

Identification of Heterogeneous Causal Effects

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Identifying the Causal Effects

In this section we estimate the causal effects of additional funding on students performances. Namely, our outcome variables are *certificate* (which is a dummy variable that assumes value 1 if the student gets an “A” certificate: the highest possible grade in the Flanders) and *progress school* (which is a dummy recording whether or not the student got school retention).

First Outcome: Certificate

We now focus on the effects when we sample units in a bandwidth of 0.035 (which is the optimal bandwidth for the outcome *certificate*) around the cutoff (10%).

```
students_data_randomized_03_2011 <-  
  students_data_2011[which(students_data_2011$GOKpercentage >= .065  
    & students_data_2011$GOKpercentage <= .135),]
```

Moreover, from every school we sample a number students in order to increase the balance in the covariate and to guarantee an equal representation to all the schools, avoiding biases related to the over-representation of biggest schools' students. In the first case, we sample 50 students from each school.

```
schools <-  
students_data_randomized_03_2011$school[which(  
!duplicated(students_data_randomized_03_2011$school))]  
  
sample_students <- as.data.frame(matrix(data = NA, nrow = 50*length(schools),  
                                         ncol = ncol(students_data_randomized_03_2011)))  
colnames(sample_students) <- colnames(students_data_randomized_03_2011)  
  
for (j in (0:(length(schools)-1))){  
  set.seed(j + 123)  
  sample_students[(1+(j*50)):(50+(j*50)),] <-  
  students_data_randomized_03_2011[which(  
    students_data_randomized_03_2011$school %in%  
    schools[j+1]),][sample(1:nrow(students_data_randomized_03_2011[which(  
      students_data_randomized_03_2011$school %in% schools[j+1])),],  
      50, replace = FALSE ),)]  
}  
  
sample_student <- round(sample_students[, -(1:4)], 0)  
sample_students <- cbind(sample_students[, 1:4], sample_student)
```

Then we run our BCF-IV algorithm on this sample of units.

```
# Attaching the Sample and the Covariates  
attach(sample_students)  
x <- cbind(primary_retention , man , BULO,  
  leerkracht_age , leerkracht_seniority,
```

```

        leerkracht_diploma,
        directie_age, directie_seniority
    )
    z <- as.matrix(eligible_dummy)
    y <- as.matrix(certificate)
    logit<-glm(eligible_dummy ~ GOKpercentage,
               data = sample_students, family = binomial(link = "logit"))
    summary(logit)
    pihat<-predict(logit, sample_students, type="response")
    detach(sample_students)

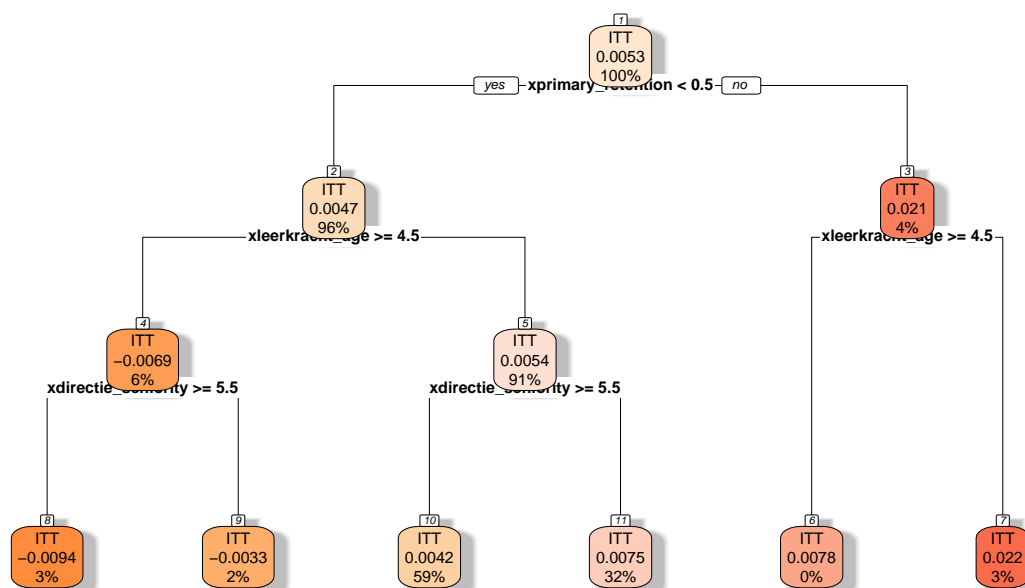
# Running the BCF algorithm on the IV
    set.seed(123)
    bcf_fit <- bcf(y, z, x, x, pihat, nburn=2000, nsim=2000)
    tau_post <- bcf_fit$tau
    tauhat <- colMeans(tau_post)

    exp <- as.data.frame(cbind(tauhat, y, x, z))

## n= 4300
##
## node), split, n, deviance, yval
##      * denotes terminal node
##
## 1) root 4300 1.248660e-01  0.005298605
##    2) xprimary_retention< 0.5 4142 7.972906e-02  0.004688791
##      4) xleerkracht_age>=4.5 241 2.307849e-03 -0.006942340
##        8) xdirectie_seniority>=5.5 143 1.346278e-05 -0.009429468 *
##        9) xdirectie_seniority< 5.5 98 1.190658e-04 -0.003313164 *
##      5) xleerkracht_age< 4.5 3901 4.280376e-02  0.005407351
##        10) xdirectie_seniority>=5.5 2523 1.473165e-02  0.004238946 *
##        11) xdirectie_seniority< 5.5 1378 1.832152e-02  0.007546601 *
##    3) xprimary_retention>=0.5 158 3.217465e-03  0.021284990
##      6) xleerkracht_age>=4.5 9 2.739628e-05  0.007767681 *
##      7) xleerkracht_age< 4.5 149 1.446280e-03  0.022101480 *

```

BCF-IV First Stage



```
ITT = mean(sample_students$certificate[which(sample_students$eligible_dummy==1)]) - mean(sample_students$certificate[which(sample_students$eligible_dummy==0)])
ITT
```

```
## [1] 0.01185908
```

```
ITT = mean(students_data_randomized_03_2011$certificate[which(students_data_randomized_03_2011$eligible_dummy==1)]) - mean(students_data_randomized_03_2011$certificate[which(students_data_randomized_03_2011$eligible_dummy==0)])
ITT
```

```
## [1] 0.01134698
```

```
z <- as.matrix(sample_students$eligible_dummy)
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
```

```
## Call:
```

```
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students)
```

```
##
```

```
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -0.99019  0.06745  0.07285  0.09695  0.26186
```

```
##
```

```
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.823208   0.057561  14.301 < 2e-16 ***
## xprimary_retention -0.144588   0.033962  -4.257 2.11e-05 ***
## xman            -0.025153   0.008465  -2.972 0.00298 **
## xBULO           0.200284   0.043835   4.569 5.04e-06 ***
```

```
## xleerkracht_age      0.020336  0.015522  1.310  0.19023
## xleerkracht_seniority 0.007495  0.013709  0.547  0.58460
## xdirectie_age        0.005404  0.005626  0.961  0.33686
## xdirectie_seniority -0.006458  0.006586 -0.981  0.32685
## GOKschool            0.051178  0.037954  1.348  0.17759
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 4291    591.935 <2e-16 ***
## Wu-Hausman          1 4290      2.969  0.085 .
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2748 on 4291 degrees of freedom
## Multiple R-Squared:  0.00796, Adjusted R-squared:  0.006111
## Wald test: 7.633 on 8 and 4291 DF,  p-value: 3.434e-10

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = primary_retention < 0.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.99124  0.06601  0.07025  0.09782  0.11868
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.829217   0.057204  14.496 < 2e-16 ***
## xman           -0.027719   0.008414  -3.294 0.000995 ***
## xleerkracht_age  0.016378   0.015371   1.065 0.286714
## xleerkracht_seniority 0.009011   0.013693   0.658 0.510528
## xdirectie_age    0.004241   0.005609   0.756 0.449604
## xdirectie_seniority -0.004387   0.006560  -0.669 0.503710
## GOKschool        0.052863   0.038095   1.388 0.165314
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 4135    561.461 <2e-16 ***
## Wu-Hausman          1 4134      2.557  0.11
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2681 on 4135 degrees of freedom
## Multiple R-Squared: -0.0006994, Adjusted R-squared: -0.002151
## Wald test: 2.55 on 6 and 4135 DF,  p-value: 0.01819

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = primary_retention >= 0.5),
        vcov = sandwich, diagnostics = TRUE)

```

```

vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention >= 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.90757  0.09386  0.20112  0.25236  0.31119
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.37432    0.50003   0.749   0.455
## xman             0.04456    0.06835   0.652   0.515
## xBULO            0.19732    0.14389   1.371   0.172
## xleerkracht_age  0.13617    0.12988   1.048   0.296
## xleerkracht_seniority -0.01808    0.07523  -0.240   0.810
## xdirectie_age    0.03478    0.04306   0.808   0.421
## xdirectie_seniority -0.05529    0.04468  -1.238   0.218
## GOKschool        0.06986    0.24429   0.286   0.775
##
## Diagnostic tests:
##              df1 df2 statistic  p-value
## Weak instruments    1 150    29.593 2.12e-07 ***
## Wu-Hausman          1 149     0.649   0.422
## Sargan              0 NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4196 on 150 degrees of freedom
## Multiple R-Squared: 0.01037, Adjusted R-squared: -0.03581
## Wald test: 5.556 on 7 and 150 DF, p-value: 1.05e-05

#summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
#              subset = primary_retention < 0.5 & leerkracht_age >= 4.5),
#        vcov = sandwich, diagnostics = TRUE)
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = primary_retention < 0.5 & leerkracht_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.00240  0.06944  0.07398  0.09948  0.12420
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.9450450    0.0852072  11.091 < 2e-16 ***
## xman             -0.0300407    0.0087981  -3.414 0.000646 ***

```

```

## xleerkracht_age      -0.0228716  0.0257181  -0.889 0.373887
## xleerkracht_seniority 0.0152747  0.0153925   0.992 0.321091
## xdirectie_age        0.0026272  0.0059871   0.439 0.660821
## xdirectie_seniority  -0.0003556  0.0072734  -0.049 0.961012
## GOKschool           0.0688538  0.0372556   1.848 0.064657 .
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 3894   598.095 <2e-16 ***
## Wu-Hausman         1 3893    4.721  0.0298 *
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2719 on 3894 degrees of freedom
## Multiple R-Squared:  -0.003032, Adjusted R-squared: -0.004578
## Wald test: 3.164 on 6 and 3894 DF, p-value: 0.004256

#summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
#              subset = primary_retention >= 0.5 & leerkraft_age >= 4.5),
#        vcov = sandwich, diagnostics = TRUE)
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = primary_retention >= 0.5 & leerkraft_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention >= 0.5 & leerkraft_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.8414  0.1018  0.2033  0.2595  0.2963
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.59828    1.06333   0.563   0.575
## xman           0.02325    0.07050   0.330   0.742
## xBULO          0.22333    0.15149   1.474   0.143
## xleerkracht_age  0.08586    0.26333   0.326   0.745
## xleerkracht_seniority -0.01287    0.07928  -0.162   0.871
## xdirectie_age    0.02981    0.04192   0.711   0.478
## xdirectie_seniority -0.05477    0.04485  -1.221   0.224
## GOKschool        0.01803    0.24681   0.073   0.942
##
## Diagnostic tests:
##              df1 df2 statistic  p-value
## Weak instruments    1 141    27.175 6.48e-07 ***
## Wu-Hausman         1 140    0.371  0.543
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4233 on 141 degrees of freedom
## Multiple R-Squared:  0.01659, Adjusted R-squared: -0.03224

```

```
## Wald test: 6.047 on 7 and 141 DF, p-value: 3.526e-06
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
  subset = primary_retention < 0.5 & directie_seniority >= 5.5
    & leerkracht_age < 4.5),
  vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & directie_seniority >=
##         5.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.98085  0.05397  0.07400  0.08370  0.10456
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.0654468   0.1141004    9.338 < 2e-16 ***
## xman             -0.0297305   0.0105957   -2.806  0.00506 **
## xleerkracht_seniority 0.0001879   0.0243074    0.008  0.99383
## xdirectie_age      0.0008311   0.0081300    0.102  0.91858
## xdirectie_seniority -0.0208591   0.0130134   -1.603  0.10908
## GOKschool         0.0331577   0.0502481    0.660  0.50939
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 2517   299.839 <2e-16 ***
## Wu-Hausman          1 2516     1.718   0.19
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2647 on 2517 degrees of freedom
## Multiple R-Squared: 0.001372, Adjusted R-squared: -0.000612
## Wald test: 2.931 on 5 and 2517 DF, p-value: 0.01211
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
  subset = primary_retention < 0.5 & directie_seniority < 5.5
    & leerkracht_age < 4.5),
  vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & directie_seniority < 5.5 &
##         leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.07621  0.07297  0.09505  0.12082  0.15065
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
```

```

## (Intercept)          0.888908    0.099599    8.925    <2e-16 ***
## xman                 -0.030666    0.015717   -1.951    0.0512 .
## xleerkracht_age      -0.007120    0.033838   -0.210    0.8334
## xleerkracht_seniority 0.024932    0.021701    1.149    0.2508
## xdirectie_age        0.006144    0.009978    0.616    0.5381
## xdirectie_seniority  -0.017187    0.019436   -0.884    0.3767
## GOKschool           0.165123    0.069672    2.370    0.0179 *
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1371   274.222 <2e-16 ***
## Wu-Hausman         1 1370    5.235  0.0223 *
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2867 on 1371 degrees of freedom
## Multiple R-Squared:  -0.02126,    Adjusted R-squared:  -0.02573
## Wald test: 2.101 on 6 and 1371 DF,  p-value: 0.0504

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = leerkracht_age >= 3.5
                & leerkracht_age < 4.5
                & directie_seniority < 5.5),
          vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age >= 3.5 & leerkracht_age < 4.5 & directie_seniority <
##       5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.23418  0.06847  0.13412  0.14934  0.29161
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.930057   0.113240   8.213 5.17e-16 ***
## xprimary_retention -0.117080   0.055796  -2.098  0.03607 *
## xman           -0.014662   0.017508  -0.837  0.40249
## xBULO           0.004945   0.107523   0.046  0.96332
## xleerkracht_seniority 0.025195   0.022549   1.117  0.26406
## xdirectie_age    0.006786   0.010044   0.676  0.49941
## xdirectie_seniority -0.039889   0.021546  -1.851  0.06435 .
## GOKschool       0.362066   0.112579   3.216  0.00133 **
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1292   153.23 < 2e-16 ***
## Wu-Hausman         1 1291   10.02 0.00159 **
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##

```



```
## Residual standard error: 0.3121 on 1292 degrees of freedom
## Multiple R-Squared: -0.1062, Adjusted R-squared: -0.1122
## Wald test: 2.802 on 7 and 1292 DF, p-value: 0.006738
```

From the help file for AER, it says it does an F-test on the first stage regression; I believe the nu

Let's see what happens when we rule out the dependency on "retention"

Teacher Age

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = leerkracht_age <= 4.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
```

```
## Call:
```

```
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age <= 4.5)
```

```
##
```

```
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -0.99925  0.06848  0.07565  0.09980  0.26848
```

```
##
```

```
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.938221   0.086855  10.802 < 2e-16 ***
## xprimary_retention -0.148516   0.035524  -4.181 2.97e-05 ***
## xman              -0.028166   0.008841  -3.186  0.00145 **
## xBULO              0.202721   0.045926   4.414 1.04e-05 ***
## xleerkracht_age   -0.017217   0.026015  -0.662  0.50814
## xleerkracht_seniority 0.012998   0.015349   0.847  0.39714
## xdirectie_age      0.004159   0.005986   0.695  0.48725
## xdirectie_seniority -0.003157   0.007265  -0.435  0.66395
## GOKschool          0.063573   0.037077   1.715  0.08649 .
```

```
##
```

```
## Diagnostic tests:
```

```
##              df1  df2 statistic p-value
## Weak instruments    1 4041    631.051 <2e-16 ***
## Wu-Hausman          1 4040     4.844  0.0278 *
## Sargan              0  NA         NA      NA
```

```
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Residual standard error: 0.2786 on 4041 degrees of freedom
```

```
## Multiple R-Squared: 0.00638, Adjusted R-squared: 0.004413
```

```
## Wald test: 7.119 on 8 and 4041 DF, p-value: 2.16e-09
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = leerkracht_age <= 4),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
```

```
## Call:
```

```
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age <= 4)
```

```
##
```

```
## Residuals:
```

```

##      Min      1Q   Median      3Q      Max
## -0.99925  0.06848  0.07565  0.09980  0.26848
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.938221   0.086855  10.802 < 2e-16 ***
## xprimary_retention -0.148516   0.035524  -4.181 2.97e-05 ***
## xman              -0.028166   0.008841  -3.186 0.00145 **
## xBULO              0.202721   0.045926   4.414 1.04e-05 ***
## xleerkracht_age   -0.017217   0.026015  -0.662 0.50814
## xleerkracht_seniority 0.012998  0.015349   0.847 0.39714
## xdirectie_age      0.004159   0.005986   0.695 0.48725
## xdirectie_seniority -0.003157   0.007265  -0.435 0.66395
## GOKschool          0.063573   0.037077   1.715 0.08649 .
##
## Diagnostic tests:
##              df1   df2 statistic p-value
## Weak instruments      1 4041    631.051 <2e-16 ***
## Wu-Hausman            1 4040     4.844 0.0278 *
## Sargan                0   NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2786 on 4041 degrees of freedom
## Multiple R-Squared: 0.00638, Adjusted R-squared: 0.004413
## Wald test: 7.119 on 8 and 4041 DF, p-value: 2.16e-09
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_age >= 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_age >= 5.5)
##
## Residuals:
##      Min      1Q   Median      3Q      Max
## -0.99370  0.06762  0.07612  0.09601  0.27917
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.737072   0.123501   5.968 2.68e-09 ***
## xprimary_retention -0.167318   0.042085  -3.976 7.18e-05 ***
## xman              -0.020661   0.010106  -2.044 0.041 *
## xleerkracht_age    0.026020   0.022292   1.167 0.243
## xleerkracht_seniority 0.022032  0.019796   1.113 0.266
## xdirectie_age      0.006957   0.008281   0.840 0.401
## xdirectie_seniority -0.007729   0.009367  -0.825 0.409
## GOKschool          0.055134   0.048834   1.129 0.259
##
## Diagnostic tests:
##              df1   df2 statistic p-value
## Weak instruments      1 2992    383.617 <2e-16 ***
## Wu-Hausman            1 2991     2.393 0.122

```

```
## Sargan          0    NA        NA        NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2747 on 2992 degrees of freedom
## Multiple R-Squared:  0.01108, Adjusted R-squared:  0.008768
## Wald test: 3.881 on 7 and 2992 DF,  p-value: 0.0003244

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_age < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_age < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.95194  0.05550  0.08235  0.09171  0.21068
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.859819   0.101831   8.444 <2e-16 ***
## xprimary_retention -0.088305   0.055573  -1.589  0.1123
## xman              -0.036206   0.015602  -2.321  0.0205 *
## xBULO              0.163037   0.065053   2.506  0.0123 *
## xleerkracht_age    0.018053   0.027384   0.659  0.5098
## xleerkracht_seniority -0.016047  0.024223  -0.662  0.5078
## xdirectie_age      0.011512   0.012851   0.896  0.3705
## xdirectie_seniority  0.003819   0.012929   0.295  0.7678
## GOKschool          0.002912   0.071257   0.041  0.9674
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1291   205.222 <2e-16 ***
## Wu-Hausman          1 1290    0.094   0.759
## Sargan              0   NA        NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2744 on 1291 degrees of freedom
## Multiple R-Squared:  0.01015, Adjusted R-squared:  0.004018
## Wald test: 4.175 on 8 and 1291 DF,  p-value: 6.026e-05

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_seniority < 5.5
              & leerkracht_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority < 5.5 & leerkracht_age < 4.5)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.08163  0.07402  0.10436  0.12339  0.26817
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.870039   0.102014   8.529  <2e-16 ***
## xprimary_retention -0.123683   0.052334  -2.363   0.0182 *
## xman            -0.021102   0.015688  -1.345   0.1788
## xBULO           0.125496   0.070429   1.782   0.0750 .
## xleerkracht_age  0.006340   0.034368   0.184   0.8537
## xleerkracht_seniority 0.019023   0.021456   0.887   0.3754
## xdirectie_age    0.009095   0.009952   0.914   0.3609
## xdirectie_seniority -0.024266   0.019209  -1.263   0.2067
## GOKschool       0.176895   0.068838   2.570   0.0103 *
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1441   294.564 <2e-16 ***
## Wu-Hausman          1 1440    7.319  0.0069 **
## Sargan              0  NA      NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2949 on 1441 degrees of freedom
## Multiple R-Squared:  -0.02383,    Adjusted R-squared:  -0.02951
## Wald test: 2.827 on 8 and 1441 DF,  p-value: 0.004093
```

In the second case we sample 62 students from every school (where 62 units is the size of the smallest school).

```
# Attaching the Sample and the Covariates
attach(sample_students)
x <- cbind(primary_retention , man , BULO,
            leerkracht_age , leerkracht_seniority,
            directie_age, directie_seniority
)
z <- as.matrix(eligible_dummy)
y <- as.matrix(certificate)
logit<-glm(eligible_dummy ~ GOKpercentage,
           data = sample_students, family = binomial(link = "logit"))
summary(logit)
pihat<-predict(logit, sample_students, type="response")
detach(sample_students)

# Running the BCF algorithm on the IV
set.seed(123)
bcf_fit <- bcf(y, z, x, x, pihat, nburn=2000, nsim=2000)
tau_post <- bcf_fit$tau
tauhat <- colMeans(tau_post)

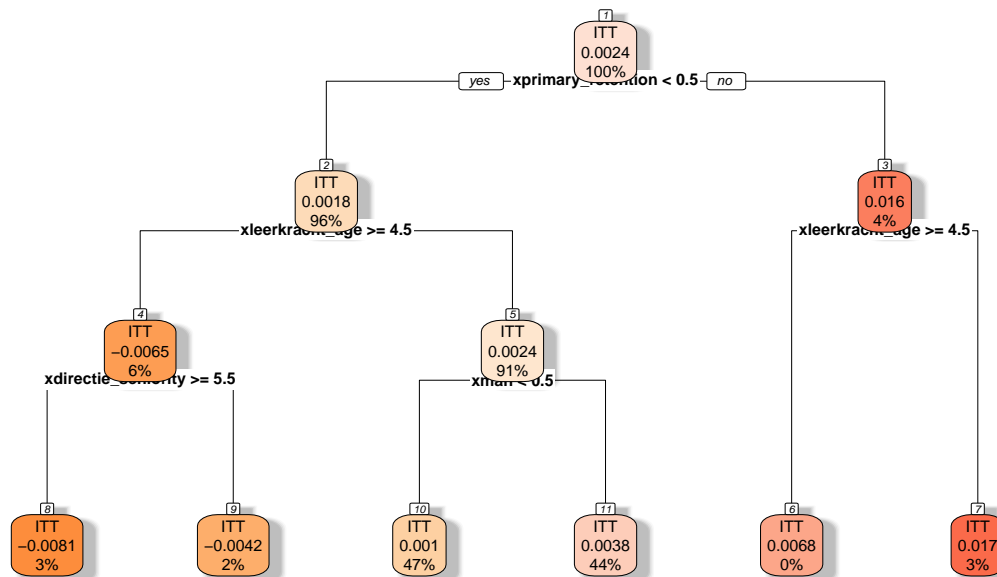
exp <- as.data.frame(cbind(tauhat, y, x, z))
```

As we can see from the plot the most important variables detected are the same: *teacher age* and *primary retention*.

```
## n= 5332
```

```
##
## node), split, n, deviance, yval
##      * denotes terminal node
##
## 1) root 5332 1.030680e-01  0.002373500
##    2) xprimary_retention< 0.5 5134 6.159266e-02  0.001842070
##      4) xleerkracht_age>=4.5 298 1.428775e-03 -0.006471185
##        8) xdirectie_seniority>=5.5 176 2.269976e-04 -0.008054058 *
##        9) xdirectie_seniority< 5.5 122 1.246648e-04 -0.004187697 *
##      5) xleerkracht_age< 4.5 4836 3.829997e-02  0.002354343
##        10) xman< 0.5 2506 1.786845e-02  0.001039199 *
##        11) xman>=0.5 2330 1.143535e-02  0.003768827 *
##    3) xprimary_retention>=0.5 198 2.429774e-03  0.016153090
##      6) xleerkracht_age>=4.5 12 1.138136e-05  0.006847326 *
##      7) xleerkracht_age< 4.5 186 1.312183e-03  0.016753460 *
```

BCF-IV First Stage



```
ITT = mean(sample_students$certificate[which(sample_students$eligible_dummy==1)]) - mean(sample_students$certificate[which(sample_students$eligible_dummy==0)])
ITT
```

```
## [1] 0.004510884
```

```
ITT = mean(students_data_randomized_03_2011$certificate[which(students_data_randomized_03_2011$eligible_dummy==1)]) - mean(students_data_randomized_03_2011$certificate[which(students_data_randomized_03_2011$eligible_dummy==0)])
ITT
```

```
## [1] 0.01134698
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students),
          vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.96645  0.06714  0.07105  0.09195  0.22746
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.828619   0.051265  16.163 < 2e-16 ***
## xprimary_retention -0.114774   0.028576  -4.016 5.99e-05 ***
## xman            -0.022850   0.007512  -3.042 0.00236 **
## xBULO             0.183079   0.036621   4.999 5.94e-07 ***
## xleerkracht_age   0.025882   0.013603   1.903 0.05714 .
## xleerkracht_seniority 0.002620   0.011818   0.222 0.82456
## xdirectie_age     0.003857   0.004980   0.774 0.43871
## xdirectie_seniority -0.005811   0.005915  -0.982 0.32594
## GOKschool         0.020797   0.033705   0.617 0.53724
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 5323   734.671 <2e-16 ***
## Wu-Hausman          1 5322     1.599  0.206
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2715 on 5323 degrees of freedom
## Multiple R-Squared: 0.007356, Adjusted R-squared: 0.005864
## Wald test: 12.86 on 8 and 5323 DF, p-value: < 2.2e-16

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = primary_retention < 0.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.96325  0.06616  0.06892  0.09288  0.11570
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.827704   0.051373  16.112 < 2e-16 ***
## xman            -0.025061   0.007495  -3.344 0.000833 ***
## xleerkracht_age   0.024466   0.013575   1.802 0.071567 .
## xleerkracht_seniority 0.003296   0.011820   0.279 0.780362
## xdirectie_age     0.002754   0.004997   0.551 0.581543
## xdirectie_seniority -0.003850   0.005930  -0.649 0.516180
## GOKschool         0.023290   0.033956   0.686 0.492813
##
```

```
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 5127    695.57 <2e-16 ***
## Wu-Hausman          1 5126      1.54   0.215
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2659 on 5127 degrees of freedom
## Multiple R-Squared:  0.001329,    Adjusted R-squared:  0.0001601
## Wald test: 2.705 on 6 and 5127 DF,  p-value: 0.01268

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = primary_retention >= 0.5),
         vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention >= 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.8681  0.1221  0.1698  0.2158  0.2844
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.692131   0.365136   1.896  0.0595 .
## xman           0.033686   0.056925   0.592  0.5547
## xBULO          0.206488   0.125182   1.649  0.1007
## xleerkracht_age  0.064494   0.094829   0.680  0.4973
## xleerkracht_seniority -0.008888  0.066866  -0.133  0.8944
## xdirectie_age    0.028118   0.033105   0.849  0.3967
## xdirectie_seniority -0.051551  0.037849  -1.362  0.1748
## GOKschool       -0.006835   0.204307  -0.033  0.9733
##
## Diagnostic tests:
##              df1 df2 statistic  p-value
## Weak instruments    1 190    39.474 2.22e-09 ***
## Wu-Hausman          1 189     0.085   0.772
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3944 on 190 degrees of freedom
## Multiple R-Squared:  0.01787, Adjusted R-squared: -0.01831
## Wald test:  5.68 on 7 and 190 DF,  p-value: 5.665e-06

#summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
#               subset = primary_retention < 0.5 & leerkracht_age >= 4.5),
#         vcov = sandwich, diagnostics = TRUE)
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = primary_retention < 0.5 & leerkracht_age < 4.5),
         vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.96889  0.06811  0.07000  0.09551  0.10764
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.9268324  0.0822907  11.263 < 2e-16 ***
## xman          -0.0268919  0.0078548  -3.424 0.000623 ***
## xleerkracht_age -0.0088074  0.0240459  -0.366 0.714176
## xleerkracht_seniority 0.0084156  0.0132701   0.634 0.525997
## xdirectie_age    0.0013794  0.0053372   0.258 0.796068
## xdirectie_seniority -0.0004329  0.0065595  -0.066 0.947384
## GOKschool       0.0351890  0.0331987   1.060 0.289220
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 4829   740.839 <2e-16 ***
## Wu-Hausman          1 4828     2.959  0.0855 .
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.27 on 4829 degrees of freedom
## Multiple R-Squared:  -0.0004453, Adjusted R-squared:  -0.001688
## Wald test:    2.4 on 6 and 4829 DF, p-value: 0.02565

#summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
#              subset = primary_retention >= 0.5 & leerkracht_age >= 4.5),
#              vcov = sandwich, diagnostics = TRUE)
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = primary_retention >= 0.5 & leerkracht_age < 4.5),
              vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention >= 0.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.85537  0.09838  0.17555  0.21965  0.33809
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.221208  0.602798   2.026  0.0443 *
## xman           0.019026  0.058484   0.325  0.7453
## xBULO          0.257316  0.133201   1.932  0.0550 .
## xleerkracht_age -0.071732  0.155486  -0.461  0.6451
## xleerkracht_seniority -0.004872  0.071670  -0.068  0.9459
## xdirectie_age    0.026299  0.032628   0.806  0.4213
```



```
## xdirectie_seniority    -0.048223    0.038244   -1.261    0.2090
## GOKschool             -0.073117    0.203074   -0.360    0.7192
##
## Diagnostic tests:
##               df1 df2 statistic  p-value
## Weak instruments      1 178      37.56 5.56e-09 ***
## Wu-Hausman            1 177       0.00   0.989
## Sargan                 0 NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3995 on 178 degrees of freedom
## Multiple R-Squared: 0.02161, Adjusted R-squared: -0.01686
## Wald test: 4.191 on 7 and 178 DF, p-value: 0.0002676

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = primary_retention < 0.5 & directie_seniority >= 5.5
               & leerkracht_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & directie_seniority >=
##       5.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.95684  0.04901  0.07499  0.07700  0.10301
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.122217   0.097886  11.465 < 2e-16 ***
## xman             -0.026015   0.009409  -2.765  0.00573 **
## xleerkracht_seniority -0.003842  0.020659  -0.186  0.85247
## xdirectie_age       0.002008  0.007208   0.279  0.78054
## xdirectie_seniority -0.027985  0.011710  -2.390  0.01691 *
## GOKschool          0.001635  0.045044   0.036  0.97104
##
## Diagnostic tests:
##               df1 df2 statistic p-value
## Weak instruments      1 3121    371.102 <2e-16 ***
## Wu-Hausman            1 3120     0.889   0.346
## Sargan                 0 NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2627 on 3121 degrees of freedom
## Multiple R-Squared: 0.004747, Adjusted R-squared: 0.003152
## Wald test: 3.624 on 5 and 3121 DF, p-value: 0.002851

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = primary_retention < 0.5 & directie_seniority < 5.5
               & leerkracht_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = primary_retention < 0.5 & directie_seniority < 5.5 &
##       leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.02105  0.07010  0.08569  0.11516  0.13216
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      8.981e-01  9.265e-02   9.694  <2e-16 ***
## xman             -2.964e-02  1.405e-02  -2.110   0.0350 *
## xleerkracht_age  -3.155e-03  3.034e-02  -0.104   0.9172
## xleerkracht_seniority 1.691e-02  1.885e-02   0.897   0.3697
## xdirectie_age      8.797e-05  8.732e-03   0.010   0.9920
## xdirectie_seniority -7.839e-03  1.684e-02  -0.465   0.6417
## GOKschool         1.066e-01  5.989e-02   1.779   0.0754 .
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments      1 1702   340.975 <2e-16 ***
## Wu-Hausman            1 1701     3.494  0.0618 .
## Sargan                0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2832 on 1702 degrees of freedom
## Multiple R-Squared:  -0.009766,   Adjusted R-squared:  -0.01333
## Wald test: 1.553 on 6 and 1702 DF,  p-value: 0.1571

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = leerkracht_age >= 3.5
              & leerkracht_age < 4.5
              & directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age >= 3.5 & leerkracht_age < 4.5 & directie_seniority <
##       5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.14981  0.06761  0.11809  0.13344  0.24428
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.9347140  0.0965239   9.684  < 2e-16 ***
## xprimary_retention -0.0923678  0.0472908  -1.953   0.05097 .
## xman             -0.0150113  0.0150609  -0.997   0.31906
## xBULO             0.0258112  0.0868474   0.297   0.76635
## xleerkracht_seniority 0.0184740  0.0192897   0.958   0.33835
```

```
## xdirectie_age          0.0006785  0.0086824  0.078  0.93772
## xdirectie_seniority    -0.0260867  0.0184389 -1.415  0.15733
## GOKschool             0.2675673  0.0950020  2.816  0.00492 **
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1604   191.333 <2e-16 ***
## Wu-Hausman         1 1603    7.864  0.0051 **
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3002 on 1604 degrees of freedom
## Multiple R-Squared:  -0.06259,    Adjusted R-squared:  -0.06723
## Wald test: 2.482 on 7 and 1604 DF,  p-value: 0.01551
```

From the help file for AER, it says it does an F-test on the first stage regression; I believe the nu

Let's see what happens when we rule out the dependency on "retention"

Teacher Age

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = leerkracht_age <= 4.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age <= 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.96474  0.06721  0.06991  0.09485  0.22421
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.938086   0.082169  11.417 < 2e-16 ***
## xprimary_retention -0.119101   0.029964  -3.975 7.14e-05 ***
## xman            -0.024996   0.007866  -3.178  0.00149 **
## xBULO           0.187940   0.038238   4.915 9.16e-07 ***
## xleerkracht_age -0.009581   0.023937  -0.400  0.68899
## xleerkracht_seniority 0.007690   0.013229   0.581  0.56109
## xdirectie_age     0.002699   0.005302   0.509  0.61071
## xdirectie_seniority -0.002761   0.006514  -0.424  0.67172
## GOKschool         0.029197   0.032916   0.887  0.37511
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 5013   783.329 <2e-16 ***
## Wu-Hausman         1 5012    2.683  0.102
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2756 on 5013 degrees of freedom
## Multiple R-Squared:  0.0063,    Adjusted R-squared:  0.004714
```

```
## Wald test: 10.81 on 8 and 5013 DF, p-value: 3.333e-15
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = leerkracht_age <= 4),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = leerkracht_age <= 4)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.96474  0.06721  0.06991  0.09485  0.22421
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.938086   0.082169  11.417 < 2e-16 ***
## xprimary_retention -0.119101   0.029964  -3.975 7.14e-05 ***
## xman              -0.024996   0.007866  -3.178 0.00149 **
## xBULO              0.187940   0.038238   4.915 9.16e-07 ***
## xleerkracht_age   -0.009581   0.023937  -0.400 0.68899
## xleerkracht_seniority 0.007690   0.013229   0.581 0.56109
## xdirectie_age      0.002699   0.005302   0.509 0.61071
## xdirectie_seniority -0.002761   0.006514  -0.424 0.67172
## GOKschool          0.029197   0.032916   0.887 0.37511
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 5013   783.329 <2e-16 ***
## Wu-Hausman          1 5012    2.683   0.102
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2756 on 5013 degrees of freedom
## Multiple R-Squared: 0.0063, Adjusted R-squared: 0.004714
## Wald test: 10.81 on 8 and 5013 DF, p-value: 3.333e-15
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_age >= 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_age >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.97653  0.06418  0.07431  0.09057  0.24444
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.768011   0.107288   7.158 9.79e-13 ***
```

```

## xprimary_retention    -0.136099    0.035769   -3.805 0.000144 ***
## xman                  -0.020416    0.008952   -2.281 0.022629 *
## xleerkracht_age       0.027094    0.019104    1.418 0.156194
## xleerkracht_seniority 0.019594    0.017158    1.142 0.253533
## xdirectie_age         0.005979    0.007303    0.819 0.413046
## xdirectie_seniority   -0.010131    0.008430   -1.202 0.229498
## GOKschool            0.025445    0.043524    0.585 0.558836
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 3712   475.927 <2e-16 ***
## Wu-Hausman         1 3711     1.438   0.231
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2716 on 3712 degrees of freedom
## Multiple R-Squared: 0.01009, Adjusted R-squared: 0.008223
## Wald test: 4.094 on 7 and 3712 DF, p-value: 0.0001736

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_age < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_age < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.95287  0.05569  0.07647  0.08984  0.20070
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.885386   0.091301   9.697 < 2e-16 ***
## xprimary_retention -0.064670   0.045790  -1.412  0.15805
## xman            -0.029342   0.013898  -2.111  0.03491 *
## xBULO           0.155266   0.053931   2.879  0.00404 **
## xleerkracht_age  0.021514   0.024547   0.876  0.38092
## xleerkracht_seniority -0.023495  0.021320  -1.102  0.27063
## xdirectie_age    0.004806   0.011175   0.430  0.66724
## xdirectie_seniority 0.008563   0.011398   0.751  0.45259
## GOKschool       -0.039610   0.062931  -0.629  0.52916
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1603   254.196 <2e-16 ***
## Wu-Hausman         1 1602     0.027   0.868
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.271 on 1603 degrees of freedom
## Multiple R-Squared: 0.007881, Adjusted R-squared: 0.00293

```

```
## Wald test: 8.925 on 8 and 1603 DF, p-value: 4.945e-12
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_seniority < 5.5
                & leerkracht_age < 4.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority < 5.5 & leerkracht_age < 4.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.02903  0.07117  0.09355  0.11331  0.22131
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.891500   0.093312   9.554  <2e-16 ***
## xprimary_retention -0.092144   0.043345  -2.126   0.0337 *
## xman              -0.022144   0.013968  -1.585   0.1131
## xBULO              0.116313   0.057046   2.039   0.0416 *
## xleerkracht_age    0.004257   0.030390   0.140   0.8886
## xleerkracht_seniority 0.013470   0.018561   0.726   0.4681
## xdirectie_age      0.002389   0.008667   0.276   0.7829
## xdirectie_seniority -0.013580   0.016592  -0.818   0.4132
## GOKschool          0.120197   0.059146   2.032   0.0423 *
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1789   365.500  <2e-16 ***
## Wu-Hausman          1 1788    5.347   0.0209 *
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2896 on 1789 degrees of freedom
## Multiple R-Squared:  -0.01235, Adjusted R-squared: -0.01688
## Wald test: 3.051 on 8 and 1789 DF, p-value: 0.002055
```

Second Outcome: School Progress

We now focus on the effects when we sample units in a bandwidth of 0.035 (which is the optimal bandwidth for the outcome *progress_school*) around the cutoff (10%).

```
students_data_randomized_03_2011 <-
  students_data_2011[which(students_data_2011$GOKpercentage >= .063
                        & students_data_2011$GOKpercentage <= .137),]
```

Moreover, from every school we sample a number students in order to increase the balance in the covariate and to guarantee an equal representation to all the schools, avoiding biases related to the over-representation of biggest schools' students. In the first case, we sample 50 students from each school.

```

schools <-
students_data_randomized_03_2011$school[which(
!duplicated(students_data_randomized_03_2011$school))]

sample_students <- as.data.frame(matrix(data = NA, nrow = 50*length(schools),
                                         ncol = ncol(students_data_randomized_03_2011)))
colnames(sample_students) <- colnames(students_data_randomized_03_2011)

for (j in (0:(length(schools)-1))){
  set.seed(j + 123)
  sample_students[(1+(j*50)):(50+(j*50)),] <-
  students_data_randomized_03_2011[which(
  students_data_randomized_03_2011$school %in%
  schools[j+1]),][sample(1:nrow(students_data_randomized_03_2011[which(
  students_data_randomized_03_2011$school %in% schools[j+1])),],
  50, replace = FALSE ),]
}

sample_student <- round(sample_students[, -(1:4)], 0)
sample_students <- cbind(sample_students[,1:4], sample_student)

```

Then we run our BCF-IV algorithm on this sample of units.

```

# Attaching the Sample and the Covariates
attach(sample_students)
x <- cbind(primary_retention , man , BULO,
           leerkracht_age , leerkracht_seniority,
           directie_age, directie_seniority
)
z <- as.matrix(eligible_dummy)
y <- as.matrix(progress_school)
logit<-glm(eligible_dummy ~ GOKpercentage,
           data = sample_students, family = binomial(link = "logit"))
summary(logit)
pihat<-predict(logit, sample_students, type="response")
detach(sample_students)

# Running the BCF algorithm on the IV
set.seed(123)
bcf_fit <- bcf(y, z, x, x, pihat, nburn=2000, nsim=2000)
tau_post <- bcf_fit$tau
tauhat <- colMeans(tau_post)

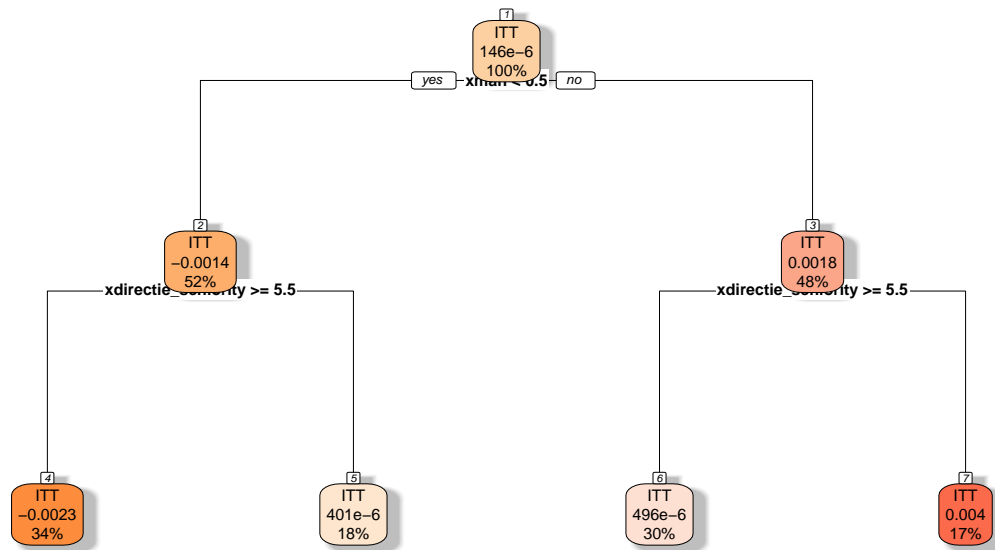
exp <- as.data.frame(cbind(tauhat, y, x, z))

## n= 4450
##
## node), split, n, deviance, yval
##      * denotes terminal node
##
## 1) root 4450 0.0258251000  0.0001457822
##    2) xman< 0.5 2317 0.0063970160 -0.0013556030
##      4) xdirectie_seniority>=5.5 1495 0.0006833538 -0.0023216590 *
##      5) xdirectie_seniority< 5.5 822 0.0017808740  0.0004013981 *
##    3) xman>=0.5 2133 0.0085317830  0.0017766820

```

```
##      6) xdirectie_seniority>=5.5 1355 0.0007275679 0.0004959880 *
##      7) xdirectie_seniority< 5.5 778 0.0017110760 0.0040071960 *
```

Causal Tree



```
ITT = mean(sample_students$progress_school[which(sample_students$eligible_dummy==1)]) - mean(sample_students$progress_school[which(sample_students$eligible_dummy==0)])
ITT
```

```
## [1] 0.001494949
```

```
ITT = mean(students_data_randomized_03_2011$progress_school[which(students_data_randomized_03_2011$eligible_dummy==1)]) - mean(students_data_randomized_03_2011$progress_school[which(students_data_randomized_03_2011$eligible_dummy==0)])
ITT
```

```
## [1] -0.001654283
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
```

```
## Call:
```

```
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students)
```

```
##
```

```
## Residuals:
```

```
##      Min      1Q   Median      3Q      Max
## -0.996598  0.008796  0.013402  0.017221  0.029630
```

```
##
```

```
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.961428   0.026799  35.875  <2e-16 ***
## xprimary_retention 0.006956   0.006454   1.078   0.2811
## xman          -0.008257   0.003514  -2.350   0.0188 *
```



```

## xBULO          0.009780    0.009426    1.037    0.2996
## xleerkracht_age    0.002255    0.007775    0.290    0.7718
## xleerkracht_seniority 0.005440    0.006161    0.883    0.3774
## xdirectie_age     -0.003652    0.002384   -1.532    0.1256
## xdirectie_seniority 0.003485    0.003227    1.080    0.2803
## GOKschool         0.001910    0.012471    0.153    0.8783
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 4441   847.466 <2e-16 ***
## Wu-Hausman          1 4440     0.234   0.629
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1153 on 4441 degrees of freedom
## Multiple R-Squared:  0.002509,    Adjusted R-squared:  0.000712
## Wald test: 2.836 on 8 and 4441 DF,  p-value: 0.00385

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man < 0.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.998958  0.004870  0.009273  0.012751  0.029864
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.005368   0.021699  46.332 < 2e-16 ***
## xprimary_retention 0.010430   0.002547   4.095 4.37e-05 ***
## xBULO          0.016214   0.011252   1.441  0.1497
## xleerkracht_age -0.015006   0.009583  -1.566  0.1175
## xleerkracht_seniority 0.017113   0.009413   1.818  0.0692 .
## xdirectie_age   -0.002202   0.002805  -0.785  0.4326
## xdirectie_seniority -0.001276   0.003781  -0.338  0.7358
## GOKschool       -0.007540   0.013197  -0.571  0.5678
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 2309   502.071 <2e-16 ***
## Wu-Hausman          1 2308     0.009   0.923
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09691 on 2309 degrees of freedom
## Multiple R-Squared:  0.004915,    Adjusted R-squared:  0.001899
## Wald test: 3.094 on 7 and 2309 DF,  p-value: 0.002998

```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.00779  0.01375  0.01661  0.02194  0.05103
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.885626   0.055958  15.826  <2e-16 ***
## xprimary_retention 0.002929   0.013562   0.216  0.8291
## xBULO          0.002617   0.016627   0.157  0.8750
## xleerkracht_age  0.025304   0.013802   1.833  0.0669 .
## xleerkracht_seniority -0.006980 0.008485  -0.823  0.4108
## xdirectie_age    -0.005992 0.004080  -1.469  0.1421
## xdirectie_seniority 0.009582 0.005534   1.732  0.0835 .
## GOKschool        0.017941  0.023201   0.773  0.4394
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 2125   348.383  <2e-16 ***
## Wu-Hausman          1 2124    0.569   0.451
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1324 on 2125 degrees of freedom
## Multiple R-Squared: 0.002227, Adjusted R-squared: -0.00106
## Wald test: 1.073 on 7 and 2125 DF, p-value: 0.3784
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man < 0.5 & directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5 & directie_seniority >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.990166 -0.002412  0.012797  0.012797  0.044397
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.128165   0.069747  16.175  < 2e-16 ***
## xprimary_retention 0.014315   0.004404   3.250  0.00118 **
## xBULO          0.023261   0.014364   1.619  0.10556
```

```
## xleerkracht_age      -0.028950    0.021747   -1.331  0.18333
## xleerkracht_seniority 0.020325    0.015180    1.339  0.18080
## xdirectie_age        0.002963    0.003967    0.747  0.45520
## xdirectie_seniority  -0.018172    0.007268   -2.501  0.01251 *
## GOKschool            -0.028636    0.017907   -1.599  0.11001
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1487   296.852 <2e-16 ***
## Wu-Hausman          1 1486     0.293   0.589
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09947 on 1487 degrees of freedom
## Multiple R-Squared:  0.009251,    Adjusted R-squared:  0.004587
## Wald test: 2.187 on 7 and 1487 DF,  p-value: 0.03286

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = man < 0.5 & directie_seniority < 5.5),
         vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5 & directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.996387  0.001192  0.003613  0.014034  0.037943
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.985647   0.017240  57.171 <2e-16 ***
## xprimary_retention 0.009305   0.003811   2.441  0.0148 *
## xBULO          0.001104   0.004288   0.258  0.7968
## xleerkracht_age -0.015264   0.008646  -1.765  0.0779 .
## xleerkracht_seniority 0.019462   0.012969   1.501  0.1338
## xdirectie_age    -0.007434   0.004094  -1.816  0.0698 .
## xdirectie_seniority 0.006224   0.009018   0.690  0.4903
## GOKschool        0.005231   0.014698   0.356  0.7220
##
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 814   163.3 <2e-16 ***
## Wu-Hausman          1 813     0.3   0.584
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09164 on 814 degrees of freedom
## Multiple R-Squared:  0.015,    Adjusted R-squared:  0.006526
## Wald test: 1.026 on 7 and 814 DF,  p-value: 0.4109
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5 & directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5 & directie_seniority >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.99228  0.01280  0.01542  0.01738  0.04547
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.958873   0.081266  11.799 < 2e-16 ***
## xprimary_retention 0.017278   0.004179   4.135 3.78e-05 ***
## xBULO             0.017376   0.005288   3.286 0.00104 **
## xleerkracht_age    0.027486   0.010792   2.547 0.01098 *
## xleerkracht_seniority -0.018130 0.005573  -3.253 0.00117 **
## xdirectie_age      -0.007699   0.005575  -1.381 0.16752
## xdirectie_seniority  0.005746   0.008949   0.642 0.52096
## GOKschool          -0.014653   0.032154  -0.456 0.64866
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1347    167.34 <2e-16 ***
## Wu-Hausman          1 1346     0.12  0.729
## Sargan              0  NA      NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1265 on 1347 degrees of freedom
## Multiple R-Squared: 0.003894, Adjusted R-squared: -0.001282
## Wald test: 3.209 on 7 and 1347 DF, p-value: 0.002239
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5 & directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5 & directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.00474  0.01010  0.01930  0.02806  0.06176
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.838956   0.091351   9.184 <2e-16 ***
## xprimary_retention -0.015026   0.033489  -0.449  0.654
## xBULO             0.012681   0.057039   0.222  0.824
```

```
## xleerkracht_age      0.005631    0.027005    0.209    0.835
## xleerkracht_seniority 0.009208    0.013236    0.696    0.487
## xdirectie_age        -0.006455    0.006439   -1.002    0.316
## xdirectie_seniority   0.024773    0.015617    1.586    0.113
## GOKschool            0.015196    0.038595    0.394    0.694
##
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 770   152.159 <2e-16 ***
## Wu-Hausman          1 769    0.154   0.695
## Sargan              0 NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1419 on 770 degrees of freedom
## Multiple R-Squared:  0.01035, Adjusted R-squared:  0.001356
## Wald test:  2.36 on 7 and 770 DF,  p-value: 0.02171
```

From the help file for AER, it says it does an F-test on the first stage regression; I believe the nu

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.99599  0.00835  0.01117  0.01857  0.03952
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.0510029   0.0534439   19.666 < 2e-16 ***
## xprimary_retention  0.0152511   0.0029613    5.150 2.78e-07 ***
## xman            -0.0073966   0.0043595   -1.697  0.08987 .
## xBULO           0.0229080   0.0077260    2.965  0.00305 **
## xleerkracht_age  -0.0012778   0.0124648   -0.103  0.91836
## xleerkracht_seniority 0.0004941   0.0077217    0.064  0.94898
## xdirectie_age    -0.0017816   0.0033494   -0.532  0.59482
## xdirectie_seniority -0.0066522   0.0057704   -1.153  0.24908
## GOKschool        -0.0227343   0.0167930   -1.354  0.17591
##
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 2841   462.554 <2e-16 ***
## Wu-Hausman          1 2840    0.394   0.53
## Sargan              0 NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1132 on 2841 degrees of freedom
## Multiple R-Squared:  0.002901, Adjusted R-squared: 9.342e-05
```

```
## Wald test: 4.031 on 8 and 2841 DF, p-value: 8.924e-05
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.999437  0.002451  0.013426  0.022301  0.042140
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.929891   0.036735  25.313  <2e-16 ***
## xprimary_retention -0.002286   0.016106  -0.142   0.8871
## xman              -0.012073   0.006130  -1.969   0.0491 *
## xBULO              0.008164   0.024696   0.331   0.7410
## xleerkracht_age   -0.007395   0.010517  -0.703   0.4821
## xleerkracht_seniority 0.014382   0.008540   1.684   0.0924 .
## xdirectie_age     -0.006432   0.003538  -1.818   0.0692 .
## xdirectie_seniority 0.014752   0.008808   1.675   0.0942 .
## GOKschool         0.008671   0.018133   0.478   0.6326
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1591   331.187  <2e-16 ***
## Wu-Hausman          1 1590    0.016    0.9
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1188 on 1591 degrees of freedom
## Multiple R-Squared: 0.009721, Adjusted R-squared: 0.004742
## Wald test: 1.608 on 8 and 1591 DF, p-value: 0.1175
```

In the second case we sample 62 students from every school (where 62 units is the size of the smallest school).

```
# Attaching the Sample and the Covariates
attach(sample_students)
x <- cbind(primary_retention , man , BULO,
           leerkracht_age , leerkracht_seniority,
           directie_age, directie_seniority
)
z <- as.matrix(eligible_dummy)
y <- as.matrix(progress_school)
logit<-glm(eligible_dummy ~ GOKpercentage,
           data = sample_students, family = binomial(link = "logit"))
summary(logit)
pihat<-predict(logit, sample_students, type="response")
detach(sample_students)

# Running the BCF algorithm on the IV
```

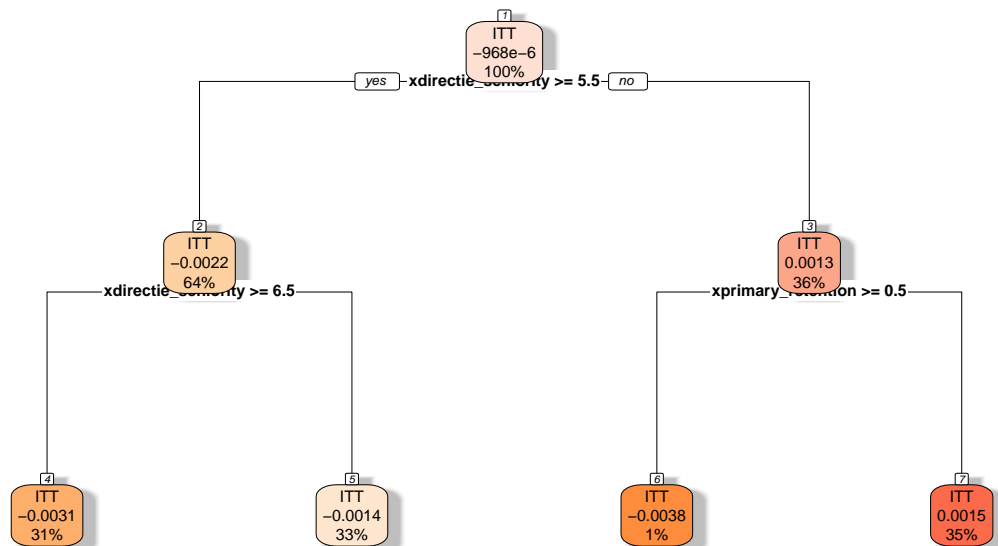
```

set.seed(123)
bcf_fit <- bcf(y, z, x, x, pihat, nburn=2000, nsim=2000)
tau_post <- bcf_fit$tau
tauhat <- colMeans(tau_post)

exp <- as.data.frame(cbind(tauhat, y, x, z))

```

Causal Tree



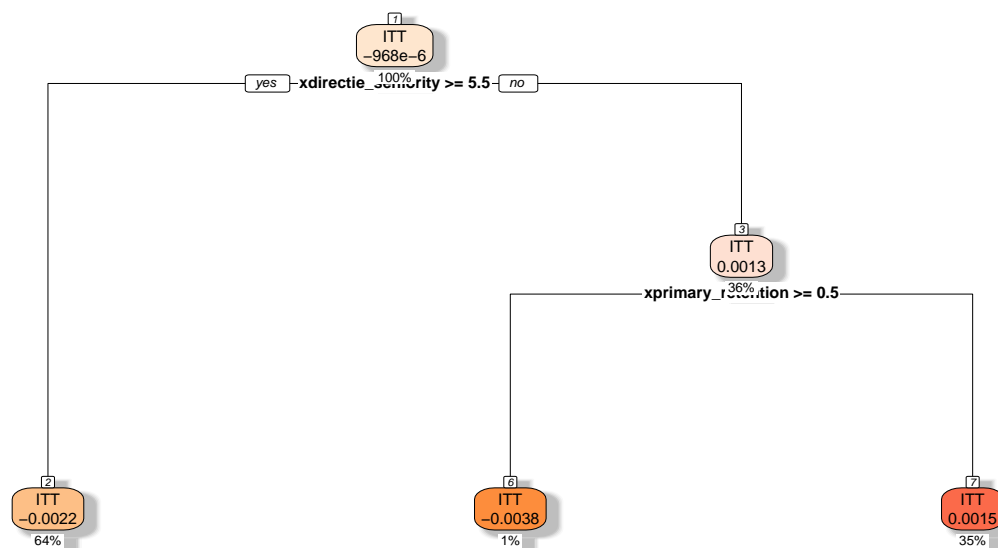
We can further trim the tree.

```

temp <- snip.rpart(fitted.tree, 2)
rpart.plot(temp, cex=0.5, box.palette="OrRd", branch.lty=1, under = TRUE,
  shadow.col="gray", nn=TRUE, main="Causal Tree", prefix="ITT\n")

```

Causal Tree



Let's now see if the heterogeneous effects are robust:

```
ITT = mean(sample_students$progress_school[which(sample_students$eligible_dummy==1)]) - mean(sample_students$progress_school[which(sample_students$eligible_dummy==0)])
ITT
```

```
## [1] -0.001735093
```

```
ITT = mean(students_data_randomized_03_2011$progress_school[which(students_data_randomized_03_2011$eligible_dummy==1)]) - mean(students_data_randomized_03_2011$progress_school[which(students_data_randomized_03_2011$eligible_dummy==0)])
ITT
```

```
## [1] -0.001654283
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students),
          vcov = sandwich, diagnostics = TRUE)
```

```
##
```

```
## Call:
```

```
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students)
```

```
##
```

```
## Residuals:
```

```
##      Min      1Q   Median      3Q      Max
## -0.996760  0.007166  0.013351  0.015120  0.038743
```

```
##
```

```
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.975971   0.021953  44.456   <2e-16 ***
## xprimary_retention -0.008629   0.010452  -0.826   0.4090
## xman           -0.007143   0.003059  -2.335   0.0196 *
## xBULO           0.022654   0.010624   2.132   0.0330 *
```



```
## xleerkracht_age      0.002345    0.006300    0.372    0.7098
## xleerkracht_seniority 0.002291    0.005051    0.454    0.6502
## xdirectie_age        -0.003925    0.002172   -1.807    0.0708 .
## xdirectie_seniority   0.003686    0.002907    1.268    0.2049
## GOKschool            -0.008194    0.010850   -0.755    0.4501
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 5509 1050.848 <2e-16 ***
## Wu-Hausman          1 5508    0.001    0.974
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1118 on 5509 degrees of freedom
## Multiple R-Squared:  0.002906,    Adjusted R-squared:  0.001458
## Wald test: 3.169 on 8 and 5509 DF,  p-value: 0.001377

summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man < 0.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.997309  0.005092  0.007049  0.013809  0.046212
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.008735    0.018423  54.754 <2e-16 ***
## xprimary_retention -0.019211    0.016335  -1.176  0.2397
## xBULO           0.031943    0.015606   2.047  0.0408 *
## xleerkracht_age  -0.010584    0.007760  -1.364  0.1727
## xleerkracht_seniority 0.010064    0.007632   1.319  0.1874
## xdirectie_age    -0.004359    0.002670  -1.633  0.1026
## xdirectie_seniority 0.002401    0.003501   0.686  0.4929
## GOKschool        -0.013192    0.011905  -1.108  0.2679
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 2876   607.219 <2e-16 ***
## Wu-Hausman          1 2875    0.226    0.634
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0962 on 2876 degrees of freedom
## Multiple R-Squared:  0.004858,    Adjusted R-squared:  0.002435
## Wald test: 1.288 on 7 and 2876 DF,  p-value: 0.2518
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5)
##
## Residuals:
##      Min      1Q  Median      3Q      Max
## -0.99448  0.01431  0.01623  0.01816  0.03633
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    9.227e-01  4.502e-02  20.496  <2e-16 ***
## xprimary_retention  3.963e-03  1.170e-02   0.339  0.7348
## xBULO           7.864e-03  1.594e-02   0.493  0.6218
## xleerkracht_age   1.853e-02  1.104e-02   1.678  0.0934 .
## xleerkracht_seniority -5.910e-03  6.931e-03  -0.853  0.3939
## xdirectie_age     -3.830e-03  3.580e-03  -1.070  0.2848
## xdirectie_seniority  5.570e-03  4.869e-03   1.144  0.2527
## GOKschool        -2.679e-05  1.949e-02  -0.001  0.9989
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 2626   447.171  <2e-16 ***
## Wu-Hausman          1 2625    0.144   0.704
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1268 on 2626 degrees of freedom
## Multiple R-Squared: 0.002136, Adjusted R-squared: -0.0005241
## Wald test: 2.977 on 7 and 2626 DF, p-value: 0.004119
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man < 0.5 & directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5 & directie_seniority >= 5.5)
##
## Residuals:
##      Min      1Q  Median      3Q      Max
## -1.003234 -0.001514  0.009861  0.009861  0.038757
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.096166  0.054273  20.197  < 2e-16 ***
## xprimary_retention  0.011932  0.003576   3.336 0.000866 ***
## xBULO           0.023942  0.012749   1.878 0.060540 .
```

```

## xleerkracht_age      -0.021638    0.016850   -1.284 0.199240
## xleerkracht_seniority 0.015038    0.011941    1.259 0.208055
## xdirectie_age        0.001720    0.003335    0.516 0.606090
## xdirectie_seniority  -0.013096    0.005997   -2.184 0.029116 *
## GOKschool            -0.027176    0.015151   -1.794 0.073033 .
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1846   354.586 <2e-16 ***
## Wu-Hausman         1 1845     0.783   0.376
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09248 on 1846 degrees of freedom
## Multiple R-Squared: 0.00468, Adjusted R-squared: 0.0009062
## Wald test: 2.318 on 7 and 1846 DF, p-value: 0.02352
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = man < 0.5 & directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man < 0.5 & directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.994308  0.001066  0.005692  0.015361  0.089013
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.011031   0.020566  49.161 <2e-16 ***
## xprimary_retention -0.063982   0.039596  -1.616  0.1064
## xBULO           0.065969   0.043338   1.522  0.1283
## xleerkracht_age  -0.005991   0.008226  -0.728  0.4666
## xleerkracht_seniority 0.007560   0.011086   0.682  0.4954
## xdirectie_age    -0.009669   0.004205  -2.300  0.0217 *
## xdirectie_seniority 0.005069   0.008677   0.584  0.5592
## GOKschool        0.001596   0.022538   0.071  0.9436
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1022   206.543 <2e-16 ***
## Wu-Hausman         1 1021     0.004   0.949
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1019 on 1022 degrees of freedom
## Multiple R-Squared: 0.02577, Adjusted R-squared: 0.01909
## Wald test: 1.641 on 7 and 1022 DF, p-value: 0.1201

```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5 & directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5 & directie_seniority >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.99200  0.01068  0.01346  0.01615  0.05109
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.997032   0.071074  14.028 < 2e-16 ***
## xprimary_retention 0.016954   0.003907   4.340 1.51e-05 ***
## xBULO          0.016150   0.004500   3.589 0.000341 ***
## xleerkracht_age  0.018586   0.009352   1.987 0.047046 *
## xleerkracht_seniority -0.012317 0.004823  -2.554 0.010748 *
## xdirectie_age    -0.002686   0.004923  -0.546 0.585339
## xdirectie_seniority -0.002779 0.008476  -0.328 0.743027
## GOKschool       -0.035038   0.028229  -1.241 0.214717
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1672   222.360 <2e-16 ***
## Wu-Hausman          1 1671    0.732   0.392
## Sargan              0  NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1237 on 1672 degrees of freedom
## Multiple R-Squared: 0.001123, Adjusted R-squared: -0.003059
## Wald test: 3.779 on 7 and 1672 DF, p-value: 0.0004481
```

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = man > 0.5 & directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = man > 0.5 & directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.001279  0.007727  0.015487  0.027381  0.051308
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.884159   0.070077  12.617 <2e-16 ***
## xprimary_retention -0.014745   0.029454  -0.501 0.6168
## xBULO          0.018426   0.047036   0.392 0.6953
```

```
## xleerkracht_age      0.002625    0.020652    0.127    0.8989
## xleerkracht_seniority 0.006382    0.010725    0.595    0.5520
## xdirectie_age        -0.006658    0.005366   -1.241    0.2150
## xdirectie_seniority   0.021076    0.012638    1.668    0.0957 .
## GOKschool            0.003770    0.031750    0.119    0.9055
##
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 946   191.414 <2e-16 ***
## Wu-Hausman          1 945     0.096   0.756
## Sargan               0 NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1323 on 946 degrees of freedom
## Multiple R-Squared:  0.007944,    Adjusted R-squared:  0.000603
## Wald test: 2.493 on 7 and 946 DF,  p-value: 0.01533
```

From the help file for AER, it says it does an F-test on the first stage regression; I believe the nu

```
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
               subset = directie_seniority >= 5.5),
        vcov = sandwich, diagnostics = TRUE)
```

```
##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority >= 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.999463  0.008285  0.008855  0.016950  0.047566
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.056704   0.044806  23.584 < 2e-16 ***
## xprimary_retention 0.014335   0.002681   5.347 9.5e-08 ***
## xman           -0.008095   0.003765  -2.150 0.03162 *
## xBULO           0.024139   0.008062   2.994 0.00277 **
## xleerkracht_age -0.002774   0.010114  -0.274 0.78390
## xleerkracht_seniority 0.001245   0.006272   0.199 0.84266
## xdirectie_age   -0.000174   0.002913  -0.060 0.95239
## xdirectie_seniority -0.008318   0.005195  -1.601 0.10944
## GOKschool       -0.030790   0.014710  -2.093 0.03640 *
##
## Diagnostic tests:
##              df1 df2 statistic p-value
## Weak instruments    1 3525   575.698 <2e-16 ***
## Wu-Hausman          1 3524     1.599   0.206
## Sargan               0 NA         NA      NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1084 on 3525 degrees of freedom
## Multiple R-Squared:  0.001862,    Adjusted R-squared: -0.0004037
```

```
## Wald test: 4.032 on 8 and 3525 DF, p-value: 8.807e-05
summary(ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
              subset = directie_seniority < 5.5),
        vcov = sandwich, diagnostics = TRUE)

##
## Call:
## ivreg(formula = y ~ x + GOKschool | x + z, data = sample_students,
##       subset = directie_seniority < 5.5)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.996927  0.003073  0.010150  0.019376  0.070756
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      0.957861   0.030754  31.146 <2e-16 ***
## xprimary_retention -0.042220   0.026075  -1.619  0.1056
## xman              -0.007077   0.005373  -1.317  0.1879
## xBULO              0.046501   0.031534   1.475  0.1405
## xleerkracht_age   -0.002538   0.009059  -0.280  0.7794
## xleerkracht_seniority 0.006579   0.007251   0.907  0.3643
## xdirectie_age     -0.008152   0.003263  -2.498  0.0126 *
## xdirectie_seniority 0.012732   0.007548   1.687  0.0918 .
## GOKschool         0.001938   0.018302   0.106  0.9157
##
## Diagnostic tests:
##              df1  df2 statistic p-value
## Weak instruments    1 1975   409.687 <2e-16 ***
## Wu-Hausman          1 1974    0.063   0.802
## Sargan              0  NA         NA     NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1176 on 1975 degrees of freedom
## Multiple R-Squared: 0.01064, Adjusted R-squared: 0.006632
## Wald test: 2.608 on 8 and 1975 DF, p-value: 0.007743
```