Exercise session: Communicating uncertainty - Wind power forecasting and participation in electricity markets

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Scope

The idea of this exercise session is to simulate a real-world situation where you may have to select a wind power forecasting tool from a set of potential competing providers, to then employ the forecasts for trading in an electricity market. In such context, a first part of the exercise consists of evaluating the performance the competing forecast systems over a period of one month. A set of error measures will be employed, along the lines of those dicussed over the training course. A cost will be assigned to each forecast system, and you will have to decide which forecaster you want to hire as an exclusive forecast provider for future decision-support. In a second part, forecasts will be used for trading in the electricity market for a month. We will analyse the revenues obtained when employing different trading strategies, and discuss the use of probabilistic forecasts in decision-making.

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1 Importing the data and starting R

Note that the instructions below are for Linux only! Equivalent steps in Windows should be more intuitive...

-1- Open a desktop Terminal window

-2- Create a new directory that will be used for storing data for this exercise session, using the following linux command:

```
mkdir WPF_exercise
```

-3- Access the newly created directory, using the following linux command:

```
cd WPF_exercise
```

-4- Import the data to be used for the exercise session, by copying them from the original folder to the newly created WPF_exercise folder.

-5- Start R from a Terminal window while being in your WPF_exercise directory.

-6- Load the set of functions necessary for the exercise:

```
source('wpfRfunctions.R')
```

2 Evaluation of wind power forecasts

2.1 Context of the evaluation

You are the owner of a 10MW wind farm in the Netherlands, which has been recently built. Owing to your knowledge of the electricity market, you know that you will need daily forecasts of the power production of the wind farm in order to participate in the market, and mainly in order for you to optimize your revenues. You also know that these forecasts ought to be probabilistic!

Before to participate in the market, it is necessary for you to decide on which forecast system to use. You have been in contact with 3 forecast providers, which we will simply refer to as M1, M2 and M3. You agreed with these 3 forecasters on the fact that they would provide you with forecasts over a period of one month (December 2006), and that after this period, you will decide on which forecaster you prefer to work with.

These 3 forecasters deliver forecasts with an hourly update over that period of one month, with an hourly resolution, for the following 43 hours. Due to the market bidding system, you are mostly interested in the forecasts issued everyday at 11:00, with horizons of interest between 13 and 37 hours ahead.

You then obtain from your forecasters 3 forecast datasets, which are called forecasts_set1_dec06.Rdat (for M1), forecasts_set2_dec06.Rdat (for M2), and forecasts_set3_dec06.Rdat (for M3). Each dataset contains probabilistic forecasts, as well as corresponding measurements. You will use these data and existing functions for evaluating them and deciding on which one to choose.

An important point is the cost of purchasing these forecast systems. The monthly costs for each of them are:

M1: 100 €/month	M2: 1.500 €/month	M3: 1.000 €/month

Please take this into consideration before to make your choice.

2.2 Guidelines for the forecast evaluation exercise

-1- First of all, you will need to load the datasets relevant to the forecast evaluation exercise:

```
wpf_set1 <- loadwpfdata('forecasts_set1_dec06.Rdat')
wpf_set2 <- loadwpfdata('forecasts_set2_dec06.Rdat')
wpf_set3 <- loadwpfdata('forecasts_set3_dec06.Rdat')
```

-2- You may see the list of available functions and data with:

```
ls()
```

Note that a description of the data frames you have loaded (wpf_set1, wpf_set2 and wpf_set3) can be found in Section 5 of the present document. In parallel, a complete list and description of the functions that can be used for the exercise is given in Section 4.

-3- You may look at some forecasts issued at a given date (timestamp) from a given forecaster, like for instance

```
plotprobforec(wpf_set3,2006120610)
```

which shows the 43-hour ahead probabilistic forecasts issued by M3 on the 6th of December 2006 at 10am. The forecasts are represented in the form of a river of blood fan chart.

-4- If aiming at looking at a particular predictive cdf (cumulative distribution function), one may use

```
plotpredcdf(wpf_set3,2006120610,10)
```

which gives you the detail of the predictive cdf of the 10-hour ahead probabilistic forecast, for the forecasts series visualized in -3-. Predictive cds are defined by a set of quantile forecasts with nominal proportions ranging between 0 and 1 with an increment of 0.05 (see list of data available in Section 5)

-5- Please check some of the forecasts provided by your 3 forecasters M1, M2 and M3, in order to get a first feeling about their characteristics and performance. Note that for some days, their probabilistic forecasts may not be available due to eg. data transmission failure.

-6- Now let us be a bit more rigorous with forecast evaluation, and first start with the reliability assessment of the various probabilistic forecasts. One can look at reliability diagrams for a given set of forecasts with

```
reldiag(wpf_set2)
```

for the example of evaluating M2.

-7- Please have look at the reliability diagrams for the 3 sets of probabilistic forecasts. The reliability of these various sets of probabilistic forecasts can also be compared with

```
reldiagcomp(wpf_set1,wpf_set2,wpf_set3)
```

-8- It is also possible to look at reliability diagrams for specific forecast horizons, with

```
reldiaghor(wpf_set2,24)
```

for the 24-hour ahead probabilistic forecasts of M2

-9- Similarly to the above, evaluate the reliability of your various forecasters for various horizons (remember that for your trading application, only horizons between 13- and 37-hour ahead of of importance). You can also directly compare your 3 forecasters for a given horizon with

```
reldiaghorcomp(wpf_set1,wpf_set2,wpf_set3,24)
```

for 24-hour ahead probabilistic forecasts

-10- For the overall skill asessment of probabilistic forecasts, we use here the CRPS (Continuous Rank Probability Score) which is a proper score. The lower the better(!). CRPS accounts for both reliability and sharpness.

In order to visualize the CRPS as a function of the forecast horizon for a given set of forecast, one types:

```
crps(wpf_set1)
```

for the example of the probabilistic forecasts provided by M1.

-11- The CRPS (as a function of the forecast horizon) may be directly compared for the 3 forecasters, with

```
crpscomp(wpf_set1,wpf_set2,wpf_set3)
```

-12- One should also look at the sharpness of the various probabilistic forecasts, defined as the width of prediction intervals, as a function of their nominal coverage (from 10% to 90%). Again, the smaller, the better (!). It can be directly compared for the 3 forecasters with

```
sharpnesscomp(wpf_set1,wpf_set2,wpf_set3)
```

-13- In view of the revealed skill, reliability, and sharpness of your forecasters, you may want to have a look again at a few forecast series in order to get a deeper feeling of the forecasters' characteristics (see -3-).

-14- Using all the tools providing above, please evaluate your 3 forecasters, and make a decision of which one you would hire as your exclusive operational forecaster.
Explain why... And write it down in 3-4 sentences.

3 Participation in electricity markets: Trading simulations

3.1 Context of the participation in electricity markets

Now that you have purchased your forecasting system (either M1, M2 or M3), you are going to use it for trading over a month in the Dutch electricity market (APX/TenneT). By the time you evaluate your forecasters and contract one, your first month of trading in the market is May 2007.

Remember that when participating in the Dutch electricity market, you have to bid every day before 12:00 (thus using the forecasts provided at 11:00), for the following day between 00:00 and 00:00. Your bid consists of 24 blocks of energy, one of each hour of the day.

During the day, your actual delivery is compared with your bid hour by hour. You are then penalized proportionally to your deviation from contract, the penalty being different if you are above or below your bid. An example will be given below.

We make here a simplification of the Dutch electricity market, prices and penalties being kept constant for each hour of the whole month of May. The various values are gathered in the Table below.

spot price: 40 €/MWh	penalty (above): 10 €/MWh	penalty (below): 30 €/MWh

As an example, let us say that you bid a production of 10MWh for a given hour of the day, but then only produce 8MWh. You will receive as a revenue $8 \times 40 = 320$€ for your actual wind energy production, minus $2 \times 30 = 60$€ as a penalty for being 2MWh below your bid. Your final revenue is then of 260€ only, while you could have received 320€ if you had perfect foresight.

The idea here is that if you have probabilistic forecasts, and know the loss function related to your decision-making problem, you then can define your decision as the optimal quantile of your predictive distributions. For instance with the wind power trading problem, your optimal bid may be a specific quantile of your predictive distributions, the nominal proportion of which directly depends upon the market penalties.

3.2 Guidelines for the market exercise

-1- Type

```
rm(list=ls())
```

in the R command window in order to clear your workspace, and then reload your set of functions with

```
source('wpfRfunctions.R')
```

-2- Then again, you will need to load the datasets relevant to the forecast evaluation exercise, which this time correspond to the month of May 2007, and to your operational forecaster only (either M1, M2 or M3)

If you have chosen M1:

```
wpf_set <- loadwpfdata('forecasts_set1_may07.Rdat')
```

If you have chosen M2:

```
wpf_set <- loadwpfdata('forecasts_set2_may07.Rdat')
```

If you have chosen M3:

```
wpf_set <- loadwpfdata('forecasts_set3_may07.Rdat')
```

-3- Please read the description of the function tradeprobforecast in Section 4

-4- Before to start trading, one should decide on the optimal quantile to be considered. How would you choose it? Which nominal proportion would you end up with?

-5- Lets now trade, and try to see what would be our returns depending on various nominal proportions for the optimal quantile to be considered (in [0,1]). Try for instance to use the function tradeprobforecast with $\alpha = 0.1, 0.2, 0.3, \ldots, 0.9$:

```
tradeprobforecast(wpf_set,10,0.1,40,10,30)
```

and compare the various revenues, also with the revenue you would have received if having perfect foresight.

-5- Use again that same function, but then with the nominal proportion of the optimal quantile to be traded being automatically derived:

```
tradeprobforecast(wpf_set,10,-1,40,10,30)
```

-6- Please compare all various revenues, and comment on the optimality of the optimal quantile. Why may this quantile actually not be optimal?

-7- Finally, load the other 2 forecasters' datasets for this month of may, let the function tradeprobforecast automatically trade for you, and compare the revenues.

-8- Do you think you actually picked the best forecaster...?

4 List of available R functions

plotprobforec(wpf,timestamp)

This function permits to plot probabilistic forecasts and related measurements for a given timestamp at which the forecast is issued. The probabilistic forecasts are defined in terms of quantiles. Prediction intervals are shown in the form of river of blood fan charts.

Example: plotprobforec(wpf_set,2006120510) (ie. 5th of December 2006, 10am)

plotpredcdf(wpf,timestamp,ihor)

This function permits to plot a single predictive cdf (and related measurements) for a given timestamp at which the forecast is issued, and a given forecast horizon. The probabilistic forecasts are defined in terms of quantiles.

Example: plotpredcdf(wpf_set,2006120510,24) (ie. 5th of December 2006, 10am, 24 hour ahead predictive cdf)

reldiag(wpf)

This function permits to visualize the reliability diagram related to the calibration assessment of the probabilistic forecasts in 'wpf'. These reliability diagrams take the form of Quantile-Quantile plots.

Example: reldiag(wpf_set)

reldiagcomp(wpf1,wpf2,wpf3)

This function permits to visualize comparative reliability diagrams related to the calibration assessment of the probabilistic forecasts in 'wpf1', 'wpf2', and 'wpf3'. These reliability diagrams take the form of Quantile-Quantile plots.

Example: reldiagcomp(wpf_set1,wpf_set2,wpf_set3)

reldiaghor(wpf,ihor)

This function permits to visualize the reliability diagram related to the calibration assessment of the probabilistic forecasts in 'wpf', for a specific forecast horizon 'ihor'. These reliability diagrams take the form of Quantile-Quantile plots.

Example: reldiaghor(wpf_set,24) (ie. for 24-hour ahead probabilistic forecasts)

reldiaghorcomp(wpf1,wpf2,wpf3,ihor)

This function permits to visualize comparative reliability diagrams related to the calibration assessment of the probabilistic forecasts in 'wpf1', 'wpf2', and 'wpf3', and this for a specific forecast horizon 'ihor'. These reliability diagrams take the form of Quantile-Quantile plots.

Example: reldiaghorcomp(wpf_set1,wpf_set2,wpf_set3,24) (ie. for 24-hour ahead probabilistic forecasts) crps(wpf)

This function permits to visualize the CRPS as a function of the forecast horizon, for the overvall skill assessment of the probabilistic forecasts in 'wpf'.

Example: crps(wpf_set)

crpscomp(wpf1,wpf2,wpf3)

This function permits to compare the CRPS scores (as a function of the forecast horizon), for the comparative overvall skill assessment of the probabilistic forecasts in 'wpf1', 'wpf2' and 'wpf3'.

Example: crpscomp(wpf_set1,wpf_set2,wpf_set3)

sharpnesscomp(wpf1,wpf2,wpf3)

This function permits to visually compare the sharpness of 3 different forecast systems, sharpness being defined as the width of prediction intervals.

Example: sharpnesscomp(wpf_set1,wpf_set2,wpf_set3)

tradeprobforecast(wpf,nomp,qbid,ps,cu,cd)

This function permits to trade a specific quantile of probabilistic forecasts (with nominal proportion 'qbid') in the electricity market, for a wind farm of nominal power 'nomp' MW. The spot price is given by 'ps', while the penalties for actually producing more or less than your bid are given by 'cu' and 'cd', respectively. If 'qbid=-1', the optimal quantile is automatically defined...

Example: tradeprobforecast(wpf_set,10,0.5,40,10,30) (ie. for a 10MW wind farm, bidding the quantile with nominal proportion 0.5, while the sport price is of 40€, and the regulation penalties for being above and below are of 10€and 30€, repsectively)

5 Contents of the data files and related data frames

You are provided with 3 different data frames related to the three probabilistic forecasters: forecasts_set1_dec06.Rdat (for M1), forecasts_set2_dec06.Rdat (for M2), and forecasts_set3_dec06.Rdat (for M3). When loading these files in R, the resulting data frames will contain (for a given model):

dati	dates (timestamps) at which a given forecast is issued
dato	dates (timestamps) for which a given forecast is made
hor	forecast horizon
pred	wind power point forecasts from the forecast provider
meas	wind power measurements corresponding to the forecasts over the period of interest
q0	quantile forecasts of wind power generation (nominal proportion $\alpha = 0$)
q0	quantile forecasts of wind power generation (nominal proportion $\alpha = 0$)
q5	quantile forecasts of wind power generation (nominal proportion $\alpha = 5$)
q10	quantile forecasts of wind power generation (nominal proportion $\alpha = 10$)
q15	quantile forecasts of wind power generation (nominal proportion $\alpha = 15$)
q20	quantile forecasts of wind power generation (nominal proportion $\alpha = 20$)
q25	quantile forecasts of wind power generation (nominal proportion $\alpha = 25$)
q30	quantile forecasts of wind power generation (nominal proportion $\alpha = 30$)
q35	quantile forecasts of wind power generation (nominal proportion $\alpha = 35$)
q40	quantile forecasts of wind power generation (nominal proportion $\alpha = 40$)
q45	quantile forecasts of wind power generation (nominal proportion $\alpha = 45$)
q55	quantile forecasts of wind power generation (nominal proportion $\alpha = 55$)
q60	quantile forecasts of wind power generation (nominal proportion $\alpha = 60$)
q65	quantile forecasts of wind power generation (nominal proportion $\alpha = 65$)
q70	quantile forecasts of wind power generation (nominal proportion $\alpha = 70$)
q75	quantile forecasts of wind power generation (nominal proportion $\alpha = 75$)
q80	quantile forecasts of wind power generation (nominal proportion $\alpha = 80$)
q85	quantile forecasts of wind power generation (nominal proportion $\alpha = 85$)
q90	quantile forecasts of wind power generation (nominal proportion $\alpha = 90$)
q95	quantile forecasts of wind power generation (nominal proportion $\alpha = 95$)
q100	quantile forecasts of wind power generation (nominal proportion $\alpha = 100$)