

# R Exercise 2: INTA 6450 - Data Analytics and Security

## R Exercise 2

### Prompt

1. Complete the following exercise:

- `exercise_2.r`

2. You may make changes to the code to explore how they work
3. Then, submit the output for running these commands. You may copy/paste output from your terminal into a word or text document. You can convert the notebook to PDF submission:File->Compile Report->Report output format as HTML/PDF.
4. Write 100-150 words describing one extension you made to the code. You may post the change description as a comment at the beginning of your code, or submit the write-up in a separate document. Make sure to clearly mark where in your code the changes were made either by commenting, highlighting, or noting the command lines where the changes occur.

### Submissions

You will submit the following:

1. Original code output (R file code and output)
2. Your code change and output from that code change (comment where your code changes start and end)
3. Your code change description (this should be between 100 to 150 words)

An example of what the change description should look like:

```
#####  
# CHANGE DESCRIPTION  
# 100-150 words on the changes I've made, including a reference to which  
# initial command I've changed >  
# END OF CHANGE DESCRIPTION  
#####
```

Files must be in one of the following formats: pdf, doc, html

*Please note some of these exercises have graphs/charts - be sure when you export the original output to also check that the file includes graphs/charts that may have been present. If it does not, you will need to re-export or manually include the graphs in your final pdf, doc or html file*

## Solution Summary

The solution first inspected residuals to check the model fit. The purpose was to understand the residuals or differences between observed and predicted values to assess the fit for both OLS and IV models. The Distributions are inspected which follow a normal distribution with most values centered around zero. This indicated a good fit.

Second, the results for `ols` with a linear regression model is evaluated. By using `ols.robust` we can see that education, marital status, age and experience are all positive impact on wages. They are also statistically significant. In addition, `black` has a significant effect on wages. The small standard errors for most coefficients indicate that the estimates are adequate and precise, and the high t-values and small p-values confirm the statistical significance of these relationships. The overall summary is that education and experience are particularly important drivers of wages, with a negative impact associated with race (Black) and a positive impact from marital status.

**Original code is attached in submission for reference or to run, as it is fully functional.**

### Original Working Code

```
# Instrumental Variables example
library(sem)
#If gets error, add code< install.packages("Hmisc",dependencies=T)> or
# download a new version R studio
wages<-read.csv('http://inta.gatech.s3.amazonaws.com/wage2.csv')
iv.results<-tsls(lwage ~ educ + age + married + black + exper, ~ feduc + age +
                 married + black + exper, data=wages)
# Run an instrumental variables regression. Note that father's education is
# used for an instrument, and is not in the first set of variables. Age,
# marital, status, and race are assumed to be less related to underlying
# ability and so are controlled for in the "first stage" regression too.

ols.results<-lm(lwage ~ educ + age + married + black + exper, data=wages)
# Run the analogous OLS regression without father's education

print(summary(ols.results))
```

```
##
## Call:
## lm(formula = lwage ~ educ + age + married + black + exper, data = wages)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.90467 -0.23071  0.03097  0.25675  1.28777
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.223088   0.158879  32.875  < 2e-16 ***
## educ         0.067974   0.006727  10.105  < 2e-16 ***
## age          0.010397   0.004819   2.158  0.031209 *
## married      0.189200   0.040738   4.644  3.90e-06 ***
## black       -0.208938   0.037984  -5.501  4.89e-08 ***
## exper        0.013345   0.003838   3.477  0.000531 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3812 on 929 degrees of freedom
## Multiple R-squared:  0.1853, Adjusted R-squared:  0.1809
## F-statistic: 42.26 on 5 and 929 DF,  p-value: < 2.2e-16
```

```
print(summary(iv.results))
```

```
##
## 2SLS Estimates
##
## Model Formula: lwage ~ educ + age + married + black + exper
##
## Instruments: ~feduc + age + married + black + exper
##
## Residuals:
##      Min.      1st Qu.      Median      Mean      3rd Qu.      Max.
## -1.800804 -0.245057  0.008959  0.000000  0.260049  1.286707
##
##              Estimate      Std. Error  t value  Pr(>|t|)
## (Intercept)  4.552925199  0.280501872  16.23135 < 2.22e-16 ***
## educ         0.132581807  0.022703924   5.83960 7.8541e-09 ***
## age         -0.003706094  0.007482199  -0.49532  0.620521
## married      0.186683907  0.046865683   3.98338 7.4703e-05 ***
## black       -0.108869556  0.054978411  -1.98022  0.048051 *
## exper        0.035846909  0.008100919   4.42504 1.1103e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3991539 on 735 degrees of freedom
```

```
# Note that the point estimate for education has now gone up. This suggests
# that people who have higher education in a way that's correlated with
# their father having higher education, even holding fixed age, marital
# status, and race, receive ~13% higher wages for every year of education.
# Also note that the standard error on education is higher for the iv than
# ols results. The reason for this is that in IV, we're using only some of
# the variation in education: only the part related to father's education,
# so it's like there's less variation overall
```

```
# Stepwise regression
```

```
library(MASS)
```

```
start.model<-lm(wage ~ hours + IQ + KWW + educ + exper + tenure + age + married + black + south + urban
```

```
# Give an initial model, which will be the most coefficients we'd want to ever use
```

```
summary(start.model)
```

```
##
## Call:
## lm(formula = wage ~ hours + IQ + KWW + educ + exper + tenure +
##      age + married + black + south + urban + sibs, data = wages)
##
## Residuals:
##      Min      1Q  Median      3Q      Max
```

```
## -849.76 -223.19 -40.18 172.09 2091.17
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -562.589    185.142  -3.039  0.00244 **
## hours        -3.485     1.621   -2.150  0.03182 *
## IQ           2.828     1.004    2.817  0.00495 **
## KWW          5.261     1.981    2.656  0.00804 **
## educ        48.213     7.182    6.713 3.33e-11 ***
## exper        9.774     3.589    2.723  0.00658 **
## tenure       5.242     2.406    2.178  0.02963 *
## age          5.046     4.930    1.024  0.30634
## married     170.231    37.883    4.494 7.89e-06 ***
## black      -108.844    39.808   -2.734  0.00637 **
## south      -53.689    25.536   -2.102  0.03578 *
## urban      160.652    26.200    6.132 1.29e-09 ***
## sibs       -1.068     5.455   -0.196  0.84488
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 352.6 on 922 degrees of freedom
## Multiple R-squared:  0.2493, Adjusted R-squared:  0.2395
## F-statistic: 25.51 on 12 and 922 DF,  p-value: < 2.2e-16
```

```
stepwise.model<- step(start.model)
```

```
## Start:  AIC=10981.26
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##        black + south + urban + sibs
##
##           Df Sum of Sq      RSS   AIC
## - sibs      1      4763 114655843 10979
## - age       1     130265 114781346 10980
## <none>                114651080 10981
## - south     1     549683 115200763 10984
## - hours     1     574799 115225880 10984
## - tenure    1     590101 115241181 10984
## - KWW       1     877455 115528536 10986
## - exper     1     922291 115573372 10987
## - black     1     929659 115580739 10987
## - IQ        1     986880 115637960 10987
## - married   1     2510929 117162009 11000
## - urban     1     4675218 119326298 11017
## - educ      1     5603726 120254807 11024
##
## Step:  AIC=10979.3
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##        black + south + urban
##
##           Df Sum of Sq      RSS   AIC
## - age       1     128704 114784547 10978
## <none>                114655843 10979
## - south     1     546953 115202796 10982
## - hours     1     575305 115231148 10982
```

```

## - tenure      1      590732 115246575 10982
## - KWW         1      911607 115567450 10985
## - exper       1      926789 115582632 10985
## - black       1     1000335 115656178 10985
## - IQ          1     1002450 115658294 10985
## - married     1     2508266 117164110 10998
## - urban       1     4686063 119341906 11015
## - educ        1     5673927 120329770 11022
##
## Step:  AIC=10978.35
## wage ~ hours + IQ + KWW + educ + exper + tenure + married + black +
##       south + urban
##
##           Df Sum of Sq      RSS   AIC
## <none>                114784547 10978
## - hours      1      562954 115347501 10981
## - south      1      565737 115350283 10981
## - tenure     1      680663 115465209 10982
## - IQ         1      907667 115692213 10984
## - black      1      980306 115764853 10984
## - KWW        1     1413125 116197671 10988
## - exper      1     1678662 116463208 10990
## - married    1     2538972 117323519 10997
## - urban      1     4639497 119424043 11013
## - educ       1     6097302 120881849 11025

```

*# The command "step" adds and subtracts coefficients to maximize a measure of  
# goodness of fit*

```

summary(stepwise.model)

```

```

##
## Call:
## lm(formula = wage ~ hours + IQ + KWW + educ + exper + tenure +
##     married + black + south + urban, data = wages)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -872.52 -224.26  -41.71   171.08  2086.14
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -453.2969    141.0390  -3.214  0.001354 **
## hours        -3.4474     1.6194   -2.129  0.033536 *
## IQ           2.6621     0.9848    2.703  0.006996 **
## KWW          6.0918     1.8062    3.373  0.000775 ***
## educ        49.4804     7.0627    7.006  4.73e-12 ***
## exper       11.5519     3.1425    3.676  0.000251 ***
## tenure       5.5777     2.3828    2.341  0.019455 *
## married     171.1045    37.8476    4.521  6.96e-06 ***
## black      -109.2993    38.9083   -2.809  0.005072 **
## south      -54.4073    25.4951   -2.134  0.033103 *
## urban      159.8942    26.1639    6.111  1.46e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
##
## Residual standard error: 352.5 on 924 degrees of freedom
## Multiple R-squared:  0.2484, Adjusted R-squared:  0.2402
## F-statistic: 30.53 on 10 and 924 DF,  p-value: < 2.2e-16
```

```
stepwise.model.interactions <- step(start.model, scope=wage~.^2)
```

```
## Start:  AIC=10981.26
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs
##
##           Df Sum of Sq      RSS   AIC
## + KWW:educ      1    1911037 112740043 10968
## + educ:age      1    1282120 113368961 10973
## + KWW:black     1    1194791 113456289 10974
## + IQ:KWW        1    1066753 113584327 10974
## + black:sibs    1     806249 113844831 10977
## + hours:KWW     1     755386 113895694 10977
## + educ:urban    1     695416 113955664 10978
## + IQ:sibs       1     694361 113956719 10978
## + educ:exper    1     667627 113983453 10978
## + KWW:age       1     631767 114019314 10978
## + hours:south   1     625168 114025912 10978
## + married:sibs  1     574498 114076582 10979
## + south:urban   1     564654 114086426 10979
## + black:south   1     487564 114163516 10979
## - sibs          1         4763 114655843 10979
## + IQ:educ       1     449771 114201309 10980
## + educ:married  1     415461 114235619 10980
## + hours:age     1     411927 114239154 10980
## + tenure:black  1     409691 114241390 10980
## + KWW:married   1     391481 114259600 10980
## + hours:sibs    1     382852 114268228 10980
## - age          1     130265 114781346 10980
## + KWW:sibs      1     354299 114296782 10980
## + exper:age     1     348719 114302361 10980
## + educ:black    1     319990 114331091 10981
## <none>          1         114651080 10981
## + hours:tenure  1     214599 114436481 10982
## + black:urban   1     200281 114450799 10982
## + tenure:south  1     187488 114463592 10982
## + educ:sibs     1     181656 114469425 10982
## + IQ:black      1     175403 114475677 10982
## + exper:south   1     163186 114487895 10982
## + hours:married 1     161641 114489439 10982
## + IQ:urban      1     155293 114495787 10982
## + IQ:age        1     139542 114511539 10982
## + age:sibs      1     139255 114511825 10982
## + tenure:urban  1     137750 114513330 10982
## + age:married   1     132430 114518650 10982
## + tenure:age    1     111540 114539540 10982
## + hours:exper   1     107393 114543688 10982
## + hours:educ    1       97692 114553388 10982
## + age:black     1       92171 114558909 10982
```

```

## + exper:urban      1      87171 114563909 10983
## + IQ:married       1      58427 114592653 10983
## + IQ:exper         1      46633 114604448 10983
## + educ:south       1      42024 114609056 10983
## + age:south        1      40889 114610192 10983
## + hours:IQ         1      26239 114624841 10983
## + exper:tenure     1      23621 114627460 10983
## + exper:black      1      22305 114628776 10983
## + tenure:sibs      1      22068 114629013 10983
## + educ:tenure      1      20822 114630258 10983
## + tenure:married   1      19810 114631271 10983
## + married:black    1      19545 114631536 10983
## + married:south    1      18028 114633052 10983
## + IQ:south         1      14743 114636338 10983
## + exper:sibs       1      13695 114637385 10983
## + age:urban        1      12597 114638483 10983
## + married:urban    1      10511 114640569 10983
## + IQ:tenure        1       8883 114642197 10983
## + KWW:south        1       7896 114643185 10983
## + hours:black      1       5003 114646077 10983
## + KWW:urban        1       4334 114646746 10983
## + hours:urban      1       2445 114648636 10983
## + south:sibs       1       2348 114648733 10983
## + KWW:exper        1       2189 114648891 10983
## + exper:married    1       1749 114649331 10983
## + KWW:tenure       1       1325 114649756 10983
## + urban:sibs       1       1141 114649939 10983
## - south           1     549683 115200763 10984
## - hours           1     574799 115225880 10984
## - tenure          1     590101 115241181 10984
## - KWW             1     877455 115528536 10986
## - exper           1     922291 115573372 10987
## - black           1     929659 115580739 10987
## - IQ              1     986880 115637960 10987
## - married         1    2510929 117162009 11000
## - urban           1    4675218 119326298 11017
## - educ            1    5603726 120254807 11024
##
## Step:  AIC=10967.55
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ
##
##
##      Df Sum of Sq      RSS      AIC
## + hours:south      1      817073 111922970 10963
## + educ:exper        1      719870 112020173 10964
## + KWW:black         1      710103 112029939 10964
## + married:sibs      1      587553 112152490 10965
## + KWW:age           1      580504 112159539 10965
## + black:sibs        1      561664 112178379 10965
## - sibs              1         9692 112749735 10966
## + educ:urban        1      463226 112276817 10966
## + south:urban       1      462838 112277205 10966
## - age               1       33893 112773936 10966
## + black:south       1      434569 112305474 10966

```

## + hours:KWW	1	434379	112305664	10966
## + hours:age	1	419380	112320663	10966
## + educ:age	1	416833	112323210	10966
## + tenure:black	1	399466	112340577	10966
## + KWW:exper	1	352312	112387731	10967
## + educ:married	1	338394	112401649	10967
## + KWW:married	1	337930	112402113	10967
## + IQ:sibs	1	327205	112412838	10967
## + hours:sibs	1	304679	112435364	10967
## + hours:tenure	1	263415	112476627	10967
## <none>			112740043	10968
## + black:urban	1	237466	112502577	10968
## + educ:south	1	191103	112548940	10968
## + age:sibs	1	188318	112551725	10968
## + hours:married	1	181409	112558634	10968
## + tenure:south	1	170538	112569505	10968
## + hours:exper	1	148645	112591398	10968
## + exper:age	1	136044	112603999	10968
## + IQ:black	1	123781	112616262	10968
## + age:married	1	105507	112634536	10969
## + age:black	1	96147	112643896	10969
## + tenure:urban	1	89523	112650520	10969
## + IQ:urban	1	88532	112651511	10969
## + exper:south	1	85995	112654048	10969
## + tenure:age	1	75240	112664803	10969
## + IQ:KWW	1	72108	112667935	10969
## + KWW:sibs	1	61009	112679034	10969
## + educ:black	1	51332	112688711	10969
## + exper:urban	1	46837	112693206	10969
## + IQ:married	1	45561	112694482	10969
## + IQ:south	1	27547	112712496	10969
## + IQ:tenure	1	24162	112715881	10969
## + hours:educ	1	23840	112716203	10969
## + married:black	1	21600	112718443	10969
## + age:south	1	17543	112722500	10969
## + KWW:south	1	17328	112722715	10969
## + south:sibs	1	16832	112723210	10969
## + IQ:age	1	15833	112724210	10969
## + KWW:urban	1	12939	112727104	10969
## + urban:sibs	1	12901	112727141	10969
## + IQ:exper	1	10976	112729067	10970
## + tenure:sibs	1	10849	112729193	10970
## + married:urban	1	10462	112729581	10970
## + hours:urban	1	9378	112730665	10970
## + IQ:educ	1	8591	112731452	10970
## + hours:IQ	1	8113	112731930	10970
## + educ:tenure	1	7158	112732885	10970
## + tenure:married	1	6599	112733444	10970
## + exper:tenure	1	6552	112733491	10970
## + age:urban	1	2718	112737325	10970
## + married:south	1	2300	112737743	10970
## + exper:married	1	1983	112738060	10970
## + educ:sibs	1	292	112739751	10970
## + hours:black	1	171	112739872	10970



```

## + exper:black      1      158 112739885 10970
## + KWW:tenure       1        6 112740037 10970
## + exper:sibs       1        0 112740042 10970
## - south           1    527821 113267864 10970
## - tenure          1    566619 113306661 10970
## - hours           1    570019 113310062 10970
## - exper           1    917406 113657449 10973
## - IQ              1   1095767 113835810 10975
## - black           1   1105170 113845212 10975
## - KWW:educ        1   1911037 114651080 10981
## - married         1   2750422 115490465 10988
## - urban           1   4874564 117614607 11005
##
## Step:  AIC=10962.74
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ + hours:south
##
##              Df Sum of Sq      RSS      AIC
## + educ:exper    1    714377 111208593 10959
## + hours:age     1    660933 111262037 10959
## + KWW:black     1    641840 111281130 10959
## + married:sibs  1    543455 111379515 10960
## + black:sibs    1    543307 111379663 10960
## + KWW:age       1    528609 111394361 10960
## + hours:KWW     1    500513 111422457 10961
## + south:urban   1    481332 111441638 10961
## + educ:urban    1    479930 111443040 10961
## - sibs          1      1402 111924372 10961
## + educ:age      1    442742 111480227 10961
## - age           1     58057 111981027 10961
## + tenure:black  1    357266 111565704 10962
## + IQ:sibs       1    313593 111609377 10962
## + black:south   1    310588 111612382 10962
## + KWW:exper     1    309651 111613319 10962
## + educ:married  1    307083 111615887 10962
## + KWW:married   1    290622 111632348 10962
## + black:urban   1    254038 111668932 10963
## <none>          111922970 10963
## + tenure:south  1    226508 111696462 10963
## + hours:sibs    1    203816 111719154 10963
## + hours:exper   1    190664 111732306 10963
## + age:sibs      1    186799 111736171 10963
## + exper:age     1    170085 111752885 10963
## + exper:south   1    136770 111786200 10964
## + educ:south    1    135744 111787226 10964
## + tenure:age    1    134542 111788428 10964
## + tenure:urban  1    125728 111797242 10964
## + hours:tenure  1    116715 111806255 10964
## + hours:married 1    114291 111808679 10964
## + age:married   1    101965 111821005 10964
## + IQ:urban      1    100857 111822113 10964
## + IQ:black      1     99401 111823569 10964
## + age:black     1     85715 111837255 10964
## + IQ:KWW        1     73083 111849887 10964

```

```

## + educ:black      1      62829 111860141 10964
## + hours:educ      1      56285 111866685 10964
## + KWW:sibs        1      53792 111869178 10964
## + exper:urban     1      51192 111871778 10964
## + hours:IQ        1      47289 111875681 10964
## + hours:black     1      44304 111878666 10964
## + IQ:married      1      40532 111882438 10964
## + urban:sibs      1      29585 111893385 10964
## + IQ:tenure       1      24936 111898034 10964
## + married:black   1      21653 111901317 10965
## + IQ:age          1      18975 111903995 10965
## + IQ:exper        1      18638 111904332 10965
## + exper:tenure    1      18376 111904594 10965
## + tenure:sibs     1      16849 111906121 10965
## + IQ:educ         1      13790 111909180 10965
## + age:south       1      11702 111911268 10965
## + IQ:south        1      9392 111913578 10965
## + educ:tenure     1      9268 111913702 10965
## + married:urban   1      8848 111914122 10965
## + south:sibs      1      3758 111919212 10965
## + KWW:urban       1      3149 111919821 10965
## + tenure:married  1      2451 111920519 10965
## + exper:black     1      2145 111920825 10965
## + exper:married   1      1927 111921043 10965
## + age:urban       1      1891 111921079 10965
## + KWW:south       1      1390 111921580 10965
## + married:south   1      800 111922170 10965
## + hours:urban     1      751 111922219 10965
## + KWW:tenure      1      421 111922549 10965
## + educ:sibs       1      95 111922875 10965
## + exper:sibs      1      1 111922969 10965
## - tenure          1      554537 112477507 10965
## - hours:south     1      817073 112740043 10968
## - exper           1      930661 112853631 10968
## - black           1      1089791 113012761 10970
## - IQ              1      1107439 113030409 10970
## - KWW:educ        1      2102942 114025912 10978
## - married         1      2538323 114461293 10982
## - urban           1      4874022 116796992 11001
##
## Step:  AIC=10958.76
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ + hours:south + educ:exper
##
##           Df Sum of Sq      RSS      AIC
## + hours:age      1      660743 110547850 10955
## + KWW:black      1      600325 110608267 10956
## + hours:KWW      1      525220 110683373 10956
## + educ:urban     1      484388 110724205 10957
## + married:sibs   1      483882 110724711 10957
## + black:sibs     1      480063 110728530 10957
## - sibs           1         34 111208627 10957
## + south:urban    1      463078 110745515 10957
## + IQ:exper       1      406361 110802232 10957

```

## + tenure:black	1	399586	110809007	10957
## - age	1	124398	111332991	10958
## + IQ:sibs	1	302204	110906389	10958
## + black:south	1	291432	110917161	10958
## + age:sibs	1	286905	110921688	10958
## + KWW:age	1	276216	110932377	10958
## + black:urban	1	241347	110967246	10959
## <none>			111208593	10959
## + exper:south	1	218073	110990520	10959
## + KWW:married	1	211555	110997038	10959
## + educ:married	1	210413	110998180	10959
## + tenure:south	1	209489	110999104	10959
## + hours:sibs	1	189802	111018791	10959
## + tenure:age	1	156068	111052525	10959
## + hours:exper	1	150329	111058264	10960
## + educ:black	1	125655	111082938	10960
## + tenure:urban	1	122549	111086043	10960
## + educ:south	1	115964	111092629	10960
## + hours:tenure	1	112868	111095725	10960
## + IQ:urban	1	107678	111100915	10960
## + age:married	1	96706	111111887	10960
## + educ:age	1	93696	111114896	10960
## + hours:married	1	93678	111114915	10960
## + IQ:black	1	90928	111117665	10960
## + hours:educ	1	87490	111121103	10960
## + IQ:educ	1	81206	111127386	10960
## + exper:age	1	73850	111134743	10960
## + KWW:exper	1	63640	111144953	10960
## + exper:urban	1	59434	111149159	10960
## + hours:IQ	1	59199	111149394	10960
## + hours:black	1	54469	111154124	10960
## + age:black	1	44306	111164287	10960
## + IQ:tenure	1	41461	111167132	10960
## + IQ:KWW	1	39868	111168725	10960
## + married:black	1	39356	111169237	10960
## + exper:black	1	37781	111170812	10960
## + urban:sibs	1	35462	111173131	10960
## + KWW:sibs	1	35391	111173202	10960
## + educ:tenure	1	29338	111179255	10960
## + IQ:married	1	21904	111186689	10961
## + exper:tenure	1	16953	111191640	10961
## + exper:sibs	1	16457	111192136	10961
## + tenure:sibs	1	11858	111196735	10961
## + KWW:tenure	1	11629	111196964	10961
## + tenure:married	1	11391	111197202	10961
## + married:urban	1	10102	111198491	10961
## + exper:married	1	9490	111199103	10961
## + IQ:south	1	8879	111199714	10961
## + south:sibs	1	6916	111201677	10961
## + IQ:age	1	5590	111203003	10961
## + hours:urban	1	3569	111205024	10961
## + age:south	1	1556	111207037	10961
## + married:south	1	1381	111207212	10961
## + KWW:urban	1	987	111207606	10961

```

## + KWW:south      1      651 111207942 10961
## + age:urban      1      265 111208328 10961
## + educ:sibs      1       99 111208494 10961
## - tenure         1     625711 111834304 10962
## - educ:exper     1     714377 111922970 10963
## - hours:south    1     811580 112020173 10964
## - IQ             1    1096866 112305459 10966
## - black          1    1103148 112311741 10966
## - KWW:educ       1    2156607 113365200 10975
## - married        1    2563689 113772282 10978
## - urban          1    4871756 116080349 10997
##
## Step:  AIC=10955.19
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ + hours:south + educ:exper +
##       hours:age
##
##           Df Sum of Sq      RSS      AIC
## + KWW:black      1    595742 109952108 10952
## + black:sibs     1    493258 110054592 10953
## + married:sibs   1    479687 110068163 10953
## - sibs           1       383 110548233 10953
## + south:urban    1    467160 110080689 10953
## + educ:urban     1    455769 110092081 10953
## + IQ:exper       1    435120 110112729 10954
## + tenure:black   1    409685 110138164 10954
## + age:sibs       1    338231 110209619 10954
## + IQ:sibs        1    317741 110230108 10954
## + hours:sibs     1    266360 110281489 10955
## + black:south    1    263143 110284706 10955
## + black:urban    1    243458 110304392 10955
## <none>           110547850 10955
## + KWW:married    1    212695 110335154 10955
## + exper:south    1    208634 110339216 10955
## + hours:tenure   1    189084 110358765 10956
## + educ:married   1    181201 110366649 10956
## + KWW:age        1    177889 110369961 10956
## + hours:KWW      1    171760 110376090 10956
## + tenure:south   1    156310 110391539 10956
## + educ:black     1    151475 110396374 10956
## + tenure:age     1    131900 110415949 10956
## + educ:south     1    129305 110418544 10956
## + IQ:urban       1    114289 110433561 10956
## + IQ:educ        1     97607 110450242 10956
## + tenure:urban   1     96942 110450907 10956
## + IQ:black       1     89715 110458135 10956
## + age:married    1     81771 110466079 10956
## + exper:black    1     75974 110471876 10956
## + hours:married  1     71498 110476351 10957
## + hours:black    1     62424 110485425 10957
## + educ:age       1     62318 110485531 10957
## + exper:age      1     54545 110493305 10957
## + married:black  1     51560 110496290 10957
## + exper:urban    1     49432 110498418 10957

```

```

## + IQ:KWW 1 46118 110501732 10957
## + hours:educ 1 45908 110501942 10957
## + KWW:exper 1 41964 110505885 10957
## + IQ:tenure 1 40064 110507785 10957
## + educ:tenure 1 34325 110513525 10957
## + hours:IQ 1 33455 110514394 10957
## + urban:sibs 1 28521 110519329 10957
## + KWW:sibs 1 27308 110520541 10957
## + IQ:married 1 22101 110525748 10957
## + IQ:age 1 17949 110529901 10957
## + KWW:tenure 1 16701 110531149 10957
## + exper:tenure 1 16371 110531478 10957
## + exper:sibs 1 13302 110534548 10957
## + tenure:married 1 12583 110535266 10957
## + IQ:south 1 12007 110535843 10957
## + age:black 1 10266 110537584 10957
## + south:sibs 1 7088 110540761 10957
## + tenure:sibs 1 5061 110542788 10957
## + hours:urban 1 4108 110543742 10957
## + exper:married 1 3968 110543882 10957
## + age:urban 1 2041 110545809 10957
## + married:urban 1 1795 110546055 10957
## + married:south 1 1081 110546769 10957
## + educ:sibs 1 980 110546870 10957
## + KWW:urban 1 593 110547256 10957
## + hours:exper 1 438 110547411 10957
## + age:south 1 197 110547652 10957
## + KWW:south 1 53 110547797 10957
## - hours:age 1 660743 111208593 10959
## - tenure 1 681596 111229446 10959
## - educ:exper 1 714187 111262037 10959
## - IQ 1 1000072 111547921 10962
## - hours:south 1 1052421 111600271 10962
## - black 1 1101064 111648913 10962
## - KWW:educ 1 2199037 112746887 10972
## - married 1 2599903 113147753 10975
## - urban 1 4709989 115257838 10992
##
## Step: AIC=10952.13
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
## black + south + urban + sibs + KWW:educ + hours:south + educ:exper +
## hours:age + KWW:black
##
## Df Sum of Sq RSS AIC
## + educ:urban 1 554648 109397460 10949
## + IQ:exper 1 506033 109446074 10950
## - sibs 1 19457 109971565 10950
## + south:urban 1 419655 109532453 10951
## + married:sibs 1 386146 109565962 10951
## + age:sibs 1 369456 109582652 10951
## + tenure:black 1 339277 109612831 10951
## + black:south 1 279647 109672461 10952
## <none> 109952108 10952
## + hours:sibs 1 230458 109721650 10952

```

## + IQ:sibs	1	215984	109736123	10952
## + hours:tenure	1	211883	109740225	10952
## + exper:south	1	204404	109747704	10952
## + black:sibs	1	195739	109756369	10952
## + KWW:age	1	186375	109765733	10952
## + educ:married	1	156799	109795309	10953
## + tenure:age	1	143678	109808430	10953
## + black:urban	1	143529	109808579	10953
## + KWW:married	1	140712	109811396	10953
## + educ:south	1	134442	109817666	10953
## + IQ:urban	1	130450	109821658	10953
## + tenure:urban	1	118316	109833792	10953
## + tenure:south	1	118258	109833850	10953
## + hours:KWW	1	108321	109843787	10953
## + IQ:educ	1	102260	109849848	10953
## + educ:age	1	82409	109869699	10953
## + hours:married	1	75462	109876646	10954
## + exper:black	1	71424	109880684	10954
## + married:black	1	66723	109885385	10954
## + age:married	1	65114	109886994	10954
## + exper:urban	1	64681	109887427	10954
## + KWW:tenure	1	47457	109904651	10954
## + exper:age	1	41165	109910943	10954
## + hours:educ	1	40651	109911457	10954
## + IQ:tenure	1	40129	109911979	10954
## + hours:black	1	36389	109915719	10954
## + educ:tenure	1	36031	109916076	10954
## + KWW:exper	1	34017	109918091	10954
## + IQ:age	1	33417	109918691	10954
## + urban:sibs	1	26306	109925802	10954
## + educ:black	1	25930	109926178	10954
## + IQ:south	1	24050	109928058	10954
## + hours:IQ	1	19444	109932664	10954
## + south:sibs	1	18240	109933868	10954
## + tenure:married	1	16072	109936035	10954
## + exper:sibs	1	13792	109938316	10954
## + married:south	1	12694	109939413	10954
## + exper:tenure	1	12137	109939971	10954
## + KWW:south	1	10535	109941573	10954
## + IQ:married	1	9760	109942348	10954
## + hours:urban	1	6628	109945479	10954
## + KWW:urban	1	6229	109945878	10954
## + educ:sibs	1	6210	109945898	10954
## + tenure:sibs	1	5613	109946495	10954
## + KWW:sibs	1	3771	109948337	10954
## + married:urban	1	3308	109948800	10954
## + exper:married	1	2740	109949368	10954
## + age:urban	1	2032	109950076	10954
## + age:black	1	1703	109950405	10954
## + IQ:KWW	1	200	109951908	10954
## + IQ:black	1	147	109951960	10954
## + age:south	1	104	109952004	10954
## + hours:exper	1	102	109952006	10954
## - tenure	1	582305	110534412	10955

```

## - KWW:black      1      595742 110547850 10955
## - hours:age      1      656160 110608267 10956
## - educ:exper     1      672833 110624940 10956
## - hours:south    1      977443 110929551 10958
## - IQ             1     1028420 110980528 10959
## - KWW:educ       1     1696292 111648400 10964
## - married        1     2560152 112512260 10972
## - urban          1     4679040 114631147 10989
##
## Step:  AIC=10949.4
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban
##
##              Df Sum of Sq      RSS      AIC
## + IQ:exper     1      505093 108892366 10947
## - sibs         1       19527 109416987 10948
## + married:sibs  1      378315 109019144 10948
## + age:sibs     1      338296 109059163 10948
## + tenure:black  1      313688 109083772 10949
## + south:urban  1      293618 109103841 10949
## + black:south  1      293270 109104190 10949
## + hours:sibs   1      238947 109158513 10949
## <none>                109397460 10949
## + IQ:sibs      1      220113 109177347 10950
## + black:sibs   1      199314 109198146 10950
## + exper:south  1      199030 109198430 10950
## + KWW:age      1      193304 109204156 10950
## + educ:married  1      182244 109215215 10950
## + educ:south   1      178084 109219375 10950
## + hours:tenure  1      158154 109239306 10950
## + KWW:married  1      148352 109249108 10950
## + tenure:south  1      130815 109266644 10950
## + tenure:age   1      127071 109270389 10950
## + educ:age     1      123308 109274152 10950
## + IQ:educ      1      117014 109280445 10950
## + hours:KWW    1       94403 109303056 10951
## + tenure:urban  1       93411 109304049 10951
## + exper:black  1       89539 109307920 10951
## + hours:married 1       88851 109308609 10951
## + age:married  1       87240 109310219 10951
## + married:black 1       72449 109325010 10951
## + black:urban  1       68142 109329318 10951
## + educ:black   1       50821 109346638 10951
## + KWW:urban    1       50451 109347009 10951
## + hours:black  1       48628 109348832 10951
## + exper:age    1       45809 109351650 10951
## + KWW:exper    1       45394 109352065 10951
## + IQ:south     1       38425 109359035 10951
## + hours:educ   1       31954 109365506 10951
## + IQ:tenure    1       31626 109365833 10951
## + educ:tenure  1       29212 109368248 10951
## + KWW:tenure   1       28064 109369396 10951
## + KWW:south    1       24944 109372515 10951

```

```

## + south:sibs      1      24515 109372945 10951
## + IQ:age          1      24436 109373024 10951
## + hours:IQ        1      20075 109377384 10951
## + hours:urban     1      16748 109380711 10951
## + IQ:married      1      14435 109383025 10951
## + exper:urban     1      10859 109386600 10951
## + educ:sibs       1      10799 109386661 10951
## + married:south   1       9637 109387823 10951
## + tenure:sibs     1       9364 109388096 10951
## + exper:tenure    1       8763 109388697 10951
## + exper:sibs      1       7290 109390170 10951
## + tenure:married  1       5634 109391825 10951
## + age:south       1       3993 109393467 10951
## + IQ:urban        1       2829 109394631 10951
## + age:black       1       2448 109395011 10951
## + age:urban       1       2123 109395337 10951
## + exper:married   1       1264 109396196 10951
## + IQ:black        1        405 109397055 10951
## + KWW:sibs        1        305 109397154 10951
## + IQ:KWW          1        196 109397264 10951
## + married:urban   1         93 109397367 10951
## + urban:sibs      1         34 109397425 10951
## + hours:exper     1          1 109397459 10951
## - tenure          1     528788 109926247 10952
## - educ:urban      1     554648 109952108 10952
## - hours:age       1     624279 110021739 10953
## - educ:exper      1     674128 110071587 10953
## - KWW:black       1     694621 110092081 10953
## - hours:south     1     984400 110381860 10956
## - IQ              1    1127889 110525349 10957
## - KWW:educ        1    1431244 110828704 10960
## - married         1    2474614 111872074 10968
##
## Step:  AIC=10947.08
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + sibs + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban + IQ:exper
##
##           Df Sum of Sq      RSS      AIC
## - sibs      1      18534 108910900 10945
## + married:sibs  1      381996 108510370 10946
## + black:south  1      301685 108590681 10946
## + tenure:black  1      299788 108592578 10946
## + south:urban  1      288156 108604210 10947
## + KWW:age      1      283894 108608473 10947
## + age:sibs     1      263436 108628931 10947
## <none>                108892366 10947
## + educ:south   1      222612 108669755 10947
## + hours:sibs   1      193761 108698606 10947
## + KWW:married  1      185026 108707340 10948
## + educ:married  1      174946 108717420 10948
## + hours:tenure  1      170092 108722274 10948
## + KWW:exper    1      149029 108743337 10948
## + black:sibs   1      147544 108744822 10948

```



## + IQ:sibs	1	143621	108748745	10948
## + educ:age	1	142317	108750049	10948
## + tenure:south	1	139591	108752776	10948
## + tenure:age	1	107018	108785348	10948
## + exper:south	1	101277	108791089	10948
## + hours:married	1	100270	108792097	10948
## + tenure:urban	1	96412	108795954	10948
## + hours:KWW	1	95520	108796846	10948
## + age:married	1	82831	108809535	10948
## + married:black	1	63333	108829033	10948
## + black:urban	1	57468	108834898	10949
## + exper:age	1	55400	108836966	10949
## + IQ:married	1	54015	108838352	10949
## + IQ:age	1	52745	108839621	10949
## + IQ:south	1	48254	108844112	10949
## + hours:black	1	41513	108850854	10949
## + KWW:urban	1	37534	108854832	10949
## + educ:tenure	1	36106	108856260	10949
## + educ:sibs	1	31021	108861346	10949
## + hours:educ	1	30199	108862168	10949
## + south:sibs	1	29936	108862430	10949
## + hours:urban	1	24537	108867829	10949
## + KWW:south	1	19811	108872555	10949
## + hours:IQ	1	18599	108873767	10949
## + educ:black	1	18088	108874278	10949
## + KWW:tenure	1	15302	108877064	10949
## + exper:urban	1	13400	108878966	10949
## + IQ:educ	1	11675	108880691	10949
## + IQ:urban	1	11339	108881027	10949
## + tenure:sibs	1	10475	108881892	10949
## + married:south	1	8622	108883744	10949
## + IQ:black	1	8353	108884013	10949
## + age:black	1	6525	108885841	10949
## + tenure:married	1	5066	108887300	10949
## + IQ:tenure	1	4622	108887744	10949
## + age:urban	1	4113	108888253	10949
## + exper:black	1	1999	108890367	10949
## + exper:sibs	1	1514	108890852	10949
## + exper:married	1	1389	108890977	10949
## + IQ:KWW	1	1053	108891314	10949
## + KWW:sibs	1	1032	108891334	10949
## + urban:sibs	1	449	108891918	10949
## + hours:exper	1	398	108891968	10949
## + exper:tenure	1	297	108892069	10949
## + married:urban	1	35	108892331	10949
## + age:south	1	19	108892347	10949
## - IQ:exper	1	505093	109397460	10949
## - educ:urban	1	553708	109446074	10950
## - tenure	1	565987	109458354	10950
## - hours:age	1	654297	109546664	10951
## - KWW:black	1	770361	109662728	10952
## - hours:south	1	1039019	109931385	10954
## - educ:exper	1	1133904	110026270	10955
## - KWW:educ	1	1277132	110169498	10956

```

## - married          1    2510032 111402398 10966
##
## Step:  AIC=10945.24
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban + IQ:exper
##
##
##      Df Sum of Sq      RSS      AIC
## + black:south      1    305279 108605621 10945
## + tenure:black      1    294360 108616540 10945
## + south:urban       1    288402 108622498 10945
## + KWW:age           1    280039 108630861 10945
## <none>                                108910900 10945
## + educ:south        1    225691 108685209 10945
## + KWW:married        1    188755 108722145 10946
## + educ:married       1    175523 108735377 10946
## + hours:tenure       1    164254 108746646 10946
## + KWW:exper          1    149097 108761803 10946
## + tenure:south       1    142289 108768611 10946
## + educ:age           1    141465 108769435 10946
## + tenure:age         1    107022 108803878 10946
## + exper:south        1    106247 108804653 10946
## + hours:KWW          1     98065 108812835 10946
## + hours:married      1     97440 108813460 10946
## + tenure:urban       1     96307 108814593 10946
## + age:married         1     79810 108831090 10947
## + married:black      1     63145 108847755 10947
## + exper:age          1     58854 108852046 10947
## + IQ:married          1     55207 108855693 10947
## + black:urban        1     52060 108858840 10947
## + IQ:south           1     50889 108860011 10947
## + IQ:age             1     49940 108860960 10947
## + hours:black        1     41036 108869864 10947
## + KWW:urban          1     36317 108874583 10947
## + educ:tenure        1     36177 108874723 10947
## + hours:educ         1     32017 108878883 10947
## + hours:urban        1     22860 108888040 10947
## + KWW:south          1     20173 108890727 10947
## + hours:IQ           1     19612 108891288 10947
## + sibs               1     18534 108892366 10947
## + educ:black         1     16763 108894137 10947
## + exper:urban        1     14733 108896167 10947
## + KWW:tenure         1     14096 108896804 10947
## + IQ:urban           1     12768 108898132 10947
## + IQ:educ            1      9628 108901272 10947
## + IQ:black           1      8341 108902559 10947
## + married:south      1      7190 108903710 10947
## + age:black          1      6480 108904420 10947
## + age:urban          1      4931 108905969 10947
## + IQ:tenure          1      4225 108906675 10947
## + tenure:married     1      4015 108906885 10947
## + exper:black        1      2096 108908804 10947
## + exper:married      1      1468 108909432 10947
## + IQ:KWW             1      1453 108909447 10947

```

```

## + hours:exper      1      382 108910518 10947
## + exper:tenure     1      365 108910535 10947
## + age:south        1       62 108910838 10947
## + married:urban    1       28 108910872 10947
## - IQ:exper         1    506087 109416987 10948
## - educ:urban       1    553639 109464539 10948
## - tenure           1    570102 109481002 10948
## - hours:age        1    648272 109559172 10949
## - KWW:black        1    751828 109662728 10950
## - hours:south      1   1062585 109973485 10952
## - educ:exper       1   1151590 110062490 10953
## - KWW:educ         1   1282127 110193027 10954
## - married          1   2503295 111414195 10964
##
## Step:  AIC=10944.61
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban + IQ:exper + black:south
##
##              Df Sum of Sq      RSS      AIC
## + KWW:age      1    298327 108307295 10944
## + tenure:black  1    265921 108339701 10944
## <none>                                108605621 10945
## + south:urban  1    231570 108374052 10945
## + black:urban  1    176159 108429462 10945
## - black:south  1    305279 108910900 10945
## + educ:married 1    158943 108446679 10945
## + educ:south   1    154547 108451075 10945
## + KWW:exper    1    153713 108451908 10945
## + hours:tenure 1    145989 108459632 10945
## + educ:age     1    144489 108461132 10945
## + KWW:married  1    134822 108470800 10946
## + married:black 1    126803 108478818 10946
## + exper:south  1    123592 108482029 10946
## + tenure:age   1    117629 108487992 10946
## + tenure:south 1    113252 108492369 10946
## + hours:married 1    109572 108496049 10946
## + hours:KWW    1     92515 108513107 10946
## + tenure:urban 1     84909 108520712 10946
## + age:married  1     77821 108527800 10946
## + exper:age    1     61400 108544221 10946
## + IQ:age       1     52401 108553221 10946
## + hours:black  1     35522 108570100 10946
## + hours:educ   1     34496 108571125 10946
## + IQ:married   1     30322 108575299 10946
## + educ:tenure  1     26621 108579000 10946
## + hours:urban  1     21085 108584536 10946
## + age:black    1     20581 108585040 10946
## + KWW:urban    1     19983 108585638 10946
## + KWW:tenure   1     15772 108589850 10946
## + sibs         1     14940 108590681 10946
## + exper:urban  1     14449 108591173 10946
## + hours:IQ     1     12691 108592930 10946
## + married:south 1     11541 108594081 10946

```

```

## + tenure:married 1      8064 108597557 10946
## + IQ:educ 1      7581 108598040 10946
## + educ:black 1      7044 108598577 10947
## + age:urban 1      4554 108601068 10947
## + IQ:black 1      2551 108603070 10947
## + IQ:tenure 1      2095 108603526 10947
## + IQ:urban 1      2028 108603593 10947
## + exper:married 1      1309 108604312 10947
## + IQ:south 1      995 108604627 10947
## + exper:tenure 1      797 108604824 10947
## + married:urban 1      608 108605013 10947
## + IQ:KWW 1      605 108605016 10947
## + exper:black 1      355 108605267 10947
## + age:south 1      101 108605521 10947
## + hours:exper 1      52 108605569 10947
## + KWW:south 1      50 108605572 10947
## - IQ:exper 1      514459 109120080 10947
## - educ:urban 1      567525 109173147 10948
## - tenure 1      573785 109179407 10948
## - hours:age 1      618667 109224288 10948
## - KWW:black 1      777029 109382650 10949
## - hours:south 1      912034 109517656 10950
## - educ:exper 1      1134103 109739725 10952
## - KWW:educ 1      1223607 109829229 10953
## - married 1      2642563 111248184 10965
##
## Step: AIC=10944.04
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban + IQ:exper + black:south +
##       KWW:age
##
##           Df Sum of Sq      RSS      AIC
## + tenure:black 1      314372 107992923 10943
## <none>                108307295 10944
## + south:urban 1      219869 108087425 10944
## + educ:south 1      181442 108125853 10944
## + hours:tenure 1      172071 108135224 10945
## - KWW:age 1      298327 108605621 10945
## + black:urban 1      163759 108143536 10945
## - black:south 1      323567 108630861 10945
## + married:black 1      136031 108171263 10945
## + educ:married 1      136030 108171264 10945
## + tenure:age 1      127289 108180006 10945
## + tenure:south 1      123367 108183927 10945
## + hours:married 1      122822 108184473 10945
## + hours:KWW 1      119425 108187870 10945
## + exper:south 1      103727 108203567 10945
## + tenure:urban 1      100713 108206581 10945
## + KWW:married 1      87961 108219334 10945
## + exper:age 1      69598 108237696 10945
## + age:married 1      58226 108249069 10946
## + KWW:tenure 1      56214 108251081 10946
## + educ:age 1      53586 108253709 10946

```

```

## + hours:black      1      39243 108268052 10946
## + hours:educ       1      39216 108268079 10946
## + educ:tenure      1      37122 108270173 10946
## + KWW:urban        1      25920 108281375 10946
## + married:south    1      24550 108282744 10946
## + IQ:married       1      19593 108287702 10946
## + sibs             1      18425 108288870 10946
## + hours:IQ         1      17420 108289874 10946
## + hours:urban      1      16063 108291232 10946
## + KWW:exper        1      14868 108292427 10946
## + IQ:urban         1       8415 108298879 10946
## + tenure:married   1       7947 108299348 10946
## + educ:black       1       7860 108299434 10946
## + IQ:tenure        1       7749 108299546 10946
## + IQ:age           1       6286 108301009 10946
## + exper:urban      1       5623 108301672 10946
## + IQ:black         1       4501 108302793 10946
## + IQ:educ          1       3686 108303608 10946
## + IQ:south         1       2691 108304603 10946
## + married:urban    1       2686 108304608 10946
## + exper:black      1       1047 108306247 10946
## + age:black        1        826 108306468 10946
## + age:south        1        702 108306592 10946
## + exper:tenure     1        485 108306809 10946
## + exper:married    1        259 108307036 10946
## + IQ:KWW           1        214 108307081 10946
## + KWW:south        1        108 108307187 10946
## + age:urban        1         38 108307256 10946
## + hours:exper      1          1 108307294 10946
## - hours:age        1    500706 108808000 10946
## - tenure           1    526154 108833448 10947
## - educ:urban       1    576645 108883939 10947
## - IQ:exper         1    608701 108915996 10947
## - KWW:black        1    795200 109102495 10949
## - hours:south      1    847708 109155003 10949
## - educ:exper       1    911431 109218726 10950
## - KWW:educ         1   1158970 109466265 10952
## - married          1   2523426 110830721 10964
##
## Step:  AIC=10943.32
## wage ~ hours + IQ + KWW + educ + exper + tenure + age + married +
##       black + south + urban + KWW:educ + hours:south + educ:exper +
##       hours:age + KWW:black + educ:urban + IQ:exper + black:south +
##       KWW:age + tenure:black
##
##              Df Sum of Sq      RSS   AIC
## <none>                107992923 10943
## + south:urban      1    226760 107766163 10943
## + educ:south       1    172188 107820735 10944
## - black:south      1    293261 108286184 10944
## + educ:married     1    152773 107840150 10944
## - tenure:black     1    314372 108307295 10944
## + black:urban      1    140382 107852540 10944
## + hours:tenure     1    131307 107861615 10944

```

```

## + tenure:urban      1      129164 107863758 10944
## + exper:south       1      127949 107864973 10944
## + hours:married     1      119348 107873574 10944
## + hours:KWW         1      116235 107876688 10944
## - KWW:age           1      346778 108339701 10944
## + KWW:married       1      104562 107888361 10944
## + tenure:age        1       96982 107895941 10944
## + exper:age         1       80304 107912619 10945
## + tenure:south      1       77999 107914923 10945
## + married:black     1       69989 107922933 10945
## + educ:age          1       58344 107934579 10945
## + hours:educ        1       40395 107952527 10945
## + age:married       1       36308 107956614 10945
## + IQ:married        1       34472 107958451 10945
## + KWW:urban         1       25931 107966991 10945
## + married:south    1       25172 107967751 10945
## + sibs              1       24630 107968293 10945
## + hours:black       1       22216 107970706 10945
## + hours:urban      1       19490 107973432 10945
## + age:black         1       18419 107974504 10945
## + educ:tenure       1       13074 107979849 10945
## + hours:IQ          1       12379 107980543 10945
## + IQ:age            1       12336 107980586 10945
## + KWW:exper         1       12234 107980689 10945
## + IQ:urban          1       11707 107981216 10945
## + IQ:tenure         1        9040 107983883 10945
## + educ:black        1        6092 107986830 10945
## + exper:black       1        5723 107987200 10945
## + KWW:tenure        1        5494 107987429 10945
## + tenure:married    1        5167 107987756 10945
## + IQ:educ           1        4939 107987984 10945
## + IQ:black          1        3222 107989700 10945
## + IQ:south          1        2497 107990426 10945
## + exper:urban       1        1973 107990950 10945
## + age:south         1        1677 107991246 10945
## + KWW:south         1        1673 107991250 10945
## + married:urban     1         973 107991950 10945
## + exper:tenure      1         694 107992228 10945
## + IQ:KWW            1         355 107992568 10945
## + exper:married     1         343 107992579 10945
## + hours:exper       1         205 107992717 10945
## + age:urban         1          75 107992847 10945
## - hours:age         1      501050 108493973 10946
## - educ:urban        1      550444 108543367 10946
## - IQ:exper          1      601609 108594531 10946
## - KWW:black         1      705363 108698286 10947
## - hours:south       1      816354 108809277 10948
## - educ:exper        1      929219 108922142 10949
## - KWW:educ          1     1172742 109165664 10951
## - married           1     2364942 110357865 10962

```

```

# The command "step" adds and subtracts coefficients to maximize a measure of
# goodness of fit.

```

```

summary(stepwise.model.interactions)

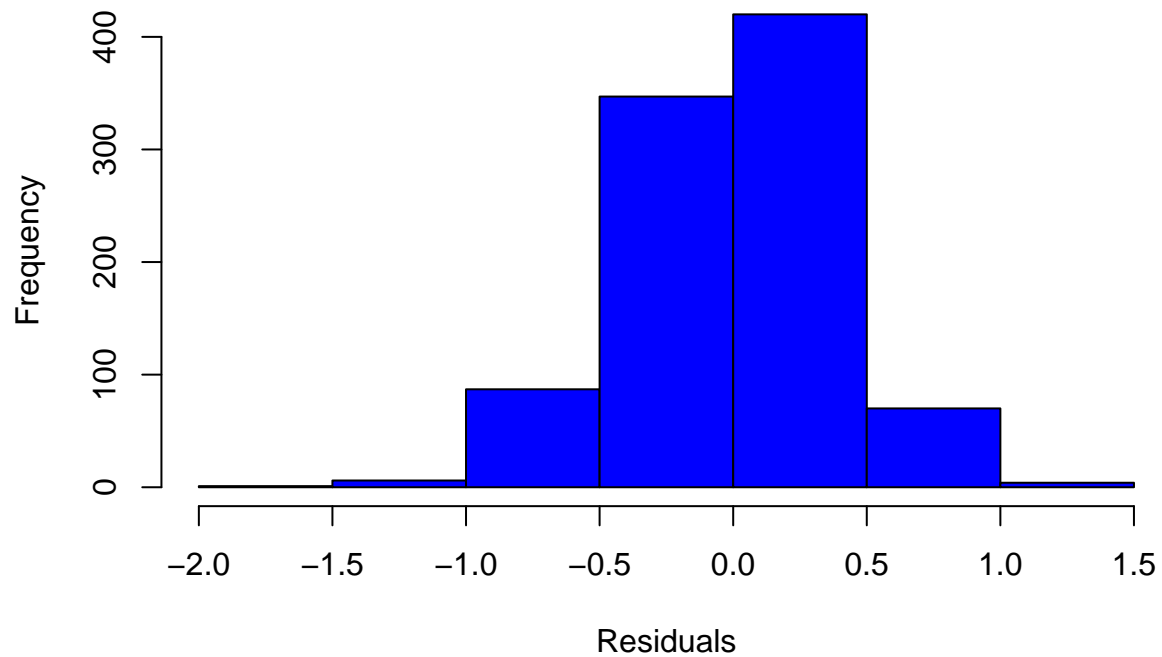
```

```
##
## Call:
## lm(formula = wage ~ hours + IQ + KWW + educ + exper + tenure +
##     age + married + black + south + urban + KWW:educ + hours:south +
##     educ:exper + hours:age + KWW:black + educ:urban + IQ:exper +
##     black:south + KWW:age + tenure:black, data = wages)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -840.95 -217.56  -36.92   175.98  1972.19
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  3557.21923   993.37267    3.581  0.00036 ***
## hours        -40.59382    16.84503   -2.410  0.01616 *
## IQ           8.60609     2.62919    3.273  0.00110 **
## KWW          -52.96021    19.81093   -2.673  0.00765 **
## educ        -105.91470    32.69827   -3.239  0.00124 **
## exper        -0.07971    22.30843   -0.004  0.99715
## tenure        3.69311     2.49869    1.478  0.13975
## age          -73.93581    27.83318   -2.656  0.00804 **
## married      167.53913    37.46867    4.471 8.75e-06 ***
## black        237.42907   168.52142    1.409  0.15921
## south       -416.46084   149.65943   -2.783  0.00550 **
## urban       -178.50960   159.21454   -1.121  0.26250
## KWW:educ      2.25091     0.71486    3.149  0.00169 **
## hours:south    8.75759     3.33355    2.627  0.00876 **
## educ:exper     4.47284     1.59583    2.803  0.00517 **
## hours:age      1.02681     0.49890    2.058  0.03986 *
## KWW:black    -11.40575     4.67067   -2.442  0.01480 *
## educ:urban     25.36348    11.75748    2.157  0.03125 *
## IQ:exper     -0.48403     0.21463   -2.255  0.02435 *
## black:south  -112.74961    71.60609   -1.575  0.11570
## KWW:age        0.92317     0.53916    1.712  0.08719 .
## tenure:black   11.87634     7.28489    1.630  0.10339
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 343.9 on 913 degrees of freedom
## Multiple R-squared:  0.2929, Adjusted R-squared:  0.2766
## F-statistic:   18 on 21 and 913 DF,  p-value: < 2.2e-16
```

## Inspect Residuals

```
# Residuals for OLS model
ols.residuals <- residuals(ols.results)
hist(ols.residuals, main = "Histogram of OLS Residuals",
     xlab = "Residuals", col = "blue")
```

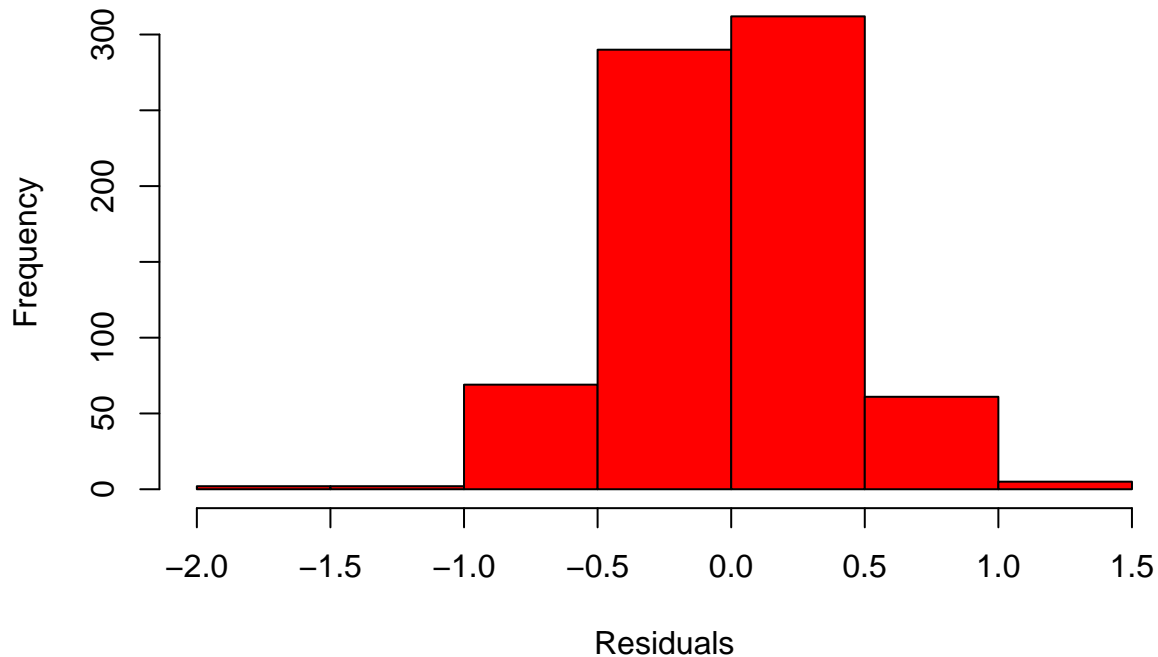
## Histogram of OLS Residuals



```
# Residuals for IV model  
iv.residuals <- residuals(iv.results)  
hist(iv.residuals, main = "Histogram of IV Residuals",  
      xlab = "Residuals", col = "red")
```



## Histogram of IV Residuals



## Evaluating Results

```
# Load sandwich package
library(sandwich)
library(lmtest) # coeftest

# Robust standard errors for OLS
ols.robust <- coeftest(ols.results, vcov = vcovHC(ols.results, type = "HC1"))
print(ols.robust)
```

```
##
## t test of coefficients:
##
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.2230882  0.1637997  31.8871 < 2.2e-16 ***
## educ         0.0679743  0.0068088   9.9833 < 2.2e-16 ***
## age          0.0103972  0.0048646   2.1373 0.0328322 *
## married      0.1891997  0.0419447   4.5107 7.289e-06 ***
## black       -0.2089377  0.0385120  -5.4253 7.384e-08 ***
## exper        0.0133448  0.0038475   3.4685 0.0005474 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```