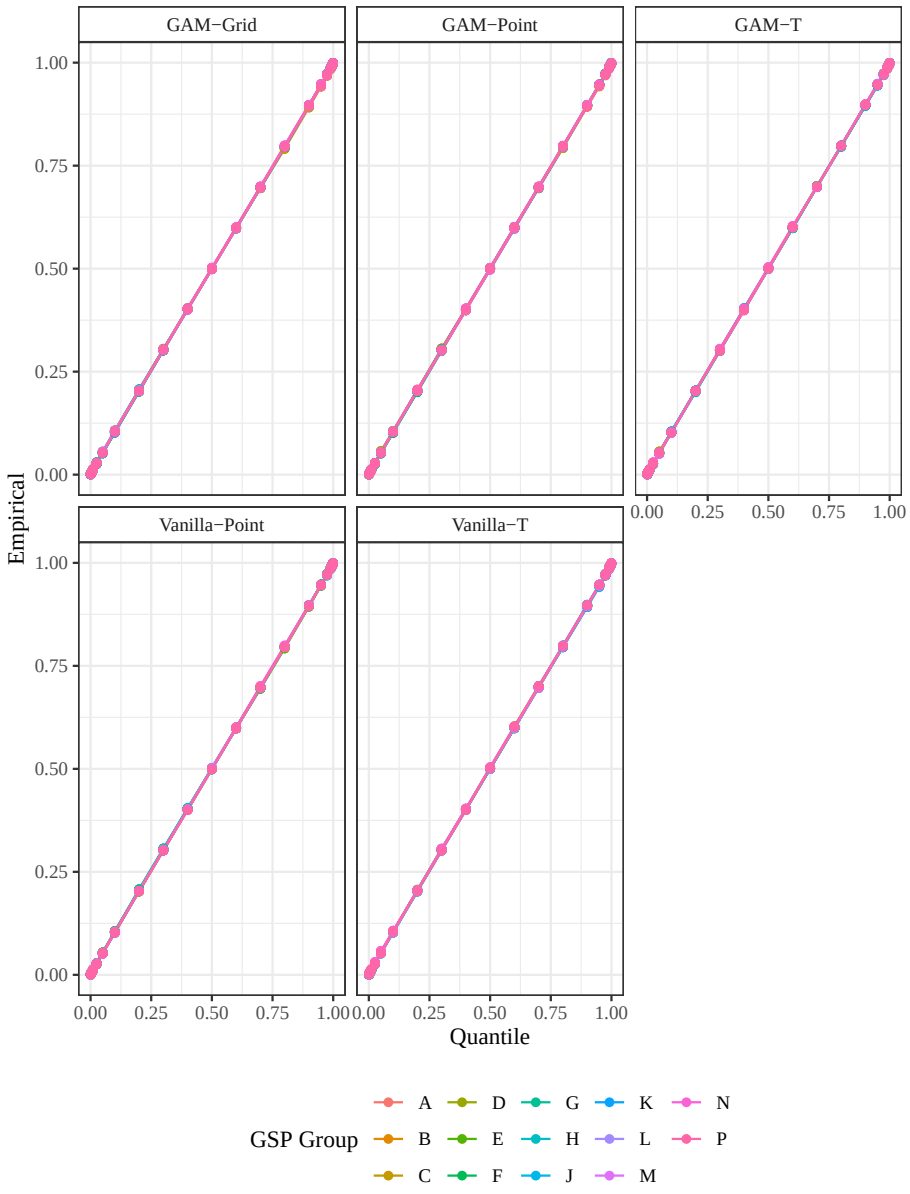

Figure 7: Reliability diagram for all models and GSP Groups from cross-validation exercise.

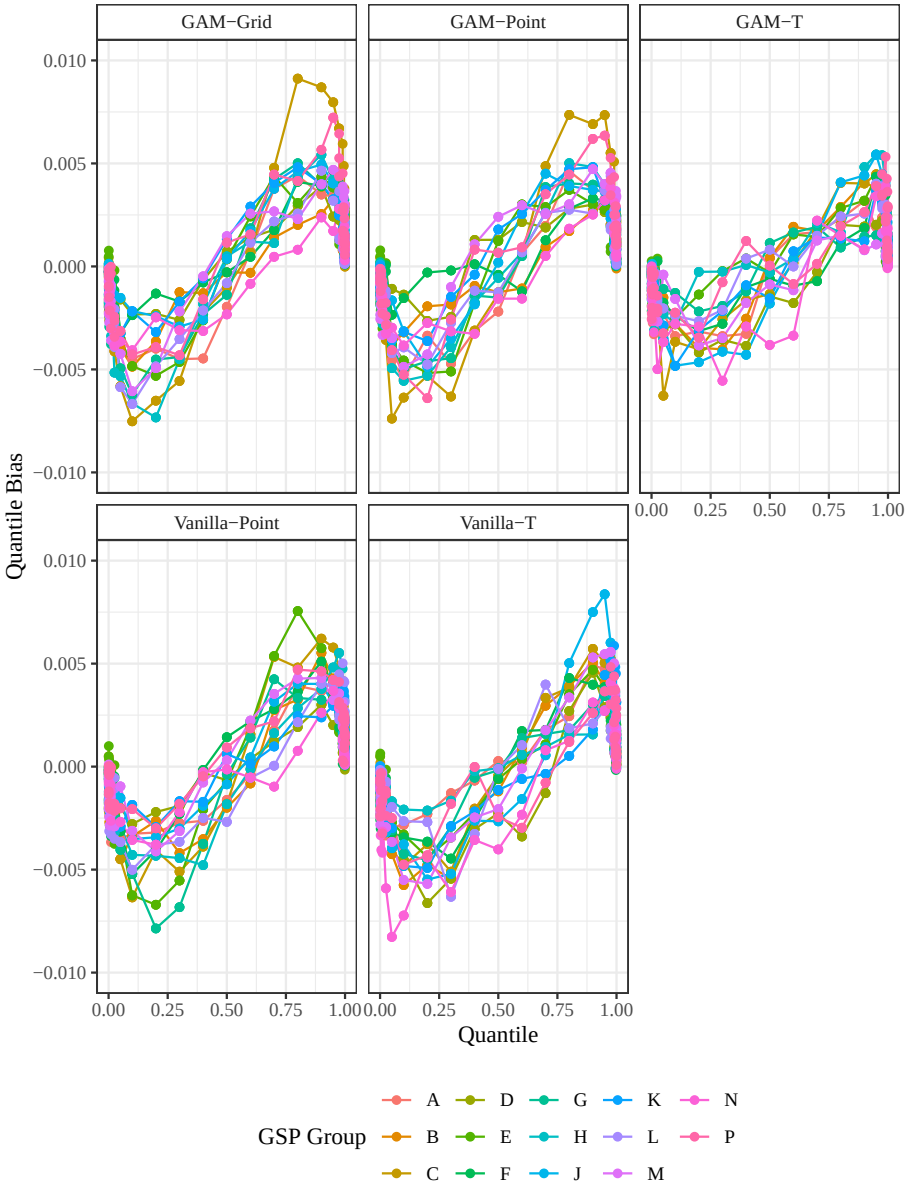

Figure 8: Quantile bias (deviation from nominal) for all models and GSP Groups from cross-validation exercise.

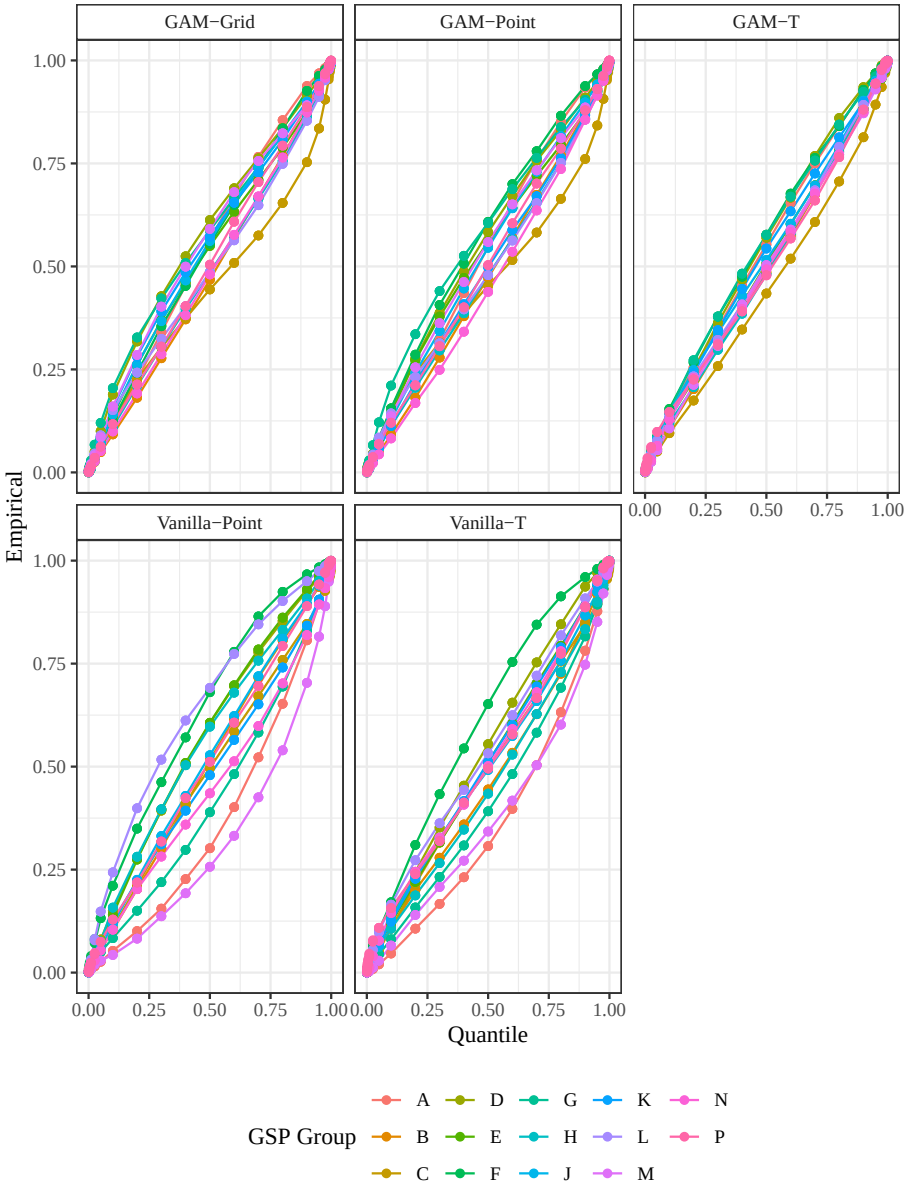

Figure 9: Reliability diagram for all models and GSP Groups on Test data.

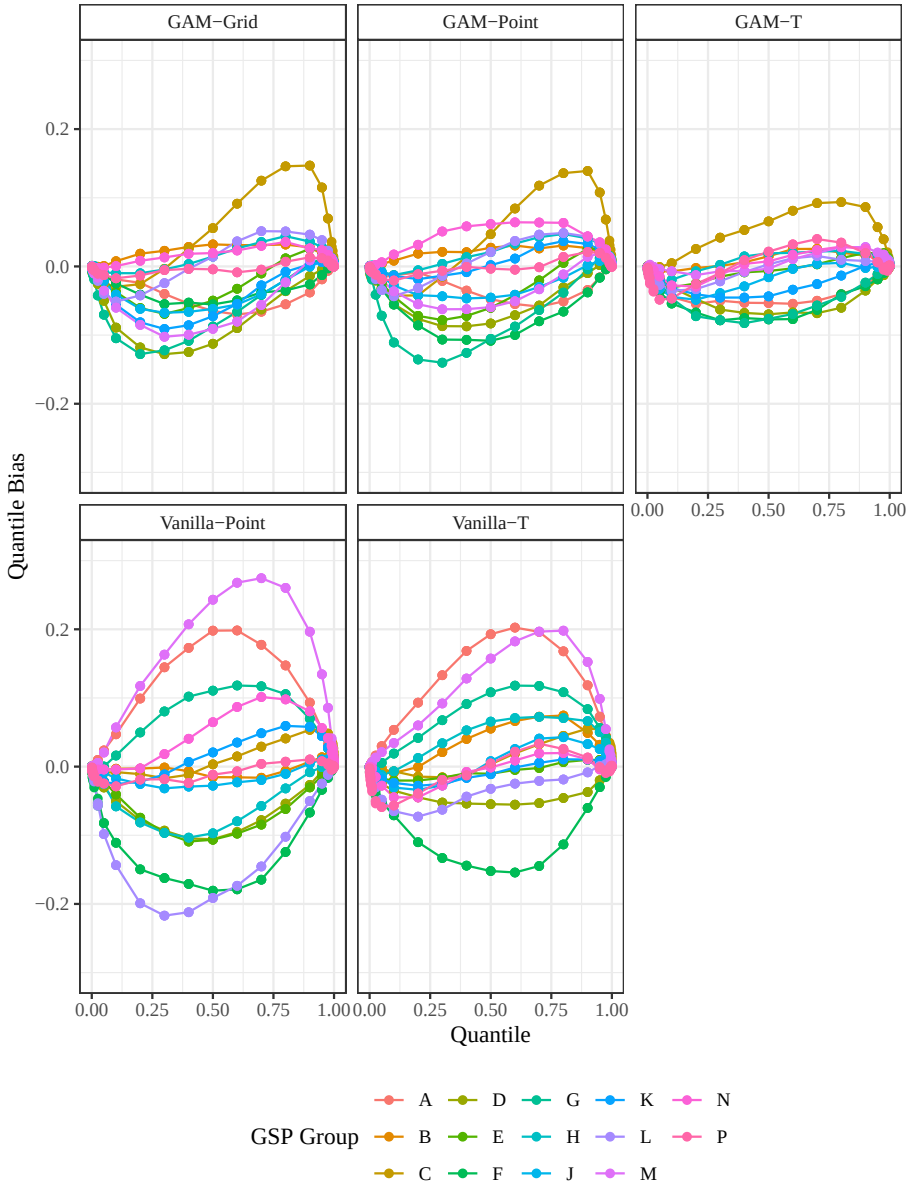

Figure 10: Quantile bias (deviation from nominal) for all models and GSP Groups on Test data.

4.4 Sharpness

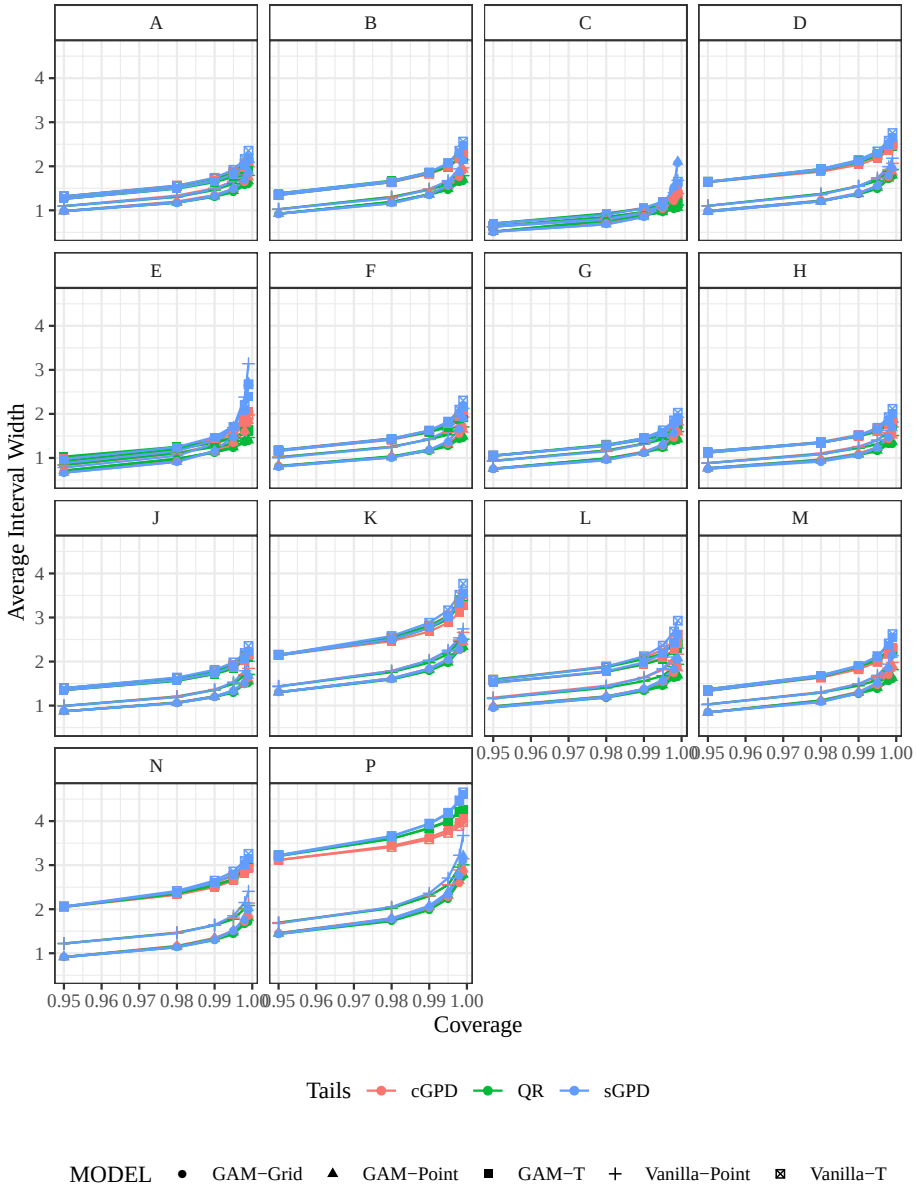

Figure 11: Sharpness diagrams for all models and GSP Groups for cross-validation exercises.

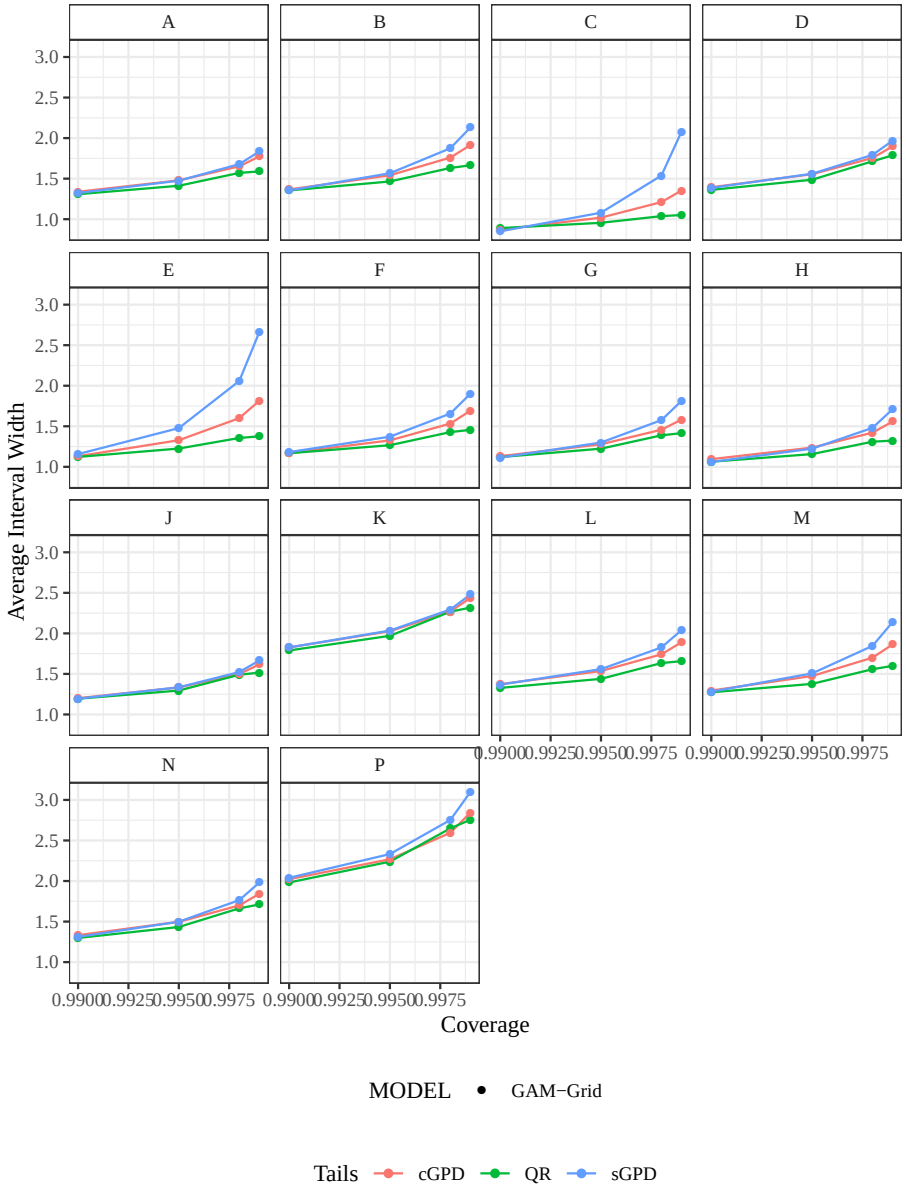

Figure 12: Sharpness diagrams for GAM-Grid and all tail models and GSP Groups for cross-validation exercises.

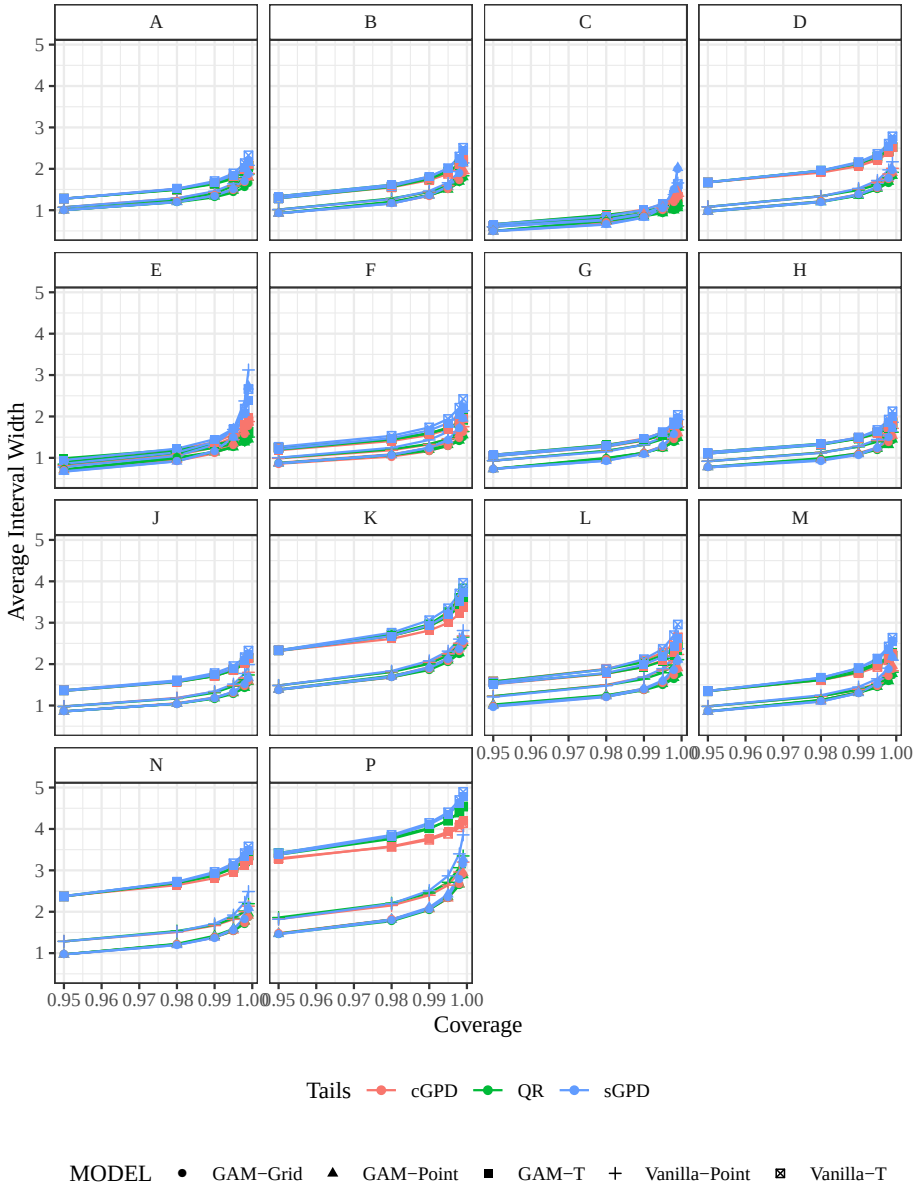

Figure 13: Sharpness diagrams for all models and GSP Groups on Test data.

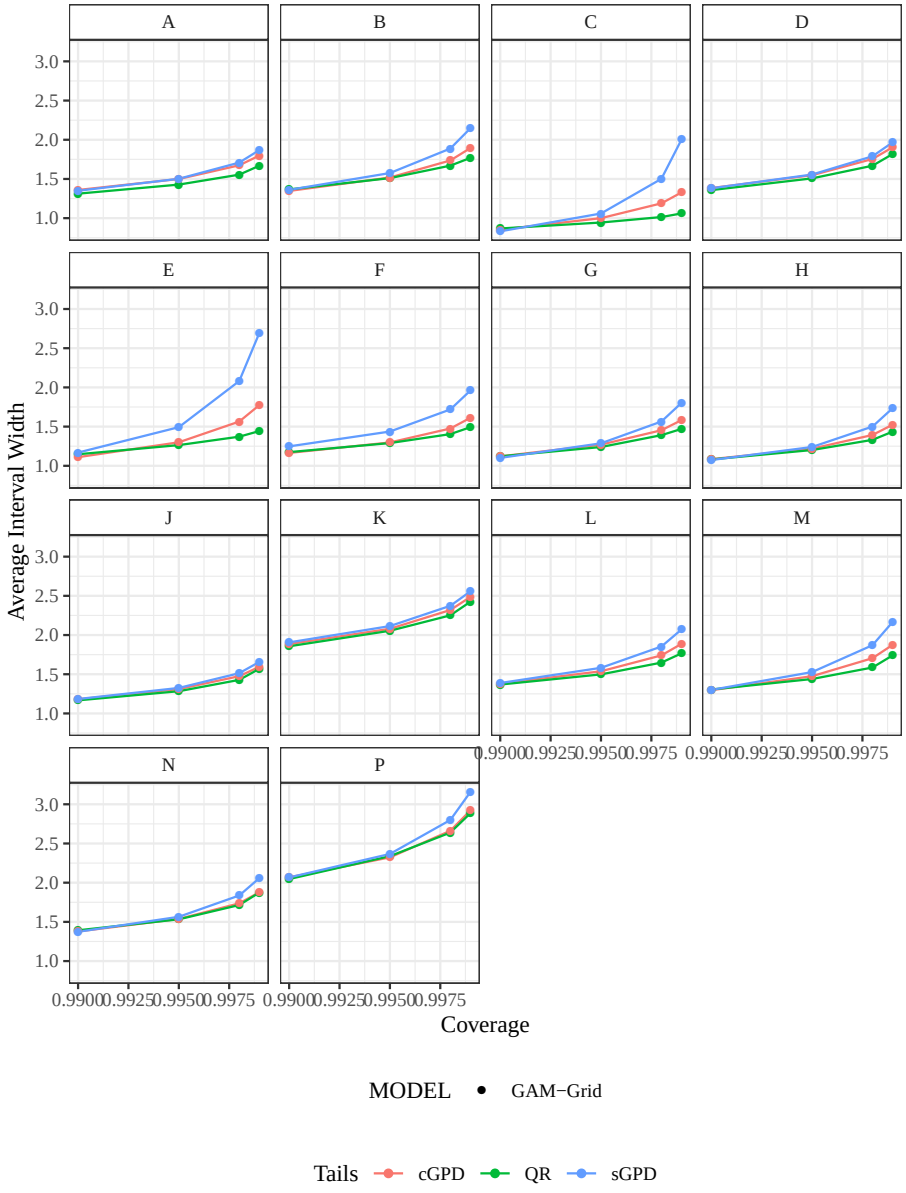

Figure 14: Sharpness diagrams for GAM-Grid and all tail models and GSP Groups on Test data.

4.5 Pinball Skill and Significance

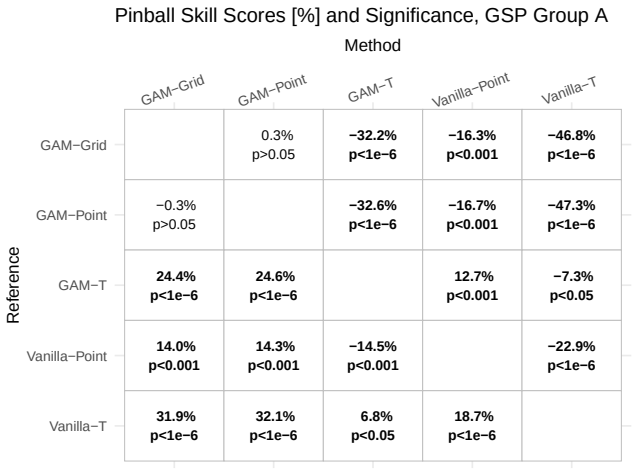

Figure 15: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group A on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

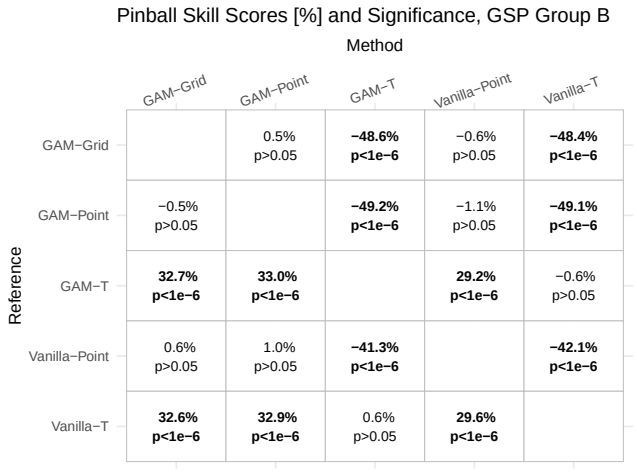

Figure 16: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group B on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

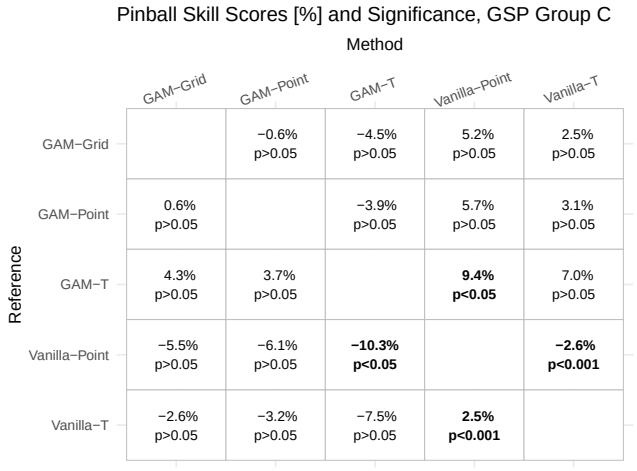

Figure 17: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group C on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

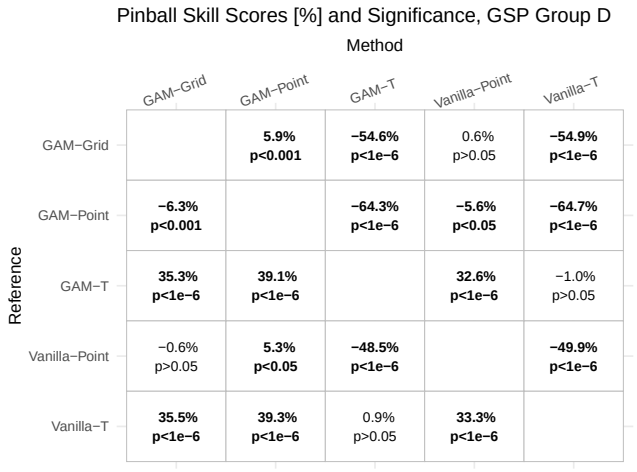

Figure 18: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group D on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

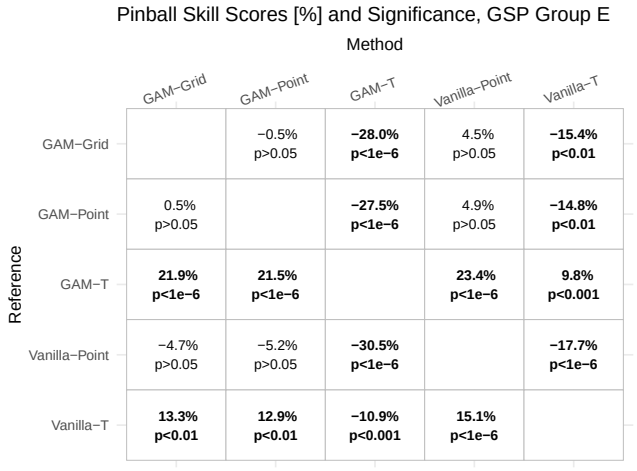

Figure 19: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group E on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

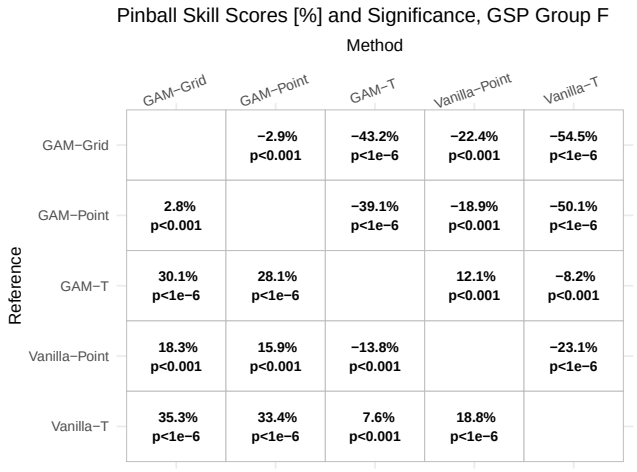

Figure 20: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group F on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

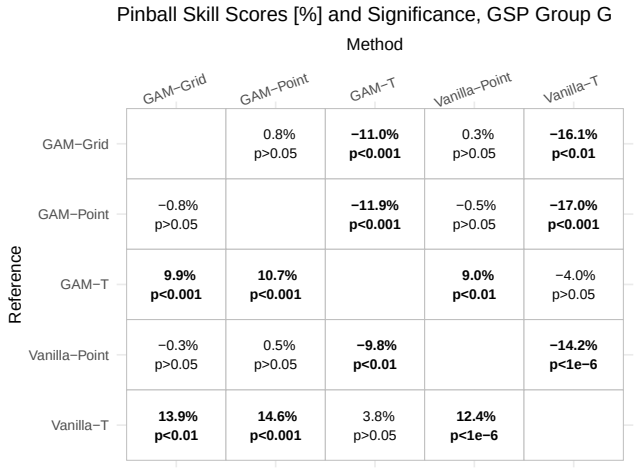

Figure 21: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group G on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

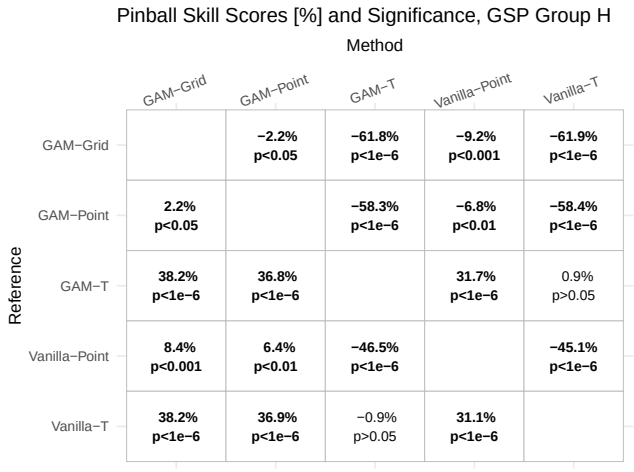

Figure 22: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group H on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

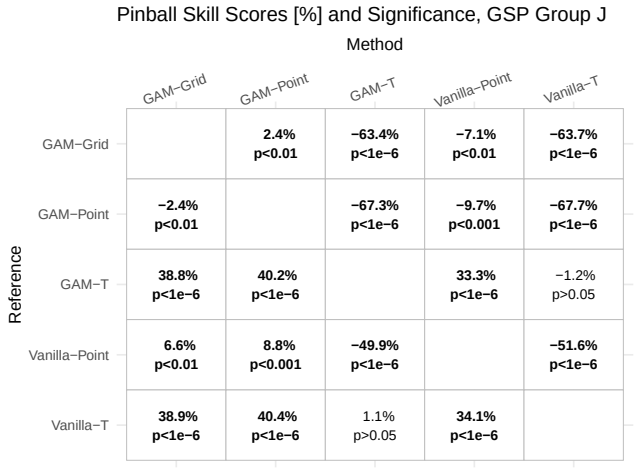

Figure 23: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group J on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

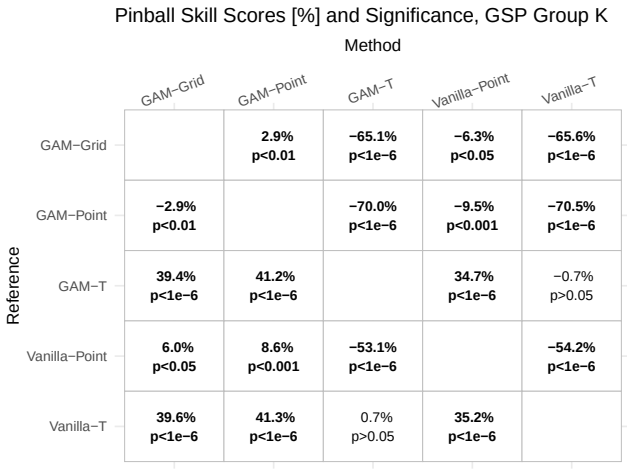

Figure 24: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group K on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

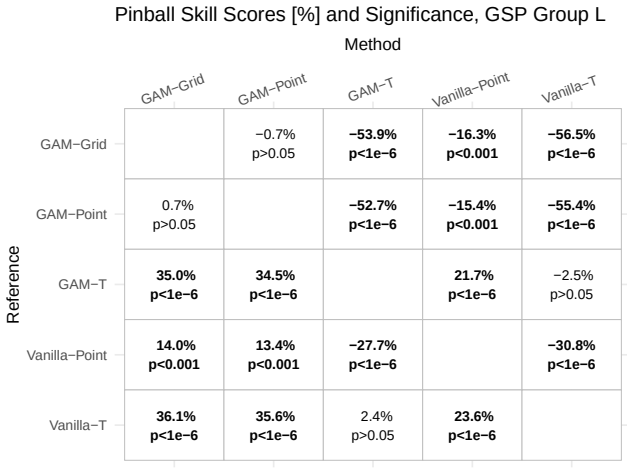

Figure 25: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group L on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

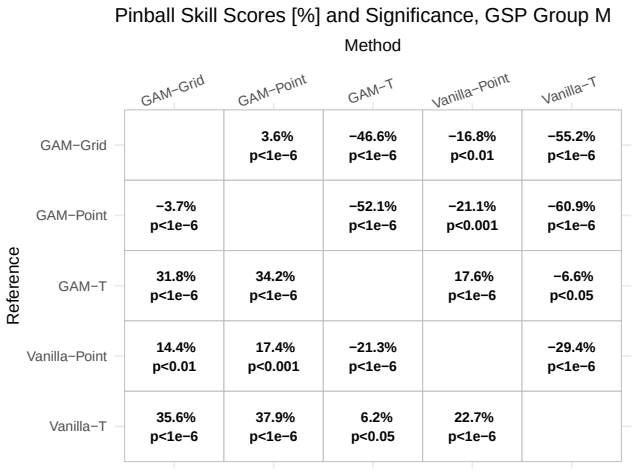

Figure 26: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group M on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

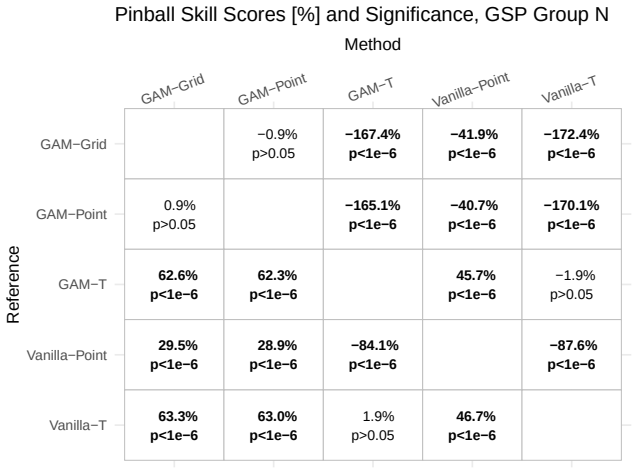

Figure 27: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group N on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

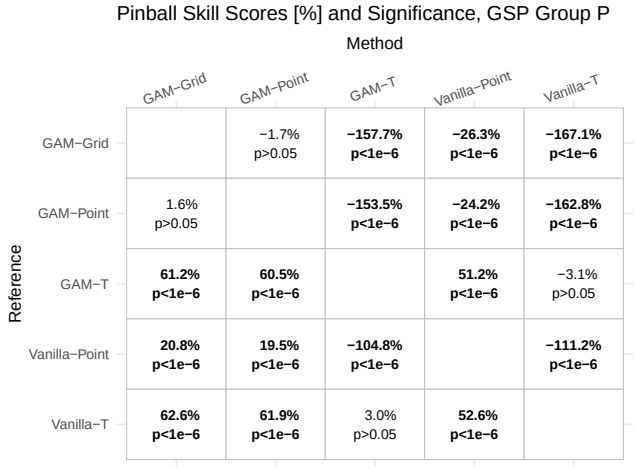

Figure 28: Pinball skill scores and significance (p-values from the Diebold-Mariano test [3]) for the all pairs of methods, computed for GSP Group P on the test set. A value of $p < 0.05$ indicates strong evidence that the skill of forecast produced by 'Method' relative to 'Reference' is not zero. These value are emboldened.

References

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