Assignment 1
Solution Guideline
Review OLS

From the given data set, `assign1.dta`, estimate the following models:

Capital Asset Pricing Model (CAPM)

CAPM: $$r_{jt} = \alpha_j + \beta_{j1} r_{mt} + \varepsilon_{jt} \quad (1)$$

Fama & French three-factor Model (FF)

Fama & French: $$r_{jt} = \alpha_j + \beta_{j1} r_{mt} + \beta_{j2} r_{smbt} + \beta_{j3} r_{hmlt} + \varepsilon_{jt} \quad (2)$$

Carhart four-factor Model

Carhart: $$r_{jt} = \alpha_j + \beta_{j1} r_{mt} + \beta_{j2} r_{smbt} + \beta_{j3} r_{hmlt} + \beta_{j4} r_{wmlt} + \varepsilon_{jt} \quad (3)$$

Where: r_{jt} = excess return on mutual fund j at time t and j = 1, 2, …, 20.

r_{mt} = excess return on market portfolio at time t – representing market risk premium.

r_{smbt} = return on a small-stock portfolio minus the return on a large-stock portfolio (Small Minus Big) at time t – representing size premium.

r_{hmlt} = return on a value-stock portfolio minus the return on a growth-stock portfolio (High Minus Low) at time t – representing value premium.

r_{wmlt} = return on a winners portfolio minus the return on a losers portfolio (Winners Minus Losers) at time t – representing momentum premium.

(a) From CAPM, determine top 3 mutual fund in term of their performance based on Jensen Alpha.

```
mat Alpha_CAPM=(0,9999)

forvalue i=1(1)20 {
   qui reg r`i' rmrf
   est store capm`i'
   mat beta=e(b)
   sca a_capm`i'=el(beta,1,2)
   mat Alpha_CAPM=(Alpha_CAPM \ `i',a_capm`i')
}
est table capm*, star(.1 .05 .01) stat(N rss F r2 r2_a)
```

```
. est table capm*, star(.1 .05 .01) stat(N rss F r2 r2_a)

----------------------------------------------------------------------------
    Variable |     capm1           capm2           capm3           capm4
-------------+--------------------------------------------------------------
        rmrf |   86.67481***    .33259034       79.458292***    71.566194***
       _cons | -.28045261       .02705237       .04241345       .41910739*
-------------+--------------------------------------------------------------
```

N	120	120	120	120
rss	408.66469	17.49366	608.13953	723.83913
F	503.19828	.17308485	284.18142	193.68422
r2	.81004455	.00146467	.70660007	.6214117
r2_a	.80843476	-.00699749	.70411363	.61820332

legend: * p<.1; ** p<.05; *** p<.01

Variable	capm5	capm6	capm7	capm8
rmrf	89.883716***	68.863747***	99.202503***	101.10416***
_cons	.1533913	.2460271*	.06639442	.22738701
N	120	120	120	120
rss	444.17823	259.81331	347.73031	406.34169
F	497.88063	499.62062	774.68148	688.60011
r2	.80840443	.8089442	.86781399	.85370694
r2_a	.80678074	.80732509	.86669377	.85246717

legend: * p<.1; ** p<.05; *** p<.01

Variable	capm9	capm10	capm11	capm12
rmrf	10.99266***	95.818659***	92.431281***	103.15122***
_cons	.03444878	.15557323	.19464246	.03145185
N	120	120	120	120
rss	95.443848	1155.1959	425.2018	298.82029
F	34.655976	217.55296	550.00079	974.67347
r2	.22702011	.64834165	.8233535	.89200799
r2_a	.22046943	.64536149	.8218565	.89109281

legend: * p<.1; ** p<.05; *** p<.01

Variable	capm13	capm14	capm15	capm16
rmrf	95.215162***	95.059925***	99.733614***	96.735158***
_cons	.13681104	.17849533	.09946436	.02742681
N	120	120	120	120
rss	273.31705	271.52934	1344.5332	431.54133
F	907.9584	910.95859	202.50328	593.56291
r2	.88498559	.88532094	.63182904	.83416786
r2_a	.88401089	.88434909	.62870894	.8327625

legend: * p<.1; ** p<.05; *** p<.01

Variable	capm17	capm18	capm19	capm20
rmrf	103.90009***	91.703867***	91.012912***	90.702947***
_cons	.03352088	.09933407	.00020766	.04748425
N	120	120	120	120
rss	2003.3903	368.5193	513.53595	501.25227
F	147.49821	624.64823	441.52533	449.26947
r2	.55555256	.84110916	.78910696	.79198598
r2_a	.55178605	.83976263	.78731973	.79022315

legend: * p<.1; ** p<.05; *** p<.01

```
. mat list Alpha_CAPM

Alpha_CAPM[21,2]
              c1          c2
 r1            0        9999
 r2            1  -.28045261
 r3            2   .02705237
 r4            3   .04241345
 r5            4   .41910739
 r6            5    .1533913
 r7            6    .2460271
 r8            7   .06639442
 r9            8   .22738701
r10            9   .03444878
r11           10   .15557323
r12           11   .19464246
r13           12   .03145185
r14           13   .13681104
r15           14   .17849533
r16           15   .09946436
r17           16   .02742681
r18           17   .03352088
r19           18   .09933407
r20           19   .00020766
r21           20   .04748425
```

According to CAPM, the top 3 mutual funds are mutual fund 4, 6, and 8.

(b) From FF, determine top 3 mutual fund in term of their performance based on Jensen Alpha.

```
mat Alpha_FF=(0,9999)
forvalue i=1(1)20 {
  qui reg r`i' rmrf smb hml
  est store ff`i'
  mat beta=e(b)
  sca a_ff`i'=el(beta,1,4)
  mat Alpha_FF=(Alpha_FF\ `i',a_ff`i')
}
est table ff*, star(.1 .05 .01) stat(N rss F r2 r2_a)
mat list Alpha_FF
```

```
. est table ff*, star(.1 .05 .01) stat(N rss F r2 r2_a)

----------------------------------------------------------------------------
    Variable |      ff1             ff2             ff3             ff4
-------------+--------------------------------------------------------------
        rmrf |  88.458388***    .15618323       75.024622***    61.286991***
         smb | -30.483305**     .60757858        1.092207       53.954532***
         hml | -29.652027**     .01421362      -16.831267       23.318083
       _cons | -.30036799*      .02917021       .09651371       .54137257**
-------------+--------------------------------------------------------------
           N |        120             120             120             120
         rss |  394.50442       17.442327       557.60582       576.53565
           F |  172.19625       .17068035       105.06507       89.562091
          r2 |  .81662652       .00439475       .73098031       .69845558
        r2_a |   .8118841      -.02135366        .7240229       .69065701
----------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01


----------------------------------------------------------------------------
    Variable |      ff5             ff6             ff7             ff8
-------------+--------------------------------------------------------------
```

```
        rmrf |   82.28291***    65.828077***    99.363511***    99.933834***
         smb |  17.510869       7.0524714      -4.2836123       4.2470385
         hml | -9.8956295      -3.8808586      -4.5338083       .35644319
       _cons |  .24517545       .28268096**     .06469084       .24142393
-------------+------------------------------------------------------------
           N |        120            120            120            120
         rss |  333.87253       242.26493       347.39698       404.13022
           F |  229.82317       178.37712        254.1311       227.08932
          r2 |  .85598462       .82184855       .86794071       .85450312
        r2_a |  .85226008       .81724118       .86452538       .85074027
-------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------
    Variable |      ff9            ff10            ff11            ff12
-------------+------------------------------------------------------------
        rmrf |  12.587241***    88.602574***    88.395815***    106.51349***
         smb | -7.7456739       28.144644       21.866246      -16.608141
         hml | -2.8606204       4.5713118       9.9841502      -6.3663201
       _cons |  .01544377       .24200303       .24259989      -.00860432
-------------+------------------------------------------------------------
           N |        120            120            120            120
         rss |  91.799415       1073.6006       402.73013       282.71843
           F |  13.342101       79.645306       192.44011       339.77687
          r2 |  .25653561       .67318044       .83268917       .89782712
        r2_a |  .23730809       .66472821       .82836216       .89518472
-------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------
    Variable |     ff13            ff14            ff15            ff16
-------------+------------------------------------------------------------
        rmrf |   95.41369***    95.023693***     96.70656***    91.734718***
         smb | -9.3380346      -6.5211564       32.201686       13.987945
         hml | -10.507753      -8.0541036       26.643361      -3.5183434
       _cons |  .13495997       .17933912       .13446597       .08765823
-------------+------------------------------------------------------------
           N |        120            120            120            120
         rss |   271.3924       270.18671        1328.344       386.84485
           F |  299.90727        300.1817        67.63698       221.44127
          r2 |   .8857955         .885888       .63626209       .85134377
        r2_a |  .88284194       .88293682       .62685507       .84749921
-------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------
    Variable |     ff17            ff18            ff19            ff20
-------------+------------------------------------------------------------
        rmrf |  97.066451***    87.040137***    84.999799***    84.673247***
         smb |  44.444846       14.334871       12.156005       11.773332
         hml |  25.898477      -1.7189686      -9.886029      -10.417874
       _cons |  .11427555       .15543046       .07292389       .12042667
-------------+------------------------------------------------------------
           N |        120            120            120            120
         rss |  1941.3309       330.98711       441.74976       428.36742
           F |  51.113897       232.28201       174.47532       178.84575
          r2 |  .56932029       .85729155       .81858729       .82223237
        r2_a |  .55818203       .85360081       .81389558       .81763493
-------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

. mat list Alpha_FF

Alpha_FF[21,2]
```

```
             c1          c2
 r1           0        9999
 r2           1  -.30036799
 r3           2   .02917021
 r4           3   .09651371
 r5           4   .54137257
 r6           5   .24517545
 r7           6   .28268096
 r8           7   .06469084
 r9           8   .24142393
r10           9   .01544377
r11          10   .24200303
r12          11   .24259989
r13          12  -.00860432
r14          13   .13495997
r15          14   .17933912
r16          15   .13446597
r17          16   .08765823
r18          17   .11427555
r19          18   .15543046
r20          19   .07292389
r21          20   .12042667
```

According to FF, the top 3 mutual funds are mutual fund 4, 6, and 5.

(c) From Carhart, determine top 3 mutual fund in term of their performance based on Jensen Alpha.

```
mat Alpha_Carh=(0,9999)
forvalue i=1(1)20 {
  qui reg r`i' rmrf smb hml wml
  est store carh`i'
  mat beta=e(b)
  sca a_carh`i'=el(beta,1,5)
  mat Alpha_Carh=(Alpha_Carh\ `i',a_carh`i')
}
est table carh*, star(.1 .05 .01) stat(N rss F r2 r2_a)
mat list Alpha_Carh
```

```
. est table carh*, star(.1 .05 .01) stat(N rss F r2 r2_a)

----------------------------------------------------------------------------
    Variable |      ff1            ff2            ff3            ff4
-------------+--------------------------------------------------------------
        rmrf |   88.37442***    .17216893      74.961681***    61.414372***
         smb | -30.555228**     .62127126      1.0382938       54.063641***
         hml | -29.554175**    -.00441541     -16.757917       23.169639
         wml | -16.896434       3.2167406     -12.665517       25.632471*
       _cons |  .71766532      -.16464281      .85962846      -1.0030189
-------------+--------------------------------------------------------------
           N |         120            120            120            120
         rss |   387.65219      17.193972      553.75558      560.76597
           F |    130.8052      .54401476      78.862559      69.273695
          r2 |   .81981157      .01857085      .73283787      .70670357
        r2_a |   .81354415     -.01556582      .72354528      .69650195
----------------------------------------------------------------------------
                                          legend: * p<.1; ** p<.05; *** p<.01


----------------------------------------------------------------------------
    Variable |      ff5            ff6            ff7            ff8
-------------+--------------------------------------------------------------
        rmrf |  82.211925***    65.851692***    99.347739***    99.956602***
         smb |  17.450066       7.0726993      -4.2971215       4.266541
```

```
         hml | -9.8129059      -3.9083788      -4.5154288       .32990977
         wml |  -14.28416       4.7520146      -3.1736513       4.5816182
       _cons |  1.1058157      -.00363444       .25590768      -.03462485
-------------+------------------------------------------------------------
           N |         120             120             120             120
         rss |   328.97529       241.72293       347.15523       403.62639
           F |   173.85324       132.99139       189.10684        169.0954
          r2 |   .85809703       .82224711        .8680326       .85468451
       r2_a |   .85316128        .8160644       .86344243       .84963006
-------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------------
    Variable |       ff9             ff10            ff11            ff12
-------------+-----------------------------------------------------------------
        rmrf |    12.61187***     88.67622***    88.493872***    106.54016***
         smb | -7.7245783       28.207726       21.950238      -16.585297
         hml | -2.8893211       4.4854877       9.8698788      -6.3973991
         wml |  4.9558586       14.819552       19.731647       5.3665241
       _cons |  -.2831535      -.6508953      -.94625889      -.33194474
-------------+-----------------------------------------------------------------
           N |         120             120             120             120
         rss |    91.20992       1068.3294       393.38536       282.02719
           F |   10.170241       59.653079       147.16777       253.32549
          r2 |   .26130981       .67478508       .83657138       .89807693
       r2_a |   .23561624       .66347326        .8308869       .89453178
-------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------------
    Variable |      ff13             ff14            ff15            ff16
-------------+-----------------------------------------------------------------
        rmrf |   95.452446***     95.059483***    96.765085***    91.676764***
         smb | -9.3048377      -6.4905003       32.251816       13.938304
         hml | -10.552918      -8.0958114       26.575159      -3.4508061
         wml |  7.7987449       7.2018442       11.776732      -11.661906
       _cons |  -.3349251      -.25458186      -.57509829       .79030403
-------------+-----------------------------------------------------------------
           N |         120             120             120             120
         rss |   269.93261       268.94182       1325.0152       383.58062
           F |   224.35281       224.36166          50.489       166.29503
          r2 |   .88640979       .88641377       .63717361       .85259814
       r2_a |   .88245883       .88246294       .62455357       .84747112
-------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

-------------------------------------------------------------------------------
    Variable |      ff17             ff18            ff19            ff20
-------------+-----------------------------------------------------------------
        rmrf |   97.002536***     87.064702***    84.946218***    84.624416***
         smb |   44.390099       14.355913        12.11011       11.731505
         hml |    25.97296      -1.7475961      -9.8235887      -10.360968
         wml | -12.861352        4.943221      -10.781798      -9.8261046
       _cons |  .88918966      -.14240538       .72254197       .71246294
-------------+-----------------------------------------------------------------
           N |         120             120             120             120
         rss |   1937.3606       330.40062       438.95963         426.05
           F |   38.141745       173.06729       130.73574       133.85767
          r2 |   .57020108       .85754442        .8197331       .82319408
       r2_a |   .55525155       .85258944       .81346295        .8170443
-------------------------------------------------------------------------------
                                        legend: * p<.1; ** p<.05; *** p<.01

. mat list Alpha_Carh
```

```
. mat list Alpha_Carh

Alpha_Carh[21,2]
              c1          c2
 r1            0        9999
 r2            1   .71766532
 r3            2  -.16464281
 r4            3   .85962846
 r5            4  -1.0030189
 r6            5   1.1058157
 r7            6  -.00363444
 r8            7   .25590768
 r9            8  -.03462485
r10            9   -.2831535
r11           10   -.6508953
r12           11  -.94625889
r13           12  -.33194474
r14           13   -.3349251
r15           14  -.25458186
r16           15  -.57509829
r17           16   .79030403
r18           17   .88918966
r19           18  -.14240538
r20           19   .72254197
r21           20   .71246294
```

According to Carhart, the top 3 mutual funds are mutual fund 5, 17, and 3.

(d) From the estimated result of Carhart four-factor model (3) of mutual fund #1, evaluate whether there exist Autocorrelation and Multicollinearity problem or not? Which model between Carhart or FF should be employed in this case? Why? Also, make evaluation of the estimated results of Carhart model in term of (i) sign and meaning of the estimated coefficients; (ii) overall test; (iii) coefficient of determination; and (iv) individual test.

```
. tsset time
        time variable:  time, 1 to 120
                delta:  1 unit

. reg r1 rmrf smb hml wml

      Source |       SS           df       MS      Number of obs   =       120
-------------+----------------------------------   F(4, 115)       =    130.81
       Model |    1763.719         4   440.92975   Prob > F        =    0.0000
    Residual |  387.652185       115  3.37088857   R-squared       =    0.8198
-------------+----------------------------------   Adj R-squared   =    0.8135
       Total |  2151.37118       119  18.0787494   Root MSE        =     1.836

------------------------------------------------------------------------------
          r1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        rmrf |   88.37442   4.132204    21.39   0.000     80.18932    96.55952
         smb |  -30.55523   15.20777    -2.01   0.047     -60.6789   -.4315607
         hml |  -29.55418   14.55813    -2.03   0.045    -58.39103   -.7173227
         wml |  -16.89643    11.8509    -1.43   0.157    -40.37078    6.57791
       _cons |   .7176653   .7344903     0.98   0.331    -.7372186    2.172549
------------------------------------------------------------------------------

. estat dwatson

Durbin-Watson d-statistic(  5,   120) =  2.349188

. estat vif
```

```
    Variable |       VIF       1/VIF
-------------+----------------------
         smb |     11.39    0.087771
         hml |     10.87    0.092012
        rmrf |      1.18    0.851025
         wml |      1.00    0.998808
-------------+----------------------
    Mean VIF |      6.11

. prais r1 rmrf smb hml wml, corc

Iteration 0:  rho = 0.0000
Iteration 1:  rho = -0.1841
Iteration 2:  rho = -0.1908
Iteration 3:  rho = -0.1910
Iteration 4:  rho = -0.1910
Iteration 5:  rho = -0.1910

Cochrane-Orcutt AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =       119
-------------+----------------------------------   F(4, 114)       =    140.63
       Model |  1818.83244         4  454.708111   Prob > F        =    0.0000
    Residual |  368.598498       114  3.23332015   R-squared       =    0.8315
-------------+----------------------------------   Adj R-squared   =    0.8256
       Total |  2187.43094       118  18.5375504   Root MSE        =    1.7981

------------------------------------------------------------------------------
          r1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        rmrf |   88.77771   4.054447    21.90   0.000     80.74588    96.80953
         smb |   -30.4676   14.69292    -2.07   0.040    -59.57416    -1.36104
         hml |  -27.87074   14.11204    -1.97   0.051    -55.82658    .0850923
         wml |  -13.78955   9.930757    -1.39   0.168     -33.4623    5.883207
       _cons |    .544089   .6141342     0.89   0.378    -.6725061    1.760684
-------------+----------------------------------------------------------------
         rho |  -.1909598
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    2.349188
Durbin-Watson statistic (transformed) 2.033707

. reg r1 rmrf smb hml

      Source |       SS           df       MS      Number of obs   =       120
-------------+----------------------------------   F(3, 116)       =    172.20
       Model |  1756.86676         3  585.622255   Prob > F        =    0.0000
    Residual |  394.504419       116  3.40090016   R-squared       =    0.8166
-------------+----------------------------------   Adj R-squared   =    0.8119
       Total |  2151.37118       119  18.0787494   Root MSE        =    1.8442

------------------------------------------------------------------------------
          r1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        rmrf |   88.45839   4.150136    21.31   0.000     80.23852    96.67826
         smb |  -30.48331   15.27524    -2.00   0.048    -60.73783   -.2287763
         hml |  -29.65203   14.62263    -2.03   0.045    -58.61399   -.6900658
       _cons |   -.300368   .1729078    -1.74   0.085    -.6428337    .0420977
------------------------------------------------------------------------------

. estat dwatson

Durbin-Watson d-statistic(  4,   120) =  2.342202

. prais r1 rmrf smb hml, corc

Iteration 0:  rho = 0.0000
```

```
Iteration 1:  rho = -0.1818
Iteration 2:  rho = -0.1861
Iteration 3:  rho = -0.1861
Iteration 4:  rho = -0.1862
Iteration 5:  rho = -0.1862

Cochrane-Orcutt AR(1) regression -- iterated estimates

      Source |       SS           df       MS      Number of obs   =       119
-------------+----------------------------------   F(3, 115)       =    185.06
       Model |  1809.53089         3  603.176963   Prob > F        =    0.0000
    Residual |  374.823832       115  3.25933767   R-squared       =    0.8284
-------------+----------------------------------   Adj R-squared   =    0.8239
       Total |  2184.35472       118  18.5114807   Root MSE        =    1.8054

------------------------------------------------------------------------------
          r1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        rmrf |   88.82326   4.073427    21.81   0.000     80.75458    96.89193
         smb |  -30.31337   14.76278    -2.05   0.042     -59.5556   -1.071135
         hml |  -27.87378   14.17844    -1.97   0.052    -55.95854    .2109794
       _cons |  -.2852309   .1443278    -1.98   0.051    -.5711166    .0006547
-------------+----------------------------------------------------------------
         rho |  -.1861513
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    2.342202
Durbin-Watson statistic (transformed) 2.031008
```

According to Durbin Watson test of 2.3491, which is greater than 2.3, it indicates that there exists significant first order autocorrelation problem in the result of Carhart model. Based on (i) VIF of wml with value of 1.0 and (ii) t-test of -1.43 with p-value of 0.157, which is greater than 0.05; it indicates that `wml` *should not be in the model. After dropping* `wml` *and solving first autocorrelation, there is no multicollinearity problem in FF model.*

Evaluation of FF model:

(1) Sign and meaning
(2) Overall test F-test is significant
(3) R-squared = 0.8284
(4) Individual t-test are all significant

(e) Based on (a), (b), and (c), which result is the most appropriated one? Why?

CAPM since estimated coefficients of factor 2-4 in FF and Carhart models of all mutual funds, except 1 and 4, are all insignificant.