The Merit Order Effect in the German Power Market

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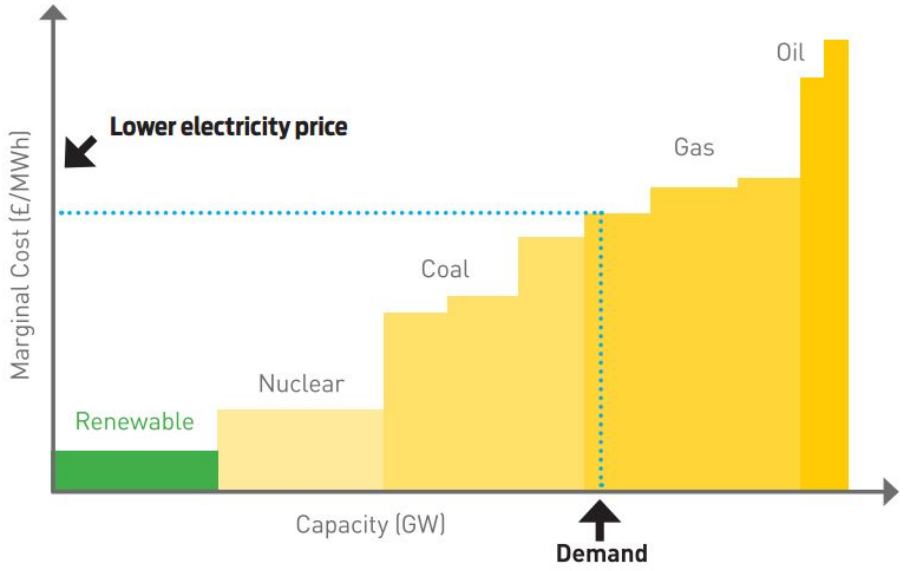
Statistical Programming Languages
https://github.com/mpff/spl2018-bfm

Motivation

We want to measure the merit order effect for the German power market, based on Clò, Cataldi, and Zoppoli 2015.



Regression

Regression equation:

$$\text{price} = \beta_0 + \beta_1 \cdot \text{dem} + \beta_2 \cdot \text{wind} + \beta_3 \cdot \text{solar} + \gamma \cdot \text{ymd} + \epsilon \quad (1)$$

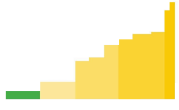
price: Mean daily day ahead price

dem: Forecasted daily demand

solar: Forecasted daily electricity production from solar

wind: Forecasted daily electricity production from wind

ymd: Year, month, day dummies



Data Sources

price: Day Ahead Price, since 2011 (Elspot Prices Data).

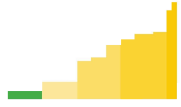
dem: Day Ahead Demand, since 2015, DE+AT+LUX (entsoe)

solar: Day Ahead Forecast, since 2012, DE (netztransparenz.de)
Day Ahead Forecast, since 2015, AT (apg.at)

wind: Day Ahead Forecast, since 2012, DE (netztransparenz.de)
Day Ahead Forecast, since 2015, AT (apg.at)

Problems:

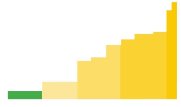
1. Different timeframes and -frequencies.
2. NA's a problem for daily averages and sums.
3. LUX in demand a (big) problem?



Data Cleaning

```
df.pun.0 <- read.csv("source/Elspot_xxx.csv")
df.pun <- subset(df.pun.0, select = c(HourUTC,
SpotPriceEUR))
names(df.pun) <- c("TIME", "PUN")
df.pun$TIME <- ymd_hm(df.pun$TIME)
df.pun <- time.FRAME(df.pun)
df.pun <- aggregate(list("PUN" = df.pun$PUN),
list("TIME" = cut(df.pun$TIME, "1 day")), FUN = mean)
...
# Bind final Dataframe
df <- cbind(df.pun, df.dm, df.solar, df.wind)
```

Github: MOErawdata.R, MOEmergedata.R



Problems with Missing Values

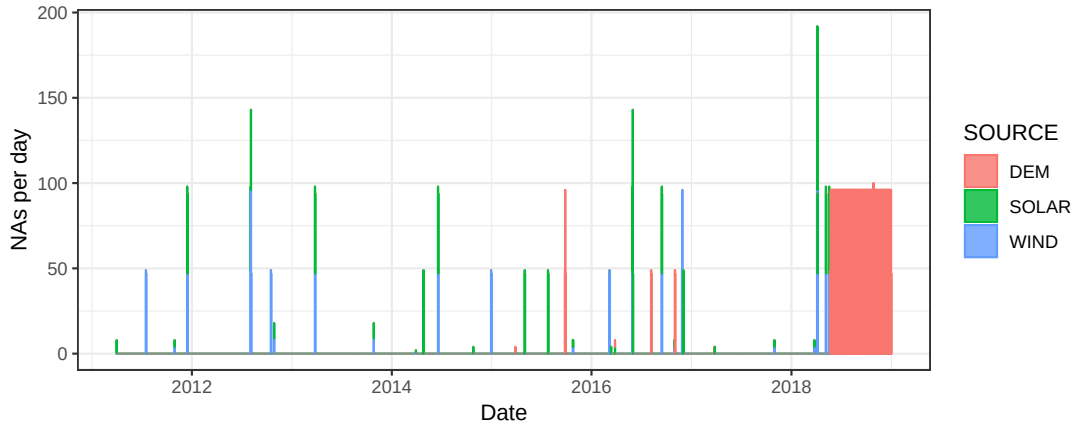
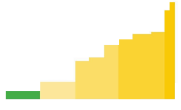


Figure 1: NAs in raw data

How big is the problem after cleaning the data?

```
temp <- DiagMissingValues(df, dlevel=1)
...
Number of incomplete cases:  21 (1.916%)
```

GitHub: MOEplotNAs.R



Problems with Missing Values

Test: Are NAs handled correctly while calculating daily values?

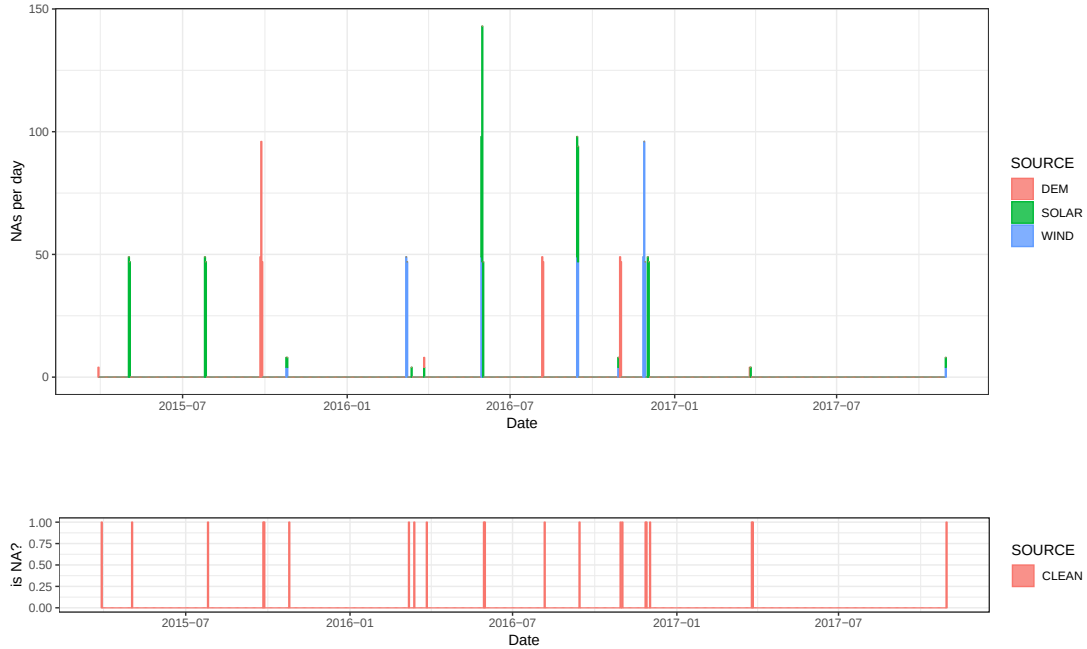
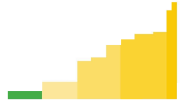


Figure 2: NAs in raw (a) and cleaned data (b)



Exploratory Analysis

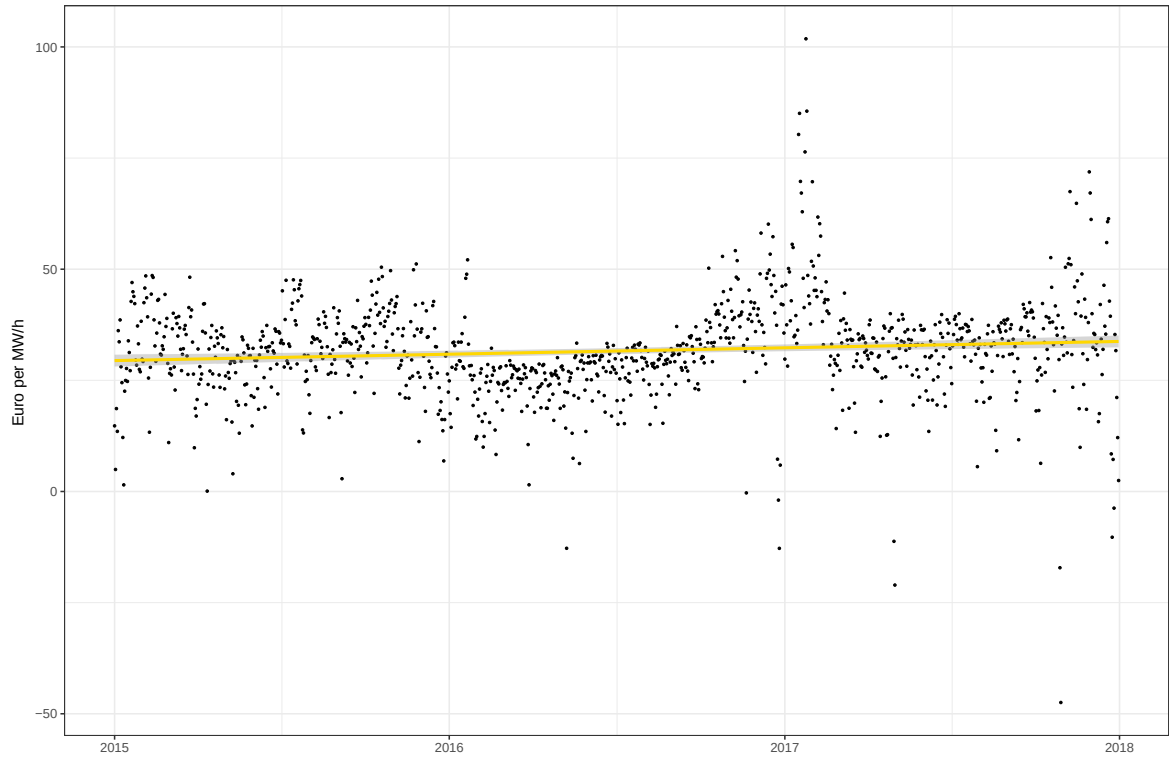


Figure 3: Mean Daily Day-Ahead Price

Exploratory Analysis

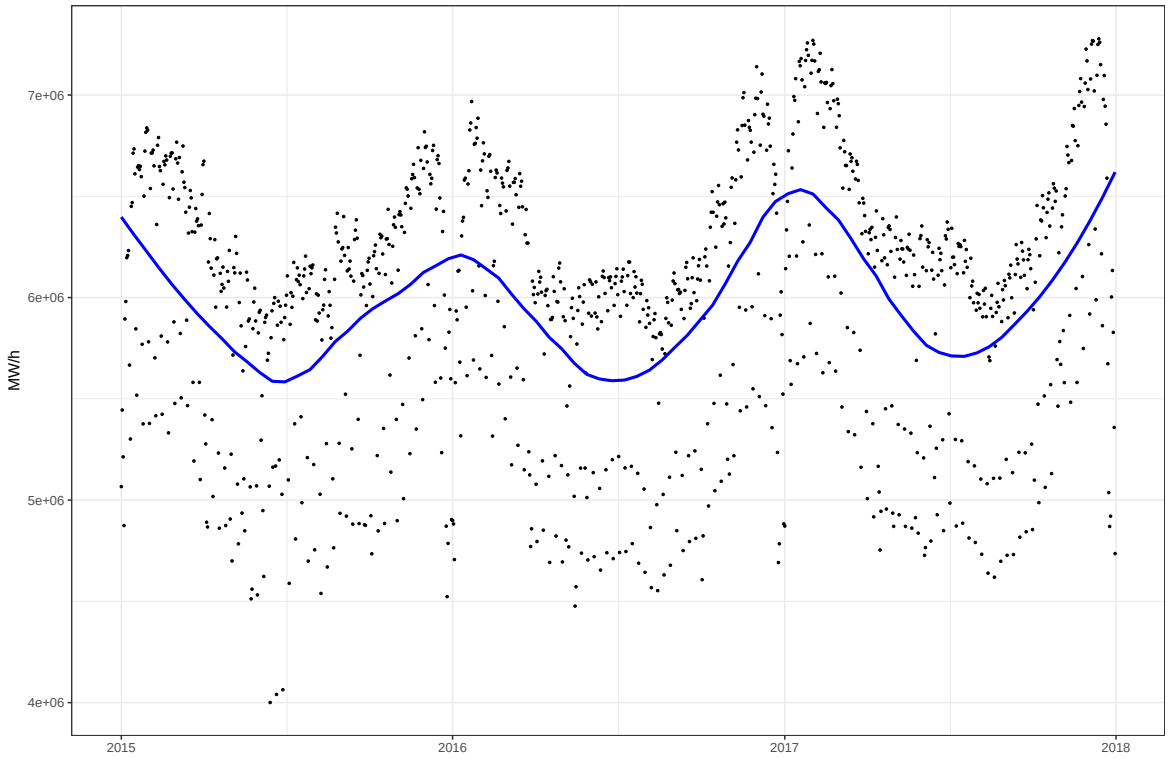


Figure 4: Daily Day-Ahead Demand

Exploratory Analysis

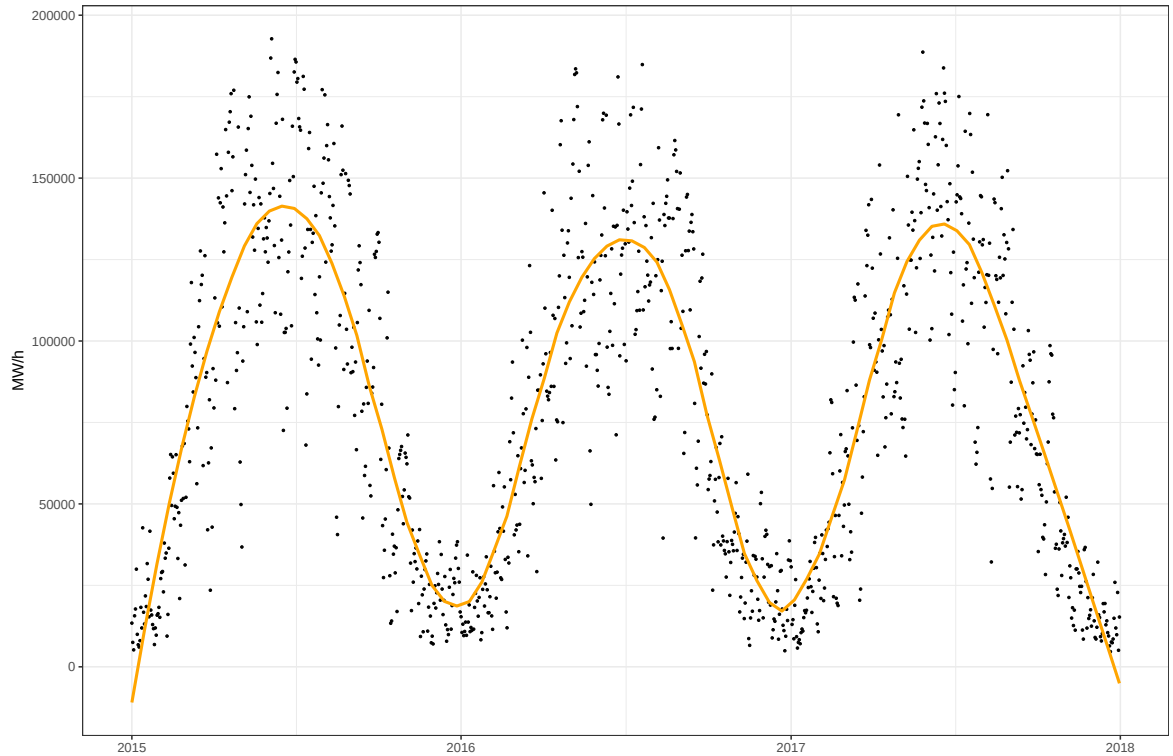


Figure 5: Daily Day-Ahead Solar Production

Exploratory Analysis

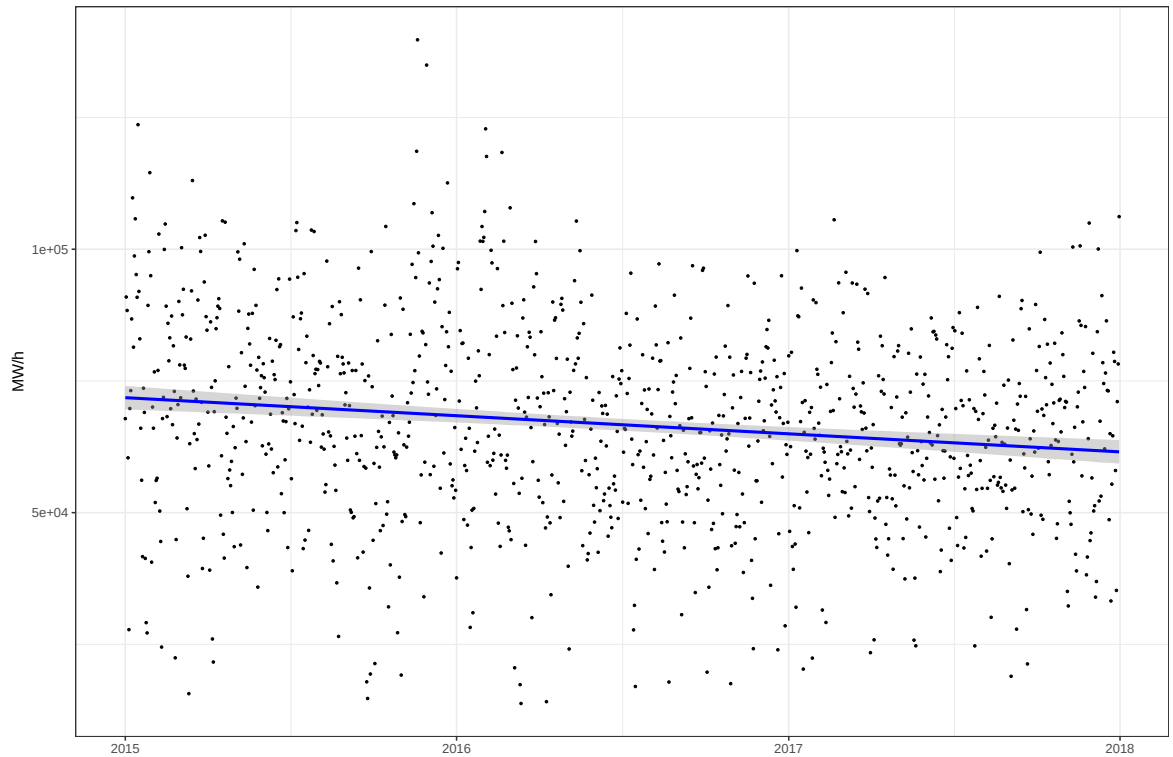


Figure 6: Daily Day-Ahead Wind Production

Exploratory Analysis

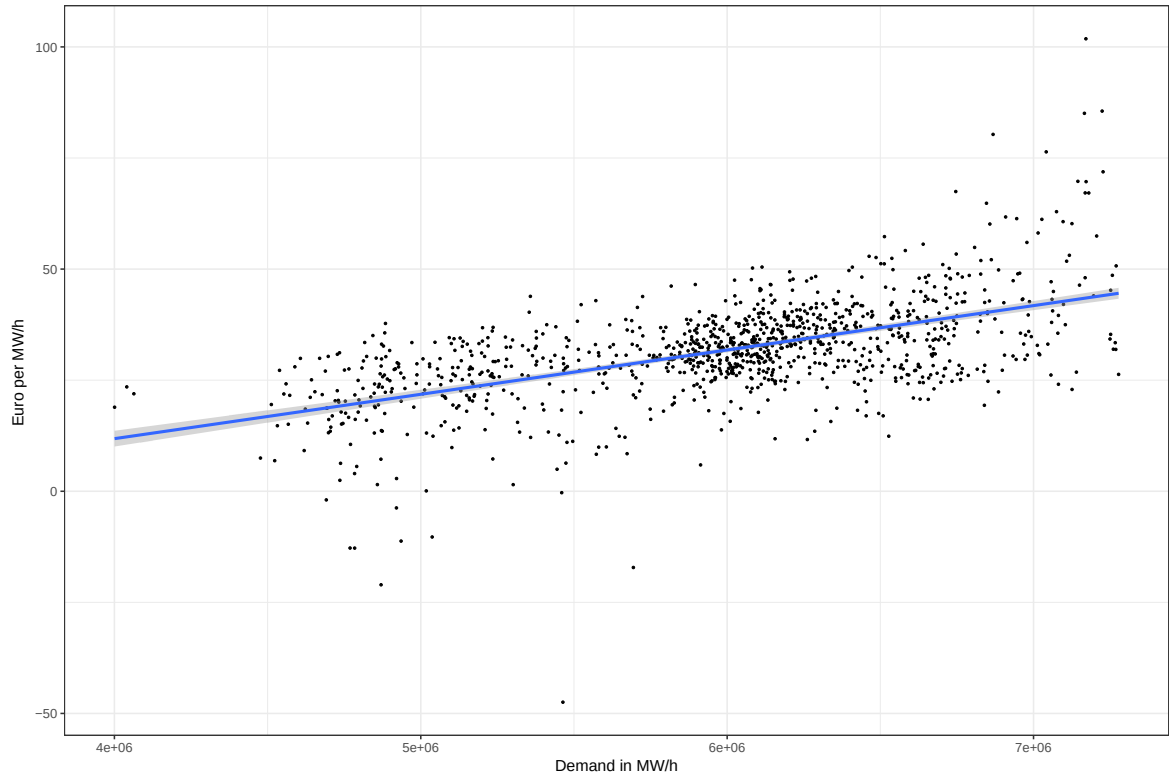


Figure 7: Price on Demand

Exploratory Analysis

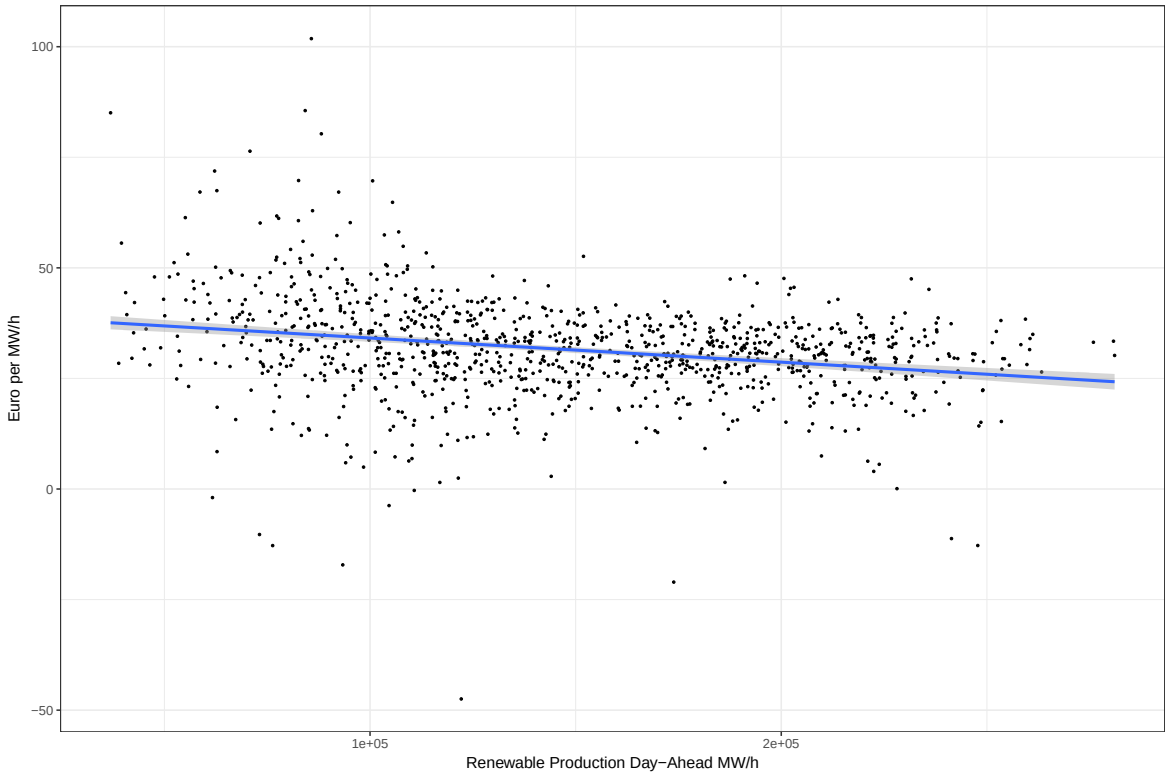


Figure 8: Price on Renewables Production

Time-Dummy generating function:

	PUN	DEMAND.DAY-AHEAD.MW/h	SOLAR.MW/h	WIND.MW/h
2015-01-01	354.32	5066593	13412.739	67844.38
2015-01-02	118.90	5444787	7497.092	90930.91
2015-01-03	447.53	5213461	5199.207	88375.82
2015-01-04	324.56	4874273	15651.090	60406.97
2015-01-05	868.25	5894292	17744.375	27798.76
2015-01-06	808.05	5980533	29969.718	69774.96

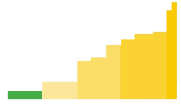
```
#Step1: Create the dummy variables for years, months and days
## 1.a Dummy variables for Years


Year.Dummy.matrix           <- matrix(,nrow = length(FullDat.xts[,1]), ncol=Year.max.number-Year.min.number+1)
colnames(Year.Dummy.matrix) =  Year.Vector

for (i in 1:length(Year.Vector)) {
  Year.Dummy.matrix[,i] <- format(index(FullDat.xts), "%Y")== Year.Vector[i]
}
```

- Creates a dummy matrix for: year, month, day o.t. week.
- Function adapts the amount of years directly from the data.
- y/m/d to be omitted, bc. of the dummy variable trap, can be specified.

GitHub: MOEtimedummies.R



Regression and Tests

$$\text{price} = \beta_0 + \beta_1 \cdot \text{dem} + \beta_2 \cdot \text{wind} + \beta_3 \cdot \text{solar} + \gamma \cdot \text{ymd} + \epsilon$$

Step 1: Check for stationarity of the variables → (augmented dickey fuller Test + Philipps-Perron)

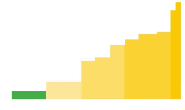
Step 2: Perform the OLS regression.

Step 3: Check for Heteroscedasticity and Autocorrelation.
→ Breusch-Pagan Test for heteroscedasticity.
→ Durbin-Watson test for autocorrelation.
→ Plot the autocorrelation structure.

Step 4: If okay [AR(1)], use the Prais-Winsten generalized estimation method.

Step 5: Check the new autocorrelation structure.

GitHub: MOEregression.R



Regression and Tests

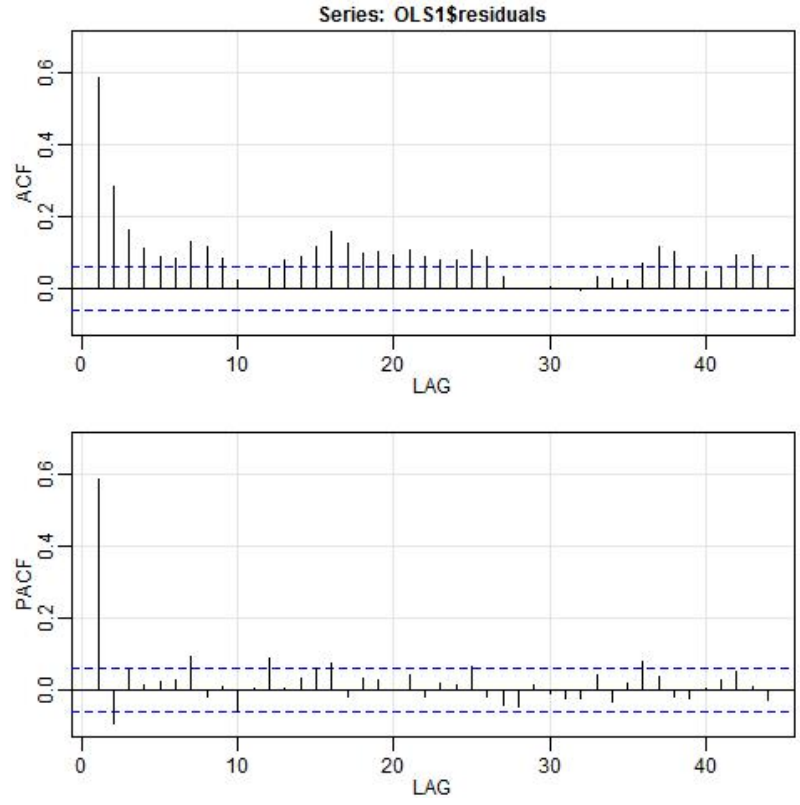


Figure 9: **OSL, ACF and PACF** Autocorrelation = TRUE (durbin-watson)

Regression and Tests

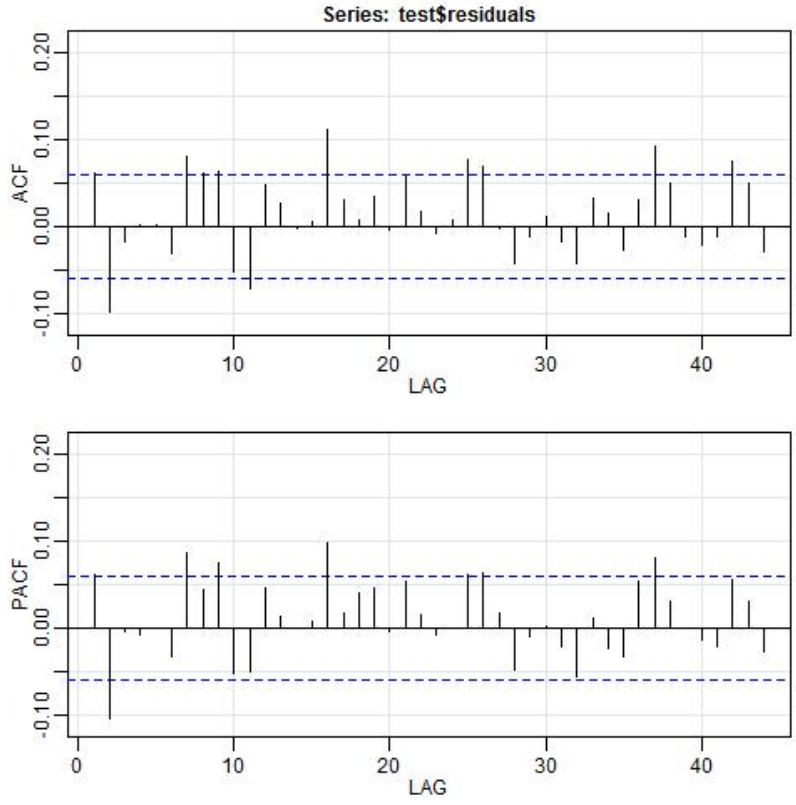
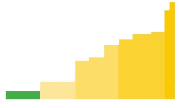


Figure 10: **Prais-Winsten, ACF and PACF**



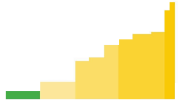
Regression and Tests

$$\text{price} = \beta_0 + \beta_1 \cdot \text{dem} + \beta_2 \cdot \text{wind} + \beta_3 \cdot \text{solar} + \gamma \cdot \text{ymd} + \epsilon$$

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
Intercept -3.541e+00  5.205e+00  -0.680 0.496445
DEM        6.751e-06  8.914e-07   7.573 7.82e-14 ***
SOLAR     -9.209e-06  9.370e-06  -0.983 0.325906
WIND      -7.679e-05  1.029e-05  -7.465 1.72e-13 ***
X2016     -2.862e+00  1.352e+00  -2.116 0.034558 *
X2017      6.009e-01  1.377e+00   0.436 0.662736
X02       -4.393e+00  2.302e+00  -1.908 0.056604 .
X03       -6.457e+00  2.449e+00  -2.637 0.008495 **
X04       -3.994e+00  2.605e+00  -1.533 0.125561
X05       -5.292e+00  2.656e+00  -1.992 0.046614 *
X06       -2.150e+00  2.692e+00  -0.798 0.424759
X07       -1.322e-01  2.652e+00  -0.050 0.960263
X08       -1.724e+00  2.648e+00  -0.651 0.515092
X09       -1.009e+00  2.542e+00  -0.397 0.691371
X10        1.165e+00  2.442e+00   0.477 0.633527
X11       -4.452e-01  2.420e+00  -0.184 0.854089
X12       -3.498e+00  2.321e+00  -1.507 0.131985
Monday     4.745e+00  1.129e+00   4.203 2.86e-05 ***
Tuesday    5.336e+00  1.350e+00   3.952 8.25e-05 ***
Wednesday  4.771e+00  1.402e+00   3.404 0.000689 ***
Thursday   4.210e+00  1.392e+00   3.025 0.002543 **
Friday     3.994e+00  1.303e+00   3.064 0.002237 **
Saturday   2.513e+00  6.881e-01   3.652 0.000273 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.595 on 1073 degrees of freedom
Multiple R-squared:  0.7858,    Adjusted R-squared:  0.7812
F-statistic: 171.1 on 23 and 1073 DF,  p-value: < 2.2e-16
```

Figure 11: **Prais-Winsten**



Outlook

1: Clean code and adhere to styleguide
2: Improve and add graphics (e.g. Fraunhofer Energycharts)
3: How much money have consumers saved due to renewables?
4: Testing of code