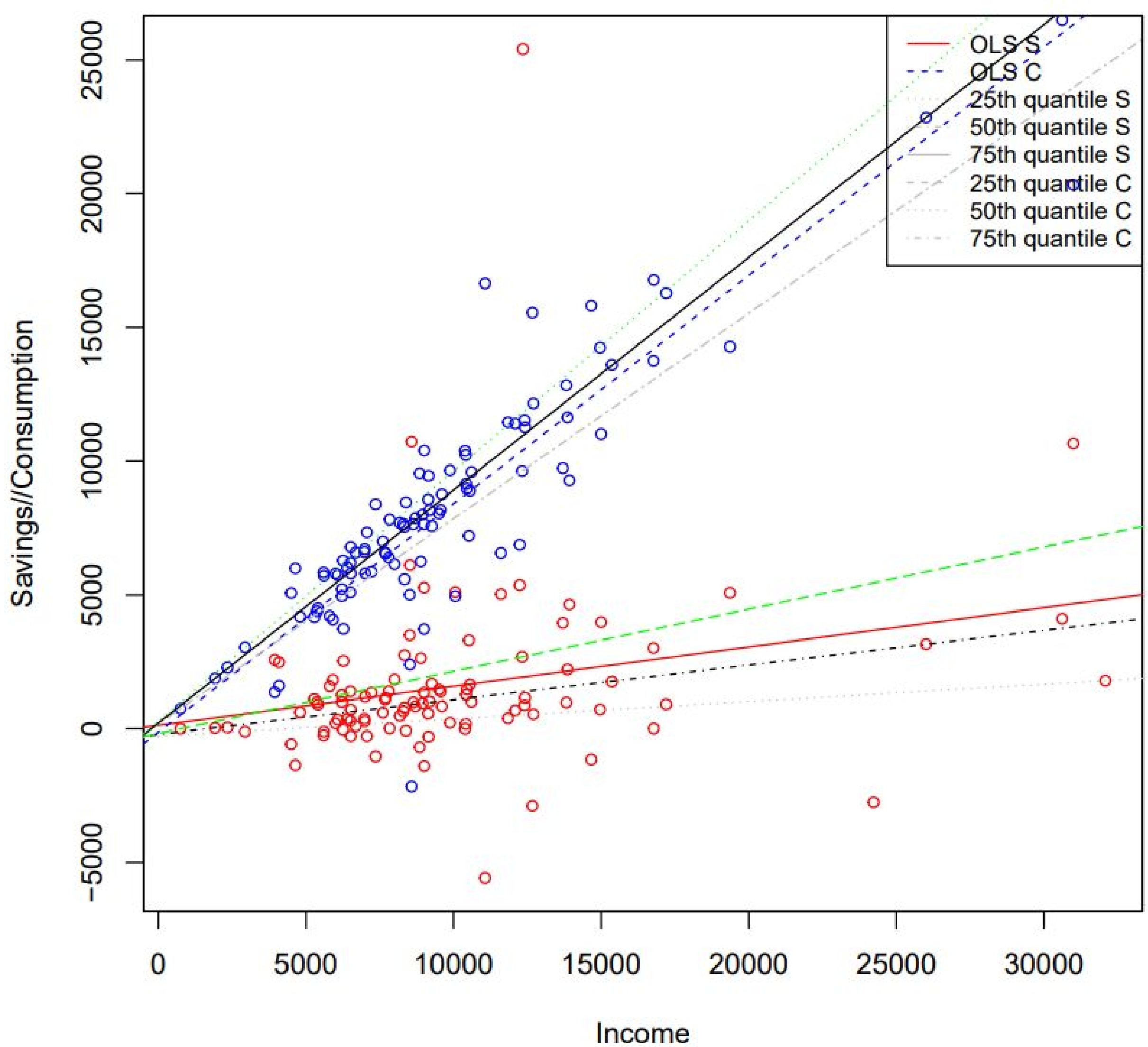
1.

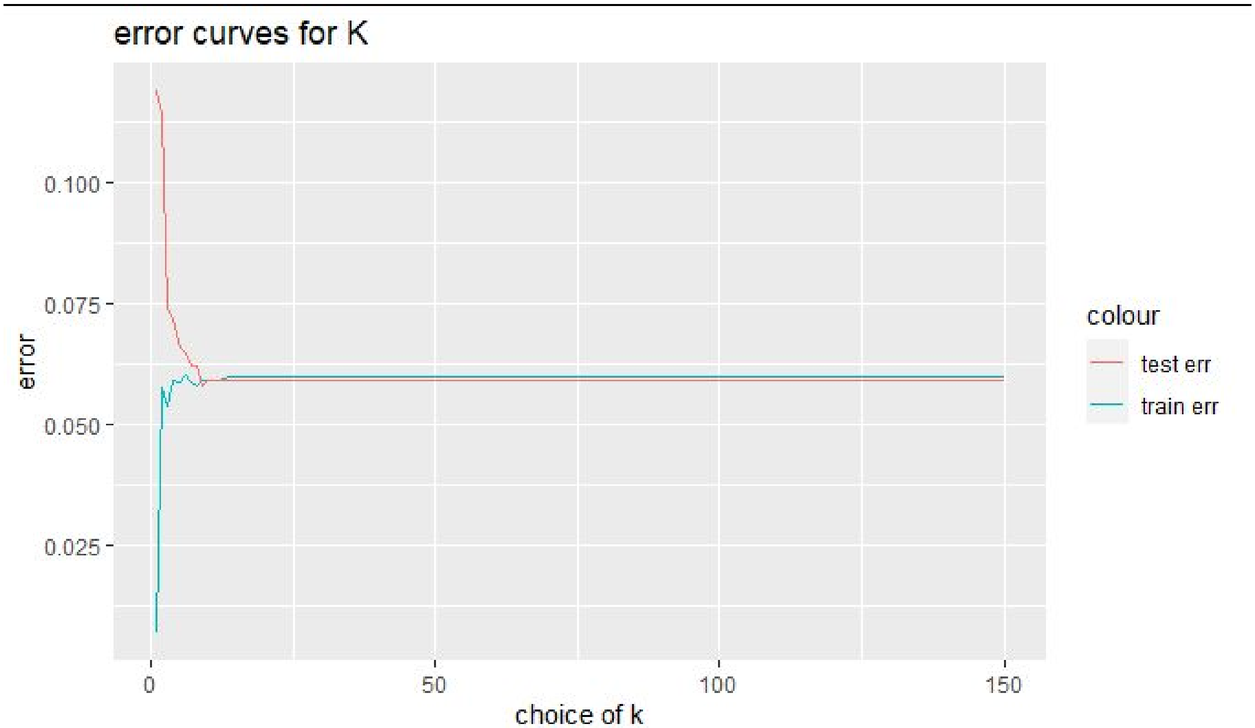



```
qfit_p25_S <- rq(sav~inc,data=saving,tau=0.25) # 25th percentile (0.25 quantile)
qfit_p50_S <- rq(sav~inc,data=saving,tau=0.5) # 50th percentile (0.5 quantile)
qfit_p75_S <- rq(sav~inc,data=saving,tau=0.75) # 75th percentile (0.75 quantile)
qfit_p25_C <- rq(cons~inc,data=saving,tau=0.25) # 25th percentile (0.25 quantile)
qfit_p50_C <- rq(cons~inc,data=saving,tau=0.5) # 50th percentile (0.5 quantile)
qfit_p75_C <- rq(cons~inc,data=saving,tau=0.75) # 75th percentile (0.75 quantile)
ols_fit1 <- lm(sav~inc,data=saving)
ols_fit2 <- lm(cons~inc,data=saving)
```

2.

```
> registerDoParallel(cores=6)
> #1
> star <- read.csv("star.csv")
> colnames(star)
 [1] "y"    "w"    "aide" "exp"  "fem"  "wh"   "fl"   "lad"  "deg"  "age"  "urb"
> attach(star)
>
> B<-500 # total number of iterations in bootstrap
> N<-nrow(star) # number of observations for the imported data
> taus<-seq(0.1,0.95, by=.05) # specifying which quantiles
> ntaus<-length(taus)
>
> bootCI<-matrix(0,nrow=ntaus,ncol=2) # creating empty matrix for storing bootstrapped C.I.'s
> bootSE<-matrix(0,nrow=ntaus,ncol=1) # empty vector for storing bootstrapped s.e.'s
>
> for(i in 1:ntaus){
+   t<-taus[i]
+   # Bootstrapping empirical distribution using a parallel for loop
+   bootDistribution<-foreach(b=1:B,.combine = rbind) %dopar% {
+     set.seed(b)
+     indices<-sample(N,N,replace = TRUE)
+     fit<-rq(y[indices]~w[indices]+fem[indices]+wh[indices]+fl[indices]+exp[indices]+lad[indices]+deg[indices]+urb[indice
au=t)
+     fit$coefficients[2] # here, only interested in 1st indep var. (which is 2nd after the intercept term)
+   }
+
+   alpha<-0.05 # alpha = significance level = 1 - confidence level
+
+   # Saving bootstrapped estimates
+   bootCI[i,]<-colQuantiles(bootDistribution,probs=c(alpha/2,(1-alpha/2)))
+   bootSE[i,]<-colSds(bootDistribution)
+ }
```

3.



which.min(test_err) #k=9

4.

```
> y<-as.matrix(growth)[,1] # outcome (response) variable
> d<-as.matrix(growth)[,2] # treatment indicator
> X<-as.matrix(growth)[,3:62] # covariates (features)
>
> set.seed(1)
> k = 5
> # Step 1: Lasso of y on X to select the controls that best predict y.
> y.fit<-cv.glmnet(X,y,family="gaussian", type.measure = "mse", nfolds = k)
> y.betas<-as.numeric(coef(y.fit,s = "lambda.min"))
> y.nonzeroindices<-which(y.betas[-1]!=0) # note: excluding 1st index, where the
>
> # Step 2: Lasso of d on X to select the controls that best predict y.
> d.fit<-cv.glmnet(X,d,family="gaussian", type.measure = "mse", nfolds = k)
> d.betas<-as.numeric(coef(d.fit,s = "lambda.min"))
> d.nonzeroindices<-which(d.betas[-1]!=0) # note: excluding 1st index, where the
>
> # Step 3: OLS of y on d and the unions of controls selected in steps 1 and 2.
> nonzeroindices<-union(y.nonzeroindices,d.nonzeroindices)
> X.selected<-X[,nonzeroindices]
> OLSfit.postLasso<-lm(y ~ d + X.selected)
> OLSfit.preLasso<-lm(y ~ d + X)
>
```

5.

```
> dim(Z_selected)
[1] 329509     91
```

```
> post_lasso_twosls <-ivreg(logwage ~ X+edu | X + Z_selected, data= ak1991
> summary(post_lasso_twosls)

Call:
ivreg(formula = logwage ~ X + edu | X + Z_selected, data = ak1991)

Residuals:
     Min       1Q   Median       3Q      Max 
-8.98801 -0.23481  0.05801  0.32753  4.70920 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)   4.465283   0.112077  39.841  < 2e-16 ***
Xmarried      0.240856   0.003959  60.834  < 2e-16 ***
Xblack       -0.206999   0.012653 -16.360  < 2e-16 ***
Xurban        0.162634   0.010651  15.270  < 2e-16 ***
XX_Iyob_1931 -0.007204   0.005164  -1.395 0.162970    
XX_Iyob_1932 -0.012964   0.005373  -2.413 0.015828 *  
XX_Iyob_1933 -0.014374   0.005736  -2.506 0.012217 *  
XX_Iyob_1934 -0.017828   0.005934  -3.005 0.002660 ** 
XX_Iyob_1935 -0.029101   0.006358  -4.577 4.72e-06 ***
XX_Iyob_1936 -0.029773   0.006632  -4.489 7.16e-06 ***
XX_Iyob_1937 -0.034891   0.007079  -4.929 8.28e-07 ***
XX_Iyob_1938 -0.036440   0.007705  -4.729 2.25e-06 ***
XX_Iyob_1939 -0.046287   0.008073  -5.734 9.82e-09 ***
XX_Istate_2   0.200942   0.072958   2.754 0.005884 ** 
XX_Istate_4   0.069344   0.023363   2.968 0.002997 ** 
XX_Istate_5   0.027691   0.010697   2.589 0.009638 ** 
XX_Istate_6   0.071009   0.020239   3.509 0.000451 ***
XX_Istate_8   0.030867   0.019045   1.621 0.105067    
XX_Istate_9   0.027449   0.017083   1.607 0.108090    
XX_Istate_10  0.059361   0.026880   2.208 0.027222 *  
XX_Istate_11  0.099505   0.027772   3.583 0.000340 ***
XX_Istate_12 -0.038414   0.014744  -2.605 0.009176 ** 
XX_Istate_13 -0.020175   0.009951  -2.028 0.042610 *  
XX_Istate_15  0.075579   0.042338   1.785 0.074243 .  
XX_Istate_16  0.040216   0.024612   1.634 0.102264    
XX_Istate_17  0.114781   0.015865   7.235 4.67e-13 ***
XX_Istate_18  0.073602   0.012310   5.979 2.25e-09 ***
XX_Istate_19  0.023825   0.016093   1.481 0.138740    
```

```
XX_Istate_20 -0.001230   0.019748  -0.062 0.950325
XX_Istate_21  0.073867   0.011724   6.301 2.97e-10 ***
XX_Istate_22  0.090576   0.011264   8.041 8.94e-16 ***
XX_Istate_23 -0.073093   0.014968  -4.883 1.04e-06 ***
XX_Istate_24  0.063840   0.012850   4.968 6.77e-07 ***
XX_Istate_25  0.002344   0.016682   0.140 0.888275
XX_Istate_26  0.137119   0.013000  10.548  < 2e-16 ***
XX_Istate_27  0.058387   0.015650   3.731 0.000191 ***
XX_Istate_28  0.032920   0.010640   3.094 0.001975 **
XX_Istate_29  0.043834   0.012108   3.620 0.000294 ***
XX_Istate_30  0.018018   0.024008   0.750 0.452962
XX_Istate_31  0.015829   0.019481   0.813 0.416492
XX_Istate_32  0.071304   0.039334   1.813 0.069867 .
XX_Istate_33 -0.039748   0.020555  -1.934 0.053144 .
XX_Istate_34  0.070248   0.016804   4.180 2.91e-05 ***
XX_Istate_35  0.008959   0.019730   0.454 0.649768
XX_Istate_36  0.053255   0.018236   2.920 0.003497 **
XX_Istate_37 -0.058075   0.009067  -6.405 1.50e-10 ***
XX_Istate_38  0.048164   0.018323   2.629 0.008574 **
XX_Istate_39  0.079283   0.012594   6.295 3.07e-10 ***
XX_Istate_40  0.017067   0.014903   1.145 0.252122
XX_Istate_41  0.055402   0.022911   2.418 0.015600 *
XX_Istate_42  0.044748   0.011340   3.946 7.95e-05 ***
XX_Istate_44 -0.058992   0.018358  -3.213 0.001312 **
XX_Istate_45 -0.042067   0.011327  -3.714 0.000204 ***
XX_Istate_46  0.011989   0.021459   0.559 0.576361
XX_Istate_47  0.019239   0.010251   1.877 0.060545 .
XX_Istate_48  0.019020   0.011046   1.722 0.085083 .
XX_Istate_49  0.024438   0.024916   0.981 0.326698
XX_Istate_50 -0.089237   0.021600  -4.131 3.61e-05 ***
XX_Istate_51  0.030689   0.010348   2.966 0.003021 **
XX_Istate_53  0.096471   0.020910   4.614 3.96e-06 ***
XX_Istate_54  0.072876   0.010514   6.931 4.17e-12 ***
XX_Istate_55  0.044197   0.013735   3.218 0.001291 **
XX_Istate_56  0.064617   0.030005   2.154 0.031277 *
edu           0.085447   0.010434   8.190 2.63e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6255 on 329445 degrees of freedom
Multiple R-Squared: 0.1511,     Adjusted R-squared: 0.1509
Wald test: 482.2 on 63 and 329445 DF,  p-value: < 2.2e-16
```

```
> twosls <-ivreg(logwage ~X +edu | X +Z, data=ak1991)
> summary(twosls)

Call:
ivreg(formula = logwage ~ X + edu | X + Z, data = ak1991)

Residuals:
     Min       1Q   Median       3Q      Max 
-8.97520 -0.23354  0.05801  0.32653  4.69866 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)   4.487575   0.104245  43.048  < 2e-16 ***
Xmarried      0.241323   0.003861  62.505  < 2e-16 ***
Xblack       -0.209371   0.011869 -17.641  < 2e-16 ***
Xurban        0.164680   0.009957  16.539  < 2e-16 ***
XX_Iyob_1931 -0.006907   0.005129  -1.347 0.178091    
XX_Iyob_1932 -0.012515   0.005303  -2.360 0.018283 *  
XX_Iyob_1933 -0.013791   0.005629  -2.450 0.014292 *  
XX_Iyob_1934 -0.017158   0.005798  -2.959 0.003087 ** 
XX_Iyob_1935 -0.028283   0.006171  -4.583 4.59e-06 ***
XX_Iyob_1936 -0.028873   0.006416  -4.500 6.81e-06 ***
XX_Iyob_1937 -0.033856   0.006812  -4.970 6.70e-07 ***
XX_Iyob_1938 -0.035234   0.007373  -4.779 1.76e-06 ***
XX_Iyob_1939 -0.044986   0.007703  -5.840 5.23e-09 ***
XX_Istate_2   0.204157   0.072635   2.811 0.004943 ** 
XX_Istate_4   0.071632   0.022957   3.120 0.001807 ** 
XX_Istate_5   0.027874   0.010680   2.610 0.009054 ** 
XX_Istate_6   0.074616   0.019107   3.905 9.42e-05 ***
XX_Istate_8   0.033517   0.018394   1.822 0.068420 .  
XX_Istate_9   0.029831   0.016496   1.808 0.070561 .  
XX_Istate_10  0.060292   0.026795   2.250 0.024443 *  
XX_Istate_11  0.103539   0.026739   3.872 0.000108 ***
XX_Istate_12 -0.036728   0.014400  -2.551 0.010753 *  
XX_Istate_13 -0.020689   0.009894  -2.091 0.036529 *  
XX_Istate_15  0.078059   0.042045   1.857 0.063375 .  
XX_Istate_16  0.043748   0.023718   1.844 0.065114 .  
XX_Istate_17  0.117482   0.015056   7.803 6.06e-15 ***
XX_Istate_18  0.075154   0.011963   6.282 3.34e-10 ***
XX_Istate_19  0.026295   0.015425   1.705 0.088257 .  
XX_Istate_20  0.001995   0.018821   0.106 0.915577    
XX_Istate_21  0.072503   0.011441   6.337 2.35e-10 ***
XX_Istate_22  0.091363   0.011159   8.188 2.67e-16 ***
XX_Istate_23 -0.072313   0.014882  -4.859 1.18e-06 ***
XX_Istate_24  0.064823   0.012709   5.101 3.39e-07 ***
XX_Istate_25  0.005104   0.015878   0.321 0.747870    
```

```
XX_Istate_26  0.139054   0.012493  11.131  < 2e-16 ***
XX_Istate_27  0.060772   0.015009   4.049 5.14e-05 ***
XX_Istate_28  0.033003   0.010627   3.106 0.001899 **
XX_Istate_29  0.045348   0.011772   3.852 0.000117 ***
XX_Istate_30  0.021177   0.023273   0.910 0.362853
XX_Istate_31  0.018788   0.018689   1.005 0.314765
XX_Istate_32  0.074326   0.038897   1.911 0.056029 .
XX_Istate_33 -0.038351   0.020371  -1.883 0.059755 .
XX_Istate_34  0.073009   0.016005   4.562 5.08e-06 ***
XX_Istate_35  0.010321   0.019549   0.528 0.597507
XX_Istate_36  0.056544   0.017191   3.289 0.001005 **
XX_Istate_37 -0.058104   0.009056  -6.416 1.40e-10 ***
XX_Istate_38  0.050114   0.017951   2.792 0.005243 **
XX_Istate_39  0.081161   0.012100   6.707 1.99e-11 ***
XX_Istate_40  0.019243   0.014343   1.342 0.179719
XX_Istate_41  0.058820   0.022012   2.672 0.007537 **
XX_Istate_42  0.046378   0.010928   4.244 2.20e-05 ***
XX_Istate_44 -0.057459   0.018120  -3.171 0.001520 **
XX_Istate_45 -0.042621   0.011269  -3.782 0.000155 ***
XX_Istate_46  0.014739   0.020835   0.707 0.479317
XX_Istate_47  0.018554   0.010162   1.826 0.067877 .
XX_Istate_48  0.020444   0.010720   1.907 0.056522 .
XX_Istate_49  0.028315   0.023854   1.187 0.235235
XX_Istate_50 -0.088191   0.021489  -4.104 4.06e-05 ***
XX_Istate_51  0.030137   0.010287   2.930 0.003393 **
XX_Istate_53  0.099818   0.019967   4.999 5.76e-07 ***
XX_Istate_54  0.072554   0.010485   6.920 4.53e-12 ***
XX_Istate_55  0.046151   0.013244   3.485 0.000493 ***
XX_Istate_56  0.068065   0.029298   2.323 0.020170 *
edu           0.083366   0.009700   8.594  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.6248 on 329445 degrees of freedom
Multiple R-Squared: 0.153,      Adjusted R-squared: 0.1529
Wald test: 483.5 on 63 and 329445 DF,  p-value: < 2.2e-16
```