Correlation study between carbon emission and

We are interested in whether E scores has an effect on carbon emission (scope 1 + scope 2). We have the following questions:

1) Is there an effect of E score on carbon emission within each Sector?
2) Is there an effect of E score on carbon emission when Sector effects are included?
3) Is there an effect of E score on carbon emission when no sector knowledge is included?
4) Is there an effect of E score on carbon emission of a sector?

Note that, when I write effect, I mean predictive effect, (i.e. a correlation).

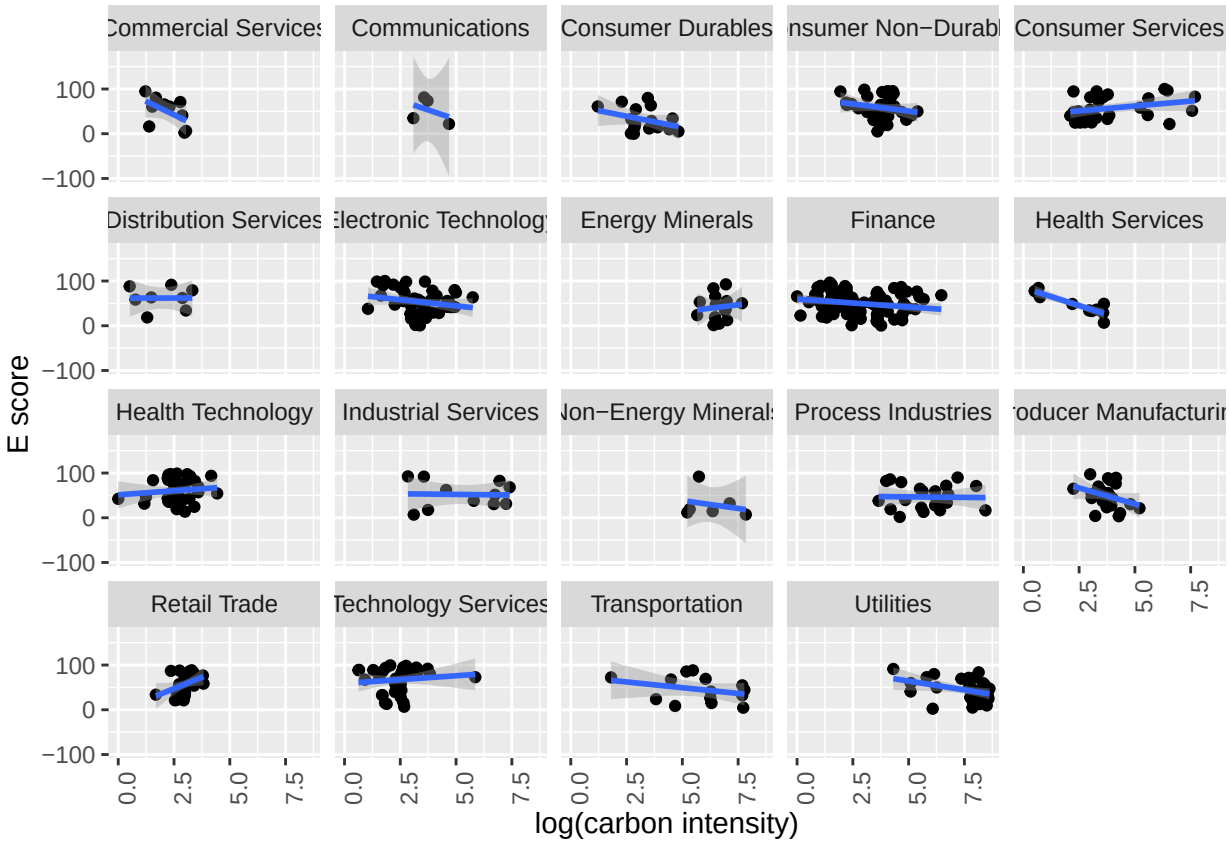
Note that, we look at log(carbonInt).

1) Is there an effect of E score on carbon emission within each Sector?

E score only have a significant effect on the carbon emission in the Consumer Services and Health Services sectors. The effects however, are only slightly significant.

```
######## By sectors ########
# Plot data. We only look at sectors with at a certain size (filter(n >= ?))
john <- data %>%
  filter(n >= 1) %>%
  ggplot(aes(x = log(carbonInt+1), y = E)) +
  geom_point() +
  theme(axis.text.x = element_text(angle = 90, hjust = 1)) +
  geom_smooth(method = "lm") +
  xlab("log(carbon intensity)") + ylab("E score") +
  #theme_classic()+
  facet_wrap(~Sector)

# png(filename="C:/Users/leneb/Desktop/Speciale/Data/New_pictures/correlation_E_carbon.png",
#     res=500, units="in", width = 7.5, height = 3.5)
# john
# dev.off()
john
```




```
model_1 <- lm(log(carbonInt+1) ~ E * Sector, data = data) # +1 before taking log to avoid (log(0))
summary(model_1)
```

```
##
## Call:
## lm(formula = log(carbonInt + 1) ~ E * Sector, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.4680 -0.6504  0.0131  0.5968  3.8272
##
## Coefficients:
##                                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    2.7653989  0.6891826   4.013 7.09e-05 ***
## E                             -0.0116498  0.0117954  -0.988 0.323879
## SectorCommunications           1.4723163  1.4901194   0.988 0.323686
## SectorConsumer Durables        0.8738509  0.8220704   1.063 0.288388
## SectorConsumer Non-Durables    1.3781447  0.8504252   1.621 0.105855
## SectorConsumer Services        0.1301514  0.8653215   0.150 0.880514
## SectorDistribution Services   -0.8101945  1.3130907  -0.617 0.537555
## SectorElectronic Technology    1.0091722  0.7908076   1.276 0.202604
## SectorEnergy Minerals          3.7771034  0.8868695   4.259 2.53e-05 ***
## SectorFinance                  0.6178173  0.7370618   0.838 0.402378
## SectorHealth Services          1.9506619  1.0600713   1.840 0.066444 .
## SectorHealth Technology       -0.3237562  0.8281404  -0.391 0.696034
```

```
## SectorIndustrial Services       2.6698861  0.9932846   2.688 0.007471 **
## SectorNon-Energy Minerals       3.7304707  0.9541558   3.910 0.000107 ***
## SectorProcess Industries        3.0910485  0.8485336   3.643 0.000303 ***
## SectorProducer Manufacturing    1.3475116  0.8423204   1.600 0.110391
## SectorRetail Trade             -0.2160543  0.9267068  -0.233 0.815763
## SectorTechnology Services      -0.6103550  0.8484985  -0.719 0.472328
## SectorTransportation            3.9149116  0.9070592   4.316 1.98e-05 ***
## SectorUtilities                 5.5873988  0.8219461   6.798 3.59e-11 ***
## E:SectorCommunications          0.0027047  0.0254669   0.106 0.915470
## E:SectorConsumer Durables      -0.0002468  0.0161484  -0.015 0.987813
## E:SectorConsumer Non-Durables   0.0052316  0.0141405   0.370 0.711586
## E:SectorConsumer Services       0.0299489  0.0144342   2.075 0.038598 *
## E:SectorDistribution Services   0.0117170  0.0205675   0.570 0.569192
## E:SectorElectronic Technology   0.0033625  0.0134576   0.250 0.802816
## E:SectorEnergy Minerals         0.0137658  0.0163321   0.843 0.399773
## E:SectorFinance                 0.0007344  0.0126966   0.058 0.953901
## E:SectorHealth Services        -0.0386497  0.0190239  -2.032 0.042809 *
## E:SectorHealth Technology       0.0148445  0.0136898   1.084 0.278822
## E:SectorIndustrial Services     0.0096118  0.0168772   0.570 0.569306
## E:SectorNon-Energy Minerals     0.0040010  0.0198356   0.202 0.840240
## E:SectorProcess Industries      0.0104954  0.0150294   0.698 0.485354
## E:SectorProducer Manufacturing  0.0041212  0.0147005   0.280 0.779349
## E:SectorRetail Trade            0.0193884  0.0154745   1.253 0.210920
## E:SectorTechnology Services     0.0156534  0.0136273   1.149 0.251331
## E:SectorTransportation         -0.0077829  0.0162545  -0.479 0.632315
## E:SectorUtilities              -0.0078907  0.0147307  -0.536 0.592471
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.134 on 427 degrees of freedom
## Multiple R-squared:  0.659,  Adjusted R-squared:  0.6294
## F-statistic:  22.3 on 37 and 427 DF,  p-value: < 2.2e-16
```

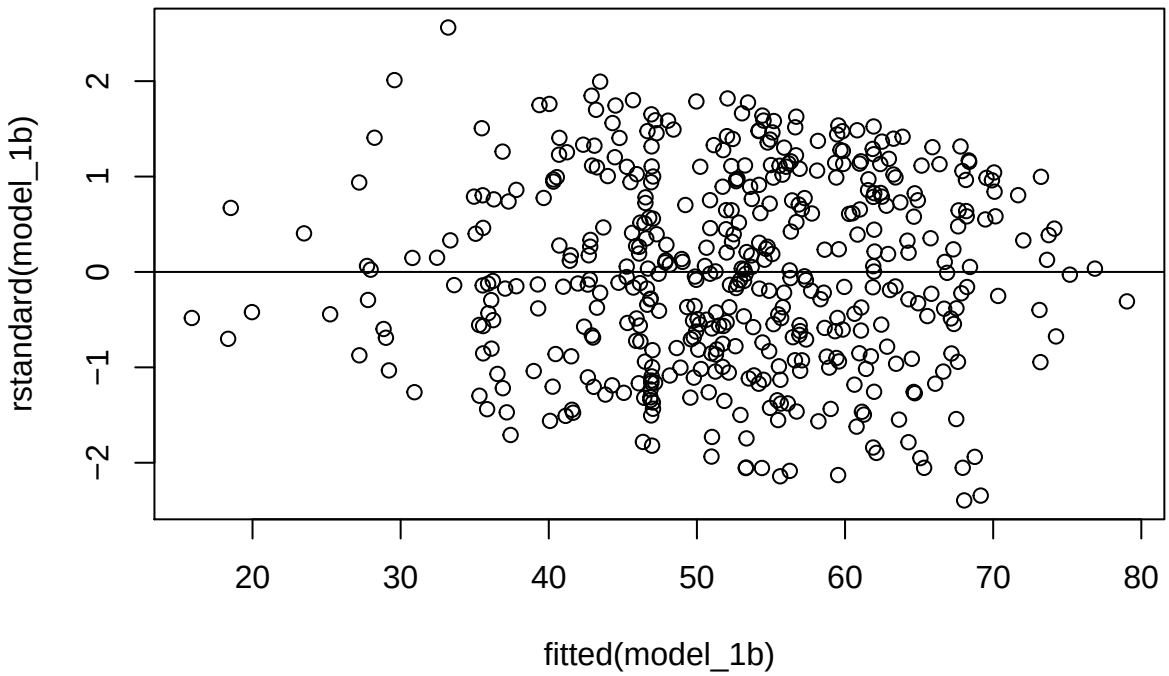
```
model_1b <- lm(E ~ Sector + log(carbonInt+1) : Sector, data = data) # +1 before taking log to avoid (lo
summary(model_1b)
```

```
##
## Call:
## lm(formula = E ~ Sector + log(carbonInt + 1):Sector, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -61.210 -18.967  -0.526  20.908  58.791
##
## Coefficients:
##                                              Estimate Std. Error t value
## (Intercept)                                 1.026e+02  2.805e+01   3.659
## SectorCommunications                        1.368e+01  8.983e+01   0.152
## SectorConsumer Durables                    -3.858e+01  3.738e+01  -1.032
## SectorConsumer Non-Durables                -2.024e+01  3.541e+01  -0.572
## SectorConsumer Services                    -6.248e+01  3.075e+01  -2.032
## SectorDistribution Services                -4.077e+01  3.444e+01  -1.184
## SectorElectronic Technology                -3.077e+01  3.104e+01  -0.991
## SectorEnergy Minerals                      -1.018e+02  9.671e+01  -1.053
```

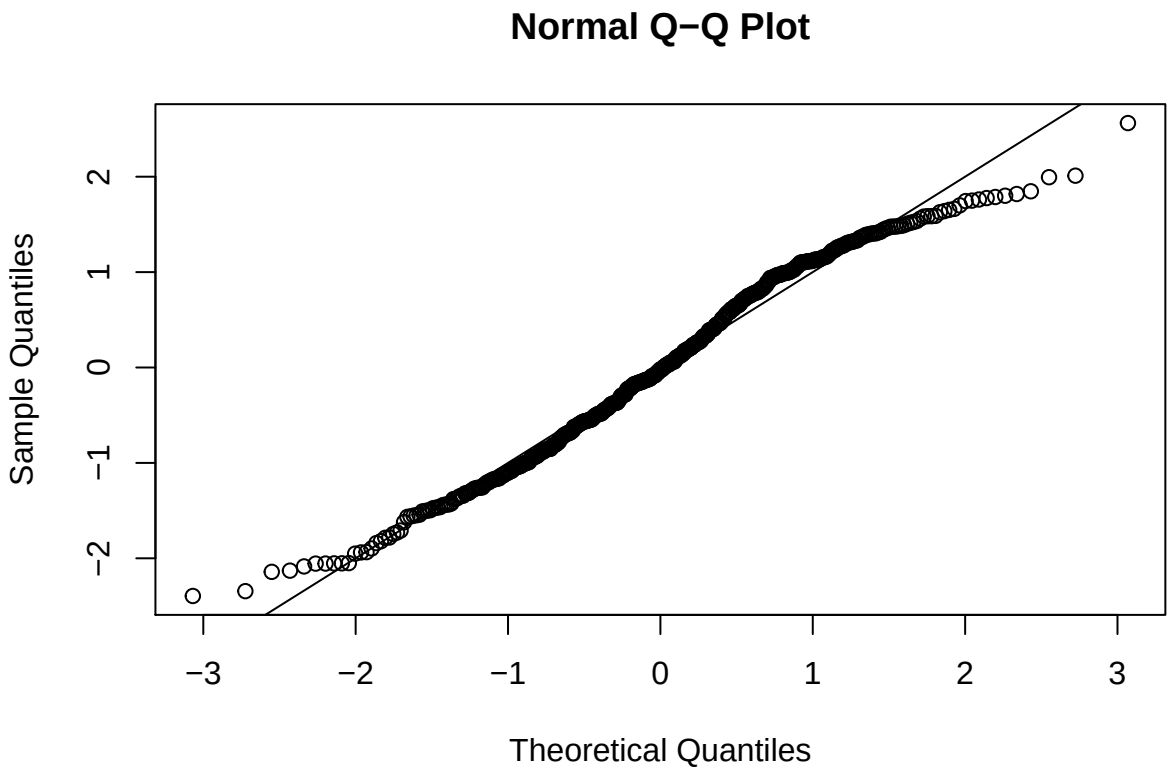
```
## SectorFinance                                       -4.304e+01  2.871e+01  -1.499
## SectorHealth Services                               -1.760e+01  3.220e+01  -0.547
## SectorHealth Technology                             -5.133e+01  3.166e+01  -1.621
## SectorIndustrial Services                           -4.758e+01  3.800e+01  -1.252
## SectorNon-Energy Minerals                           -2.879e+01  7.573e+01  -0.380
## SectorProcess Industries                            -5.336e+01  3.839e+01  -1.390
## SectorProducer Manufacturing                        -2.197e-03  4.350e+01   0.000
## SectorRetail Trade                                  -1.061e+02  4.528e+01  -2.343
## SectorTechnology Services                           -4.379e+01  3.047e+01  -1.437
## SectorTransportation                                -2.756e+01  3.765e+01  -0.732
## SectorUtilities                                      9.449e-01  4.160e+01   0.023
## SectorCommercial Services:log(carbonInt + 1)        -2.414e+01  1.228e+01  -1.966
## SectorCommunications:log(carbonInt + 1)             -1.685e+01  2.240e+01  -0.752
## SectorConsumer Durables:log(carbonInt + 1)          -9.977e+00  7.305e+00  -1.366
## SectorConsumer Non-Durables:log(carbonInt + 1)      -6.341e+00  5.606e+00  -1.131
## SectorConsumer Services:log(carbonInt + 1)           4.370e+00  2.941e+00   1.486
## SectorDistribution Services:log(carbonInt + 1)       3.714e-02  9.065e+00   0.004
## SectorElectronic Technology:log(carbonInt + 1)      -5.486e+00  3.813e+00  -1.439
## SectorEnergy Minerals:log(carbonInt + 1)             6.142e+00  1.392e+01   0.441
## SectorFinance:log(carbonInt + 1)                    -3.511e+00  1.927e+00  -1.822
## SectorHealth Services:log(carbonInt + 1)            -1.601e+01  6.091e+00  -2.629
## SectorHealth Technology:log(carbonInt + 1)           3.620e+00  5.350e+00   0.677
## SectorIndustrial Services:log(carbonInt + 1)        -5.614e-01  4.582e+00  -0.123
## SectorNon-Energy Minerals:log(carbonInt + 1)        -7.072e+00  1.109e+01  -0.638
## SectorProcess Industries:log(carbonInt + 1)         -4.962e-01  4.417e+00  -0.112
## SectorProducer Manufacturing:log(carbonInt + 1)     -1.438e+01  8.768e+00  -1.639
## SectorRetail Trade:log(carbonInt + 1)                2.033e+01  1.174e+01   1.731
## SectorTechnology Services:log(carbonInt + 1)         3.448e+00  4.580e+00   0.753
## SectorTransportation:log(carbonInt + 1)             -5.141e+00  4.161e+00  -1.236
## SectorUtilities:log(carbonInt + 1)                  -7.885e+00  4.054e+00  -1.945
##                                                    Pr(>|t|)
## (Intercept)                                        0.000285 ***
## SectorCommunications                               0.879014
## SectorConsumer Durables                            0.302684
## SectorConsumer Non-Durables                        0.567953
## SectorConsumer Services                            0.042754 *
## SectorDistribution Services                        0.237163
## SectorElectronic Technology                        0.322124
## SectorEnergy Minerals                              0.292877
## SectorFinance                                      0.134517
## SectorHealth Services                              0.584965
## SectorHealth Technology                            0.105735
## SectorIndustrial Services                          0.211264
## SectorNon-Energy Minerals                          0.703992
## SectorProcess Industries                           0.165299
## SectorProducer Manufacturing                       0.999960
## SectorRetail Trade                                 0.019566 *
## SectorTechnology Services                          0.151345
## SectorTransportation                               0.464547
## SectorUtilities                                    0.981891
## SectorCommercial Services:log(carbonInt + 1)       0.049984 *
## SectorCommunications:log(carbonInt + 1)            0.452452
## SectorConsumer Durables:log(carbonInt + 1)         0.172740
## SectorConsumer Non-Durables:log(carbonInt + 1)     0.258710
```

```
## SectorConsumer Services:log(carbonInt + 1)      0.137972
## SectorDistribution Services:log(carbonInt + 1)  0.996733
## SectorElectronic Technology:log(carbonInt + 1)  0.150915
## SectorEnergy Minerals:log(carbonInt + 1)        0.659266
## SectorFinance:log(carbonInt + 1)                0.069202 .
## SectorHealth Services:log(carbonInt + 1)        0.008880 **
## SectorHealth Technology:log(carbonInt + 1)      0.498948
## SectorIndustrial Services:log(carbonInt + 1)    0.902544
## SectorNon-Energy Minerals:log(carbonInt + 1)    0.524059
## SectorProcess Industries:log(carbonInt + 1)     0.910595
## SectorProducer Manufacturing:log(carbonInt + 1) 0.101859
## SectorRetail Trade:log(carbonInt + 1)           0.084089 .
## SectorTechnology Services:log(carbonInt + 1)    0.452041
## SectorTransportation:log(carbonInt + 1)         0.217255
## SectorUtilities:log(carbonInt + 1)              0.052446 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 25.94 on 427 degrees of freedom
## Multiple R-squared:  0.1579, Adjusted R-squared:  0.08495
## F-statistic: 2.164 on 37 and 427 DF,  p-value: 0.0001512
```

```
# Residual plot og qqplot ser fint ud for alle modeller. Har bare fjernet dem fra resten, da det fylder
plot(fitted(model_1b), rstandard(model_1b)); abline(0,0) # residual plot
```



```r
qqnorm(rstandard(model_1b));abline(0,1) # qqplot
```



2) Is there an effect of E score on carbon emission when Sector effects are included?

The E score is just significant, but the estimate is pretty small.

```r
model_2 <- lm(log(carbonInt+1) ~ E + Sector, data = data)
summary(model_2)
```

```
##
## Call:
## lm(formula = log(carbonInt + 1) ~ E + Sector, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.8523 -0.6805 -0.0298  0.6231  3.8790
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   2.447169   0.377523   6.482 2.40e-10 ***
## E                            -0.005272   0.002061  -2.558 0.010863 *
## SectorCommunications          1.596343   0.679599   2.349 0.019263 *
## SectorConsumer Durables       0.983610   0.464605   2.117 0.034807 *
## SectorConsumer Non-Durables   1.629328   0.416528   3.912 0.000106 ***
```

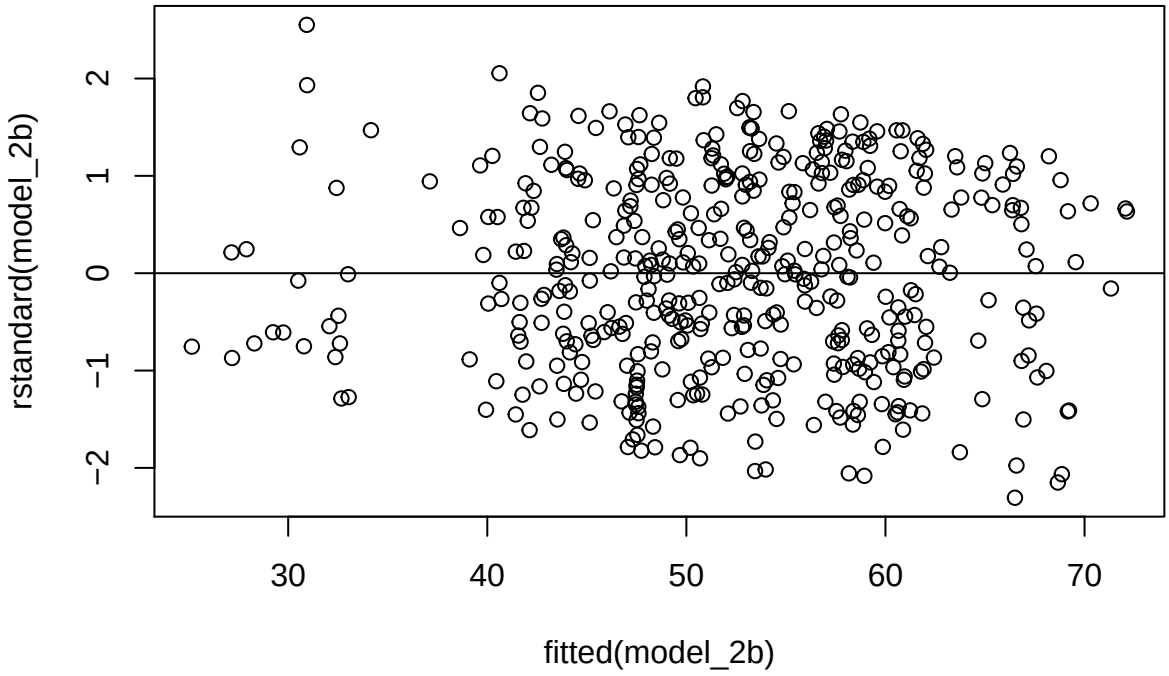
```
## SectorConsumer Services       1.800885   0.423450   4.253 2.57e-05 ***
## SectorDistribution Services  -0.161365   0.545433  -0.296 0.767485
## SectorElectronic Technology   1.165841   0.403350   2.890 0.004036 **
## SectorEnergy Minerals         4.401893   0.475916   9.249  < 2e-16 ***
## SectorFinance                 0.656111   0.382479   1.715 0.086965 .
## SectorHealth Services         0.068766   0.501901   0.137 0.891085
## SectorHealth Technology       0.509566   0.406747   1.253 0.210943
## SectorIndustrial Services     3.156438   0.501917   6.289 7.65e-10 ***
## SectorNon-Energy Minerals     3.978615   0.594668   6.690 6.70e-11 ***
## SectorProcess Industries      3.600235   0.438152   8.217 2.30e-15 ***
## SectorProducer Manufacturing  1.555679   0.429805   3.619 0.000329 ***
## SectorRetail Trade            0.848603   0.432624   1.962 0.050441 .
## SectorTechnology Services     0.331059   0.410949   0.806 0.420906
## SectorTransportation          3.592577   0.475698   7.552 2.45e-13 ***
## SectorUtilities               5.269628   0.423311  12.449  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.149 on 445 degrees of freedom
## Multiple R-squared:  0.6353, Adjusted R-squared:  0.6198
## F-statistic: 40.81 on 19 and 445 DF,  p-value: < 2.2e-16
```

```
model_2b <- lm(E ~ log(carbonInt+1) + Sector, data = data)
summary(model_2b)
```

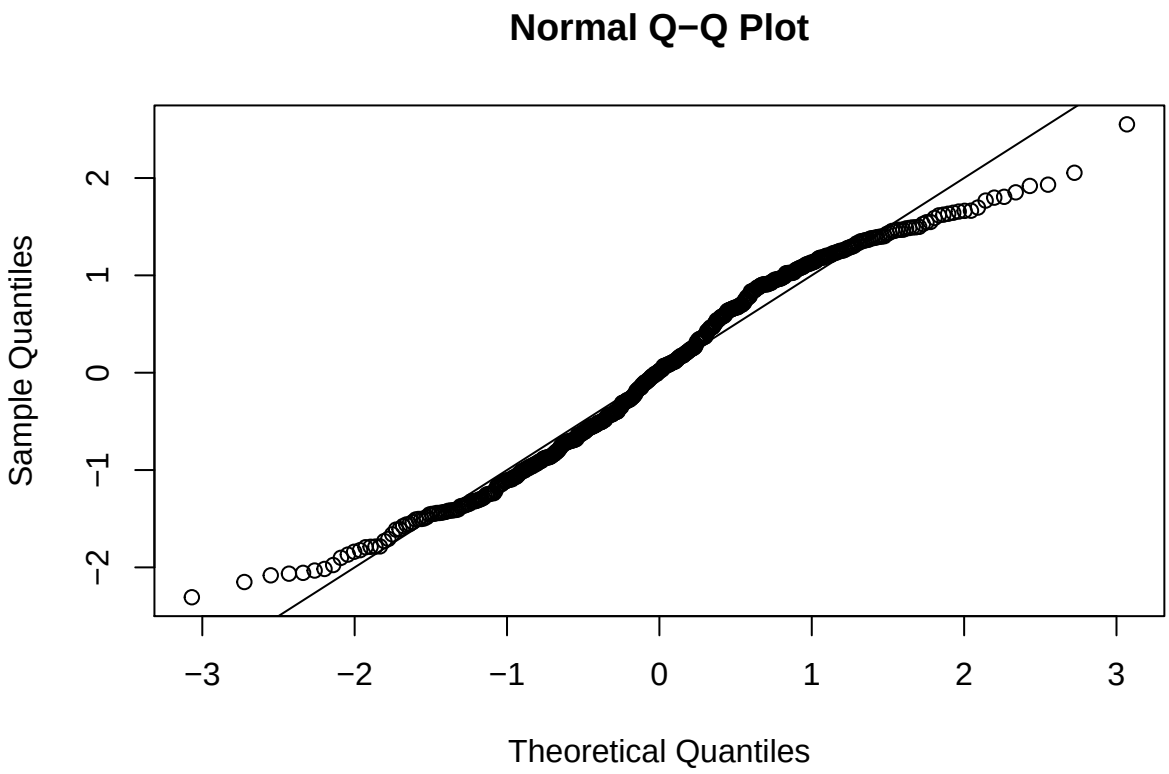
```
##
## Call:
## lm(formula = E ~ log(carbonInt + 1) + Sector, data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -59.671 -20.537   0.506  22.751  61.067
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                    55.898      8.620   6.485 2.36e-10 ***
## log(carbonInt + 1)             -2.748      1.075  -2.558   0.0109 *
## SectorCommunications            7.319     15.609   0.469   0.6394
## SectorConsumer Durables       -15.457     10.636  -1.453   0.1469
## SectorConsumer Non-Durables    12.947      9.653   1.341   0.1805
## SectorConsumer Services        12.325      9.846   1.252   0.2113
## SectorDistribution Services    11.408     12.443   0.917   0.3598
## SectorElectronic Technology     6.834      9.290   0.736   0.4623
## SectorEnergy Minerals           3.819     11.864   0.322   0.7477
## SectorFinance                   1.515      8.761   0.173   0.8628
## SectorHealth Services          -0.830     11.460  -0.072   0.9423
## SectorHealth Technology        12.184      9.286   1.312   0.1901
## SectorIndustrial Services      10.797     11.947   0.904   0.3666
## SectorNon-Energy Minerals      -9.179     14.238  -0.645   0.5195
## SectorProcess Industries        6.427     10.732   0.599   0.5496
## SectorProducer Manufacturing    3.168      9.956   0.318   0.7505
## SectorRetail Trade              9.700      9.910   0.979   0.3282
## SectorTechnology Services      17.950      9.351   1.920   0.0556 .
## SectorTransportation            5.281     11.534   0.458   0.6473
```

```
## SectorUtilities                 9.238     11.214   0.824   0.4105
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 26.23 on 445 degrees of freedom
## Multiple R-squared:  0.1026, Adjusted R-squared:  0.0643
## F-statistic: 2.678 on 19 and 445 DF,  p-value: 0.0001782
```

```
plot(fitted(model_2b), rstandard(model_2b)); abline(0,0) # residual plot
```



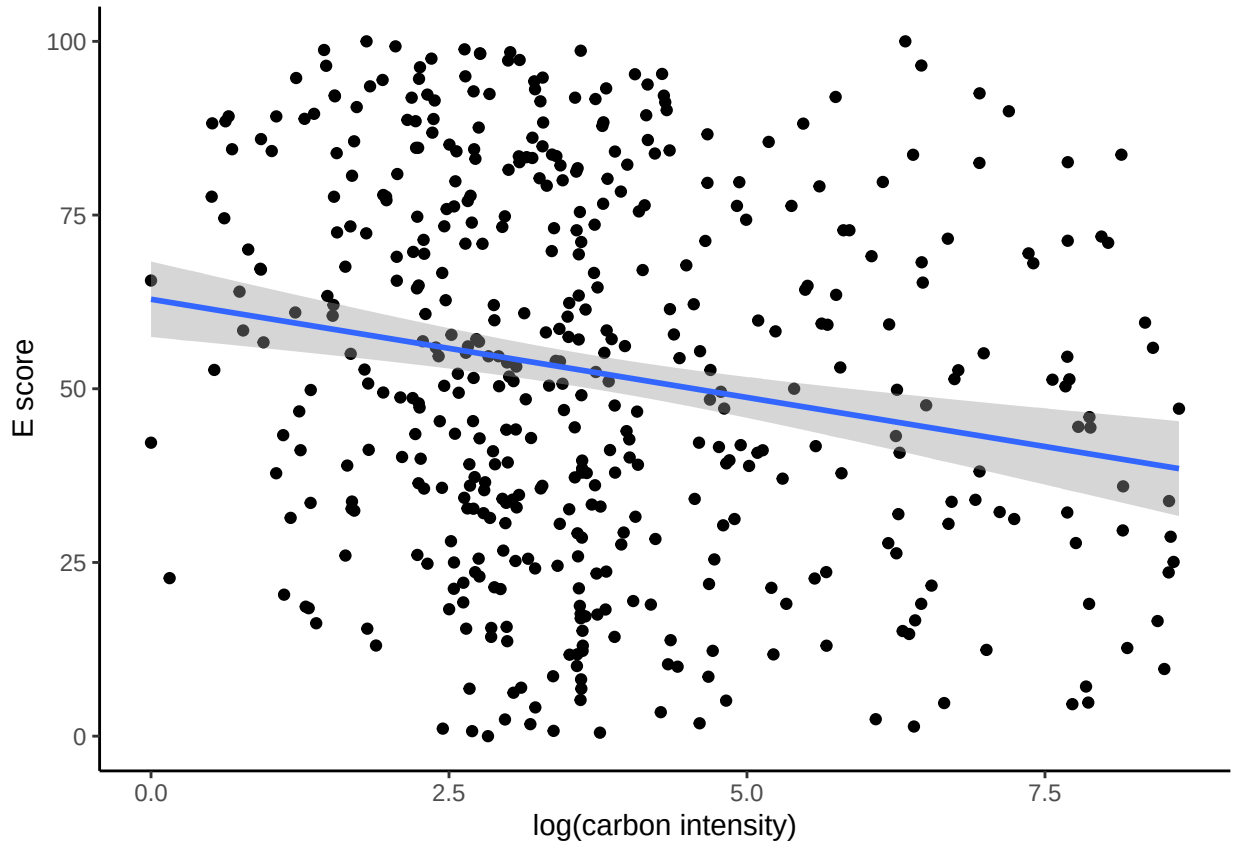

```
qqnorm(rstandard(model_2b));abline(0,1) # qqplot
```



3) Is there an effect of E score on carbon emission when no sector knowledge is included? Yes

```
######## Plot all ########
john2 <- data %>% ggplot(aes(x = log(carbonInt+1), y = E)) +
  geom_point() +
  theme(axis.text.x = element_text(angle = 90, hjust = 1)) +
  geom_smooth(method = "lm") +
  xlab("log(carbon intensity)") + ylab("E score") +
  theme_classic()

# png(filename="C:/Users/leneb/Desktop/Speciale/Data/New_pictures/correlation_E_carbon_no_sector.png",
#     res=500, units="in", width = 7.5, height = 3.5)
# john2
# dev.off()
john2
```



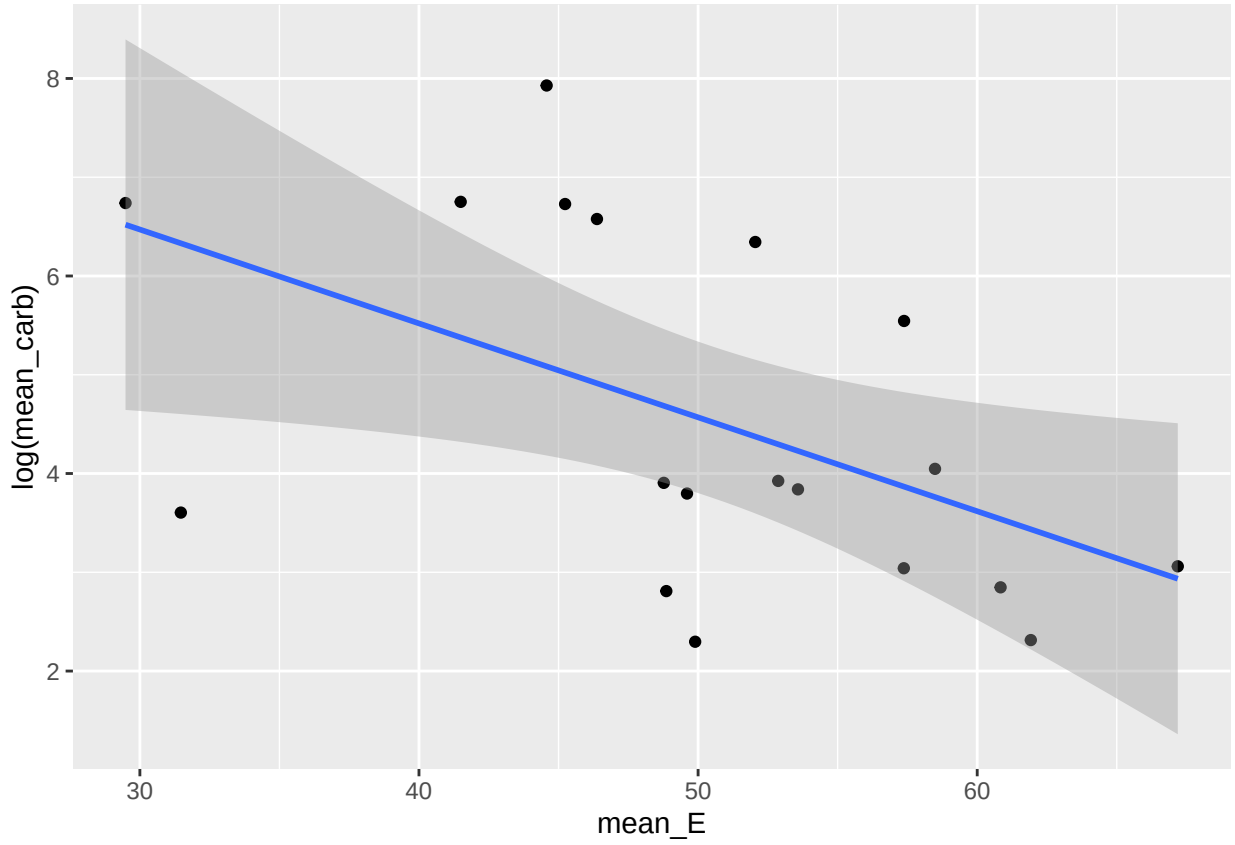

```
model_0 <- lm(E ~ log(carbonInt+1), data = data)
summary(model_0)
```

```
##
## Call:
## lm(formula = E ~ log(carbonInt + 1), data = data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -54.890 -20.882  -0.202  24.194  55.006
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)         62.8795     2.7646  22.744  < 2e-16 ***
## log(carbonInt + 1)  -2.8261     0.6635  -4.259 2.49e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 26.63 on 463 degrees of freedom
## Multiple R-squared:  0.0377, Adjusted R-squared:  0.03562
## F-statistic: 18.14 on 1 and 463 DF,  p-value: 2.486e-05
```

4) Is there an effect of E score on carbon emission of a sector? There is a significant tendency between higher E score and lower carbon emission. Note however, that we only look at the mean for each sector, hence the size of the sector does not have any influence.

```
######## Sector vs E score #########
data_sector <- data %>% group_by(Sector) %>%
  summarise(mean_E = mean(E), mean_carb = mean(carbonInt), n = n())

data_sector %>% ggplot(aes(x = mean_E, y = log(mean_carb))) +
  geom_point() + geom_smooth(method = lm)
```




```
model_sector <- lm(log(mean_carb) ~ mean_E, data = data_sector)
summary(model_sector)
```

```
##
## Call:
## lm(formula = log(mean_carb) ~ mean_E, data = data_sector)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.7267 -0.8183 -0.3707  1.5183  2.8440
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  9.32344    1.98953   4.686 0.000212 ***
## mean_E      -0.09509    0.03882  -2.450 0.025429 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 1.583 on 17 degrees of freedom
## Multiple R-squared:  0.2609, Adjusted R-squared:  0.2174
## F-statistic: 6.001 on 1 and 17 DF,  p-value: 0.02543
```

Conlcusion

The only sectors where there is a correlation between E score and carbon emission are Consumer Services and Health Services. There also is an overall correlation between E score and carbon emission, when Sector knowledge is not taken into account.