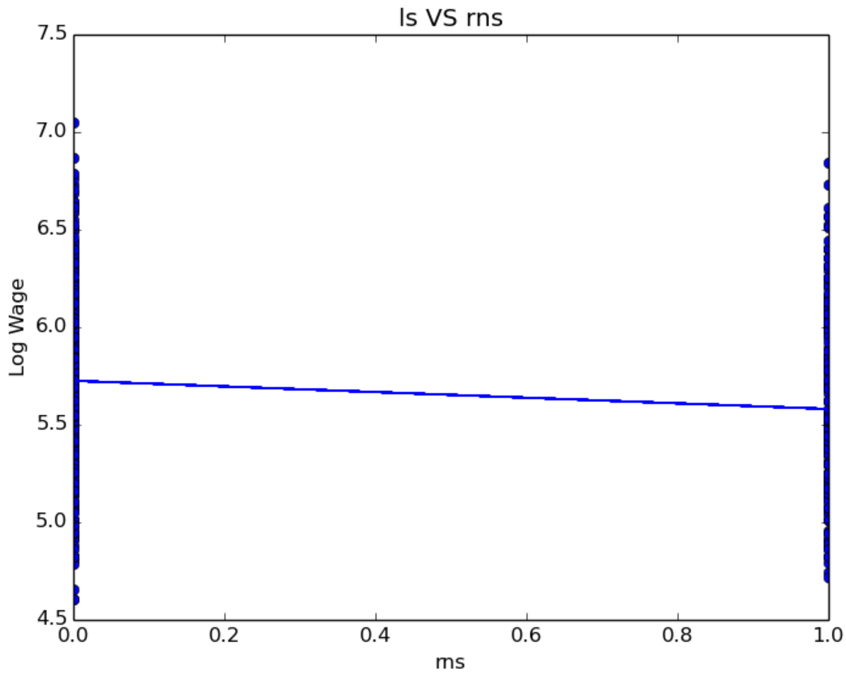
Assignment 3: Applied data science

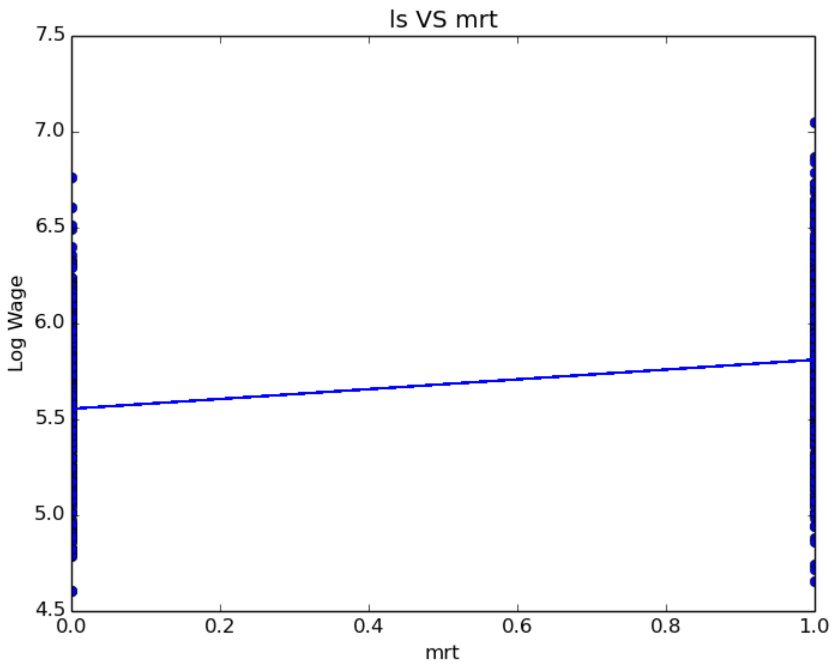
ANSWERS:

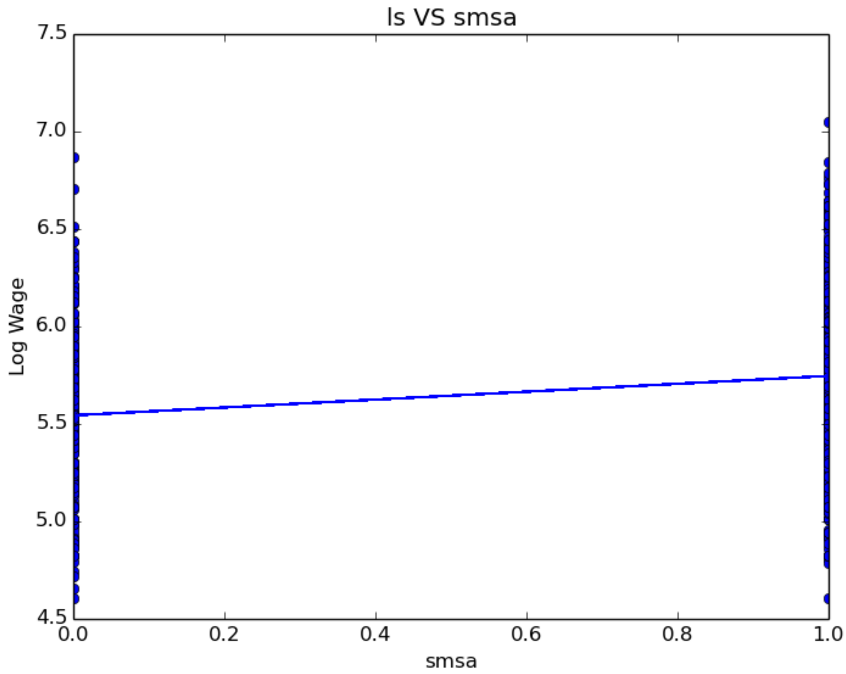
1. Solution are described in the following sections:
   a. Reading dta data process is attached in the source code.
   b. Summary of statistics :

```
rns =
count    758.000000
mean       0.269129
std        0.443800
min        0.000000
25%        0.000000
50%        0.000000
75%        1.000000
max        1.000000
dtype: float64

mrt =
count    758.000000
mean       0.514512
std        0.500119
min        0.000000
25%        0.000000
50
%       1.000000
75%        1.000000
max        1.000000
dtype: float64

smsa =
count    758.000000
mean       0.704485
std        0.456575
min        0.000000
25%        0.000000
50%        1.000000
75%        1.000000
max        1.000000
dtype: float64

med =
count    758.00000
mean      10.91029
std        2.74112
min        0.00000
25%        9.00000
50%       12.00000
75%       12.00000
max       18.00000
dtype: float64

ziq =
count    758.000000
mean     103.856201
std       13.618666
min       54.000000
25%       95.250000
50%      104.000000
75%      113.750000
max      145.000000
dtype: float64

kww =
count    758.000000
mean      36.573879
std        7.302247
min       12.000000
25%       32.000000
50%       37.000000
75%       41.000000
max       56.000000
dtype: float64

age =
count    758.000000
mean      21.835092
std        2.981756
min       16.000000
25%       20.000000
50%       22.000000
75%       24.000000
max       30.000000
dtype: float64

s =
count    758.000000
mean      13.405013
std        2.231828
min        9.000000
25%       12.000000
50%       12.000000
75%       16.000000
max       18.000000
dtype: float64

expr =
count    758.000000
mean       1.735429
std        2.105542
min        0.000000
25%        0.281500
50%        0.960000
75%        2.440000
max       11.444000
dtype: float64

lw =
count    758.000000
mean       5.686739
std        0.428949
min        4.605000
25%        5.380000
50%        5.684000
75%        5.991000
max        7.051000
dtype: float64
```

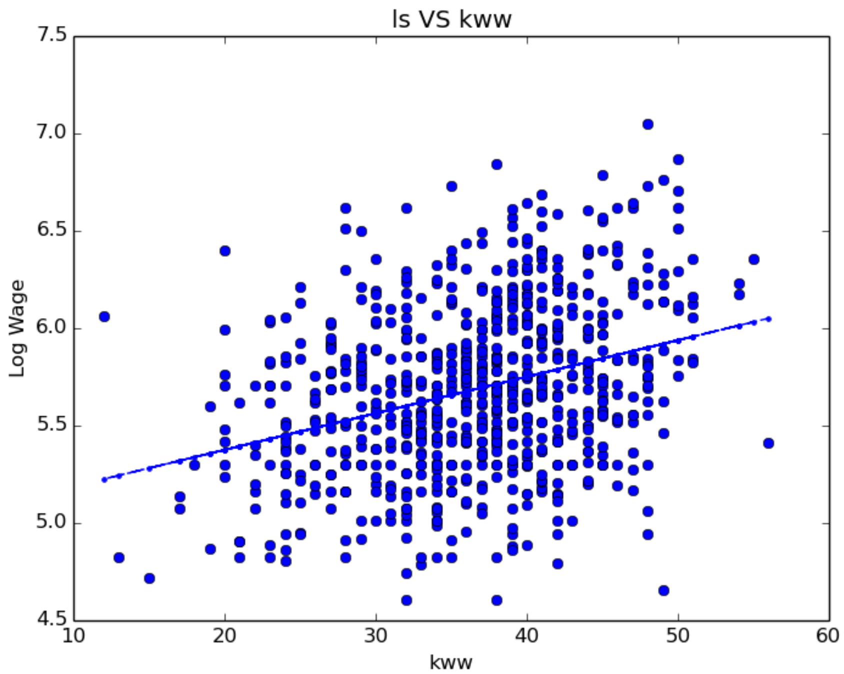
c. Scatter plot of Log Wages against (RNS ,MRT, SMSA,KWW,EXPR):



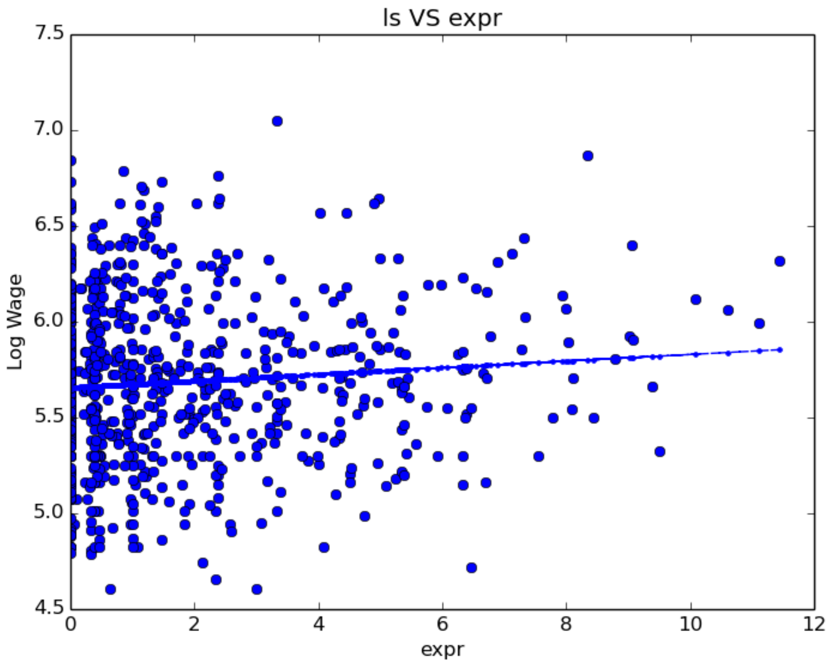




ls VS smsa
Log Wage
smsa
7.5
7.0
6.5
6.0
5.5
5.0
4.5
0.0
0.2
0.4
0.6
0.8
1.0



ls VS kww
Log Wage
kww
7.5
7.0
6.5
6.0
5.5
5.0
4.5
10
20
30
40
50
60



d. The bivariate square models for model point c:

RNS

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.022
Model:                            OLS   Adj. R-squared:                  0.021
Method:                 Least Squares   F-statistic:                     17.30
Date:                Thu, 25 Sep 2014   Prob (F-statistic):           3.56e-05
Time:                        14:47:11   Log-Likelihood:                -424.90
No. Observations:                 758   AIC:                             853.8
Df Residuals:                     756   BIC:                             863.1
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          5.7256      0.018    317.540      0.000         5.690     5.761
rns           -0.1446      0.035     -4.159      0.000        -0.213    -0.076
==============================================================================
Omnibus:                        7.316   Durbin-Watson:                   1.734
```

```
Prob(Omnibus):                  0.026   Jarque-Bera (JB):              7.370
Skew:                           0.223   Prob(JB):                     0.0251
Kurtosis:                       2.817   Cond. No.                       2.45
==============================================================================
```

MRT

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.089
Model:                            OLS   Adj. R-squared:                  0.088
Method:                 Least Squares   F-statistic:                     73.70
Date:                Thu, 25 Sep 2014   Prob (F-statistic):           5.14e-17
Time:                        14:47:12   Log-Likelihood:                -398.21
No. Observations:                 758   AIC:                             800.4
Df Residuals:                     756   BIC:                             809.7
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          5.5552      0.021    260.095      0.000         5.513     5.597
mrt            0.2556      0.030      8.585      0.000         0.197     0.314
==============================================================================
Omnibus:                        3.526   Durbin-Watson:                 1.667
Prob(Omnibus):                  0.172   Jarque-Bera (JB):              3.192
Skew:                           0.092   Prob(JB):                      0.203
Kurtosis:                       2.741   Cond. No.                       2.65
==============================================================================
```

SMSA

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.046
Model:                            OLS   Adj. R-squared:                  0.045
Method:                 Least Squares   F-statistic:                     36.85
Date:                Thu, 25 Sep 2014   Prob (F-statistic):           2.02e-09
```

```
Time:                     14:47:13         Log-Likelihood:             -415.43
No. Observations:              758         AIC:                          834.9
Df Residuals:                  756   BIC:                          844.1
Df Model:                        1
==============================================================================
              coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const         5.5441      0.028    197.967      0.000        5.489     5.599
smsa          0.2025      0.033      6.070      0.000        0.137     0.268
==============================================================================
Omnibus:                    5.469   Durbin-Watson:                1.766
Prob(Omnibus):              0.065   Jarque-Bera (JB):             5.357
Skew:                       0.174   Prob(JB):                    0.0687
Kurtosis:                   2.781   Cond. No.                      3.45
==============================================================================
```

KWW

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw          R-squared:                   0.102
Model:                            OLS          Adj. R-squared:              0.101
Method:                 Least Squares          F-statistic:                 85.91
Date:                Thu, 25 Sep 2014          Prob (F-statistic):       1.93e-19
Time:                        14:47:14          Log-Likelihood:            -392.68
No. Observations:                 758          AIC:                         789.4
Df Residuals:                     756          BIC:                         798.6
Df Model:                           1
==============================================================================
              coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const         5.0005      0.076     66.228      0.000        4.852     5.149
kww           0.0188      0.002      9.269      0.000        0.015     0.023
==============================================================================
Omnibus:                        4.135          Durbin-Watson:               1.731
Prob(Omnibus):                  0.126          Jarque-Bera (JB):            3.864
```

```
Skew:                           0.123           Prob(JB):                        0.145
Kurtosis:                        2.752          Cond. No.                         191.
==============================================================================
```

EXPR

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.007
Model:                            OLS   Adj. R-squared:                  0.006
Method:                 Least Squares   F-statistic:                     5.452
Date:                Fri, 26 Sep 2014   Prob (F-statistic):             0.0198
Time:                        18:10:22   Log-Likelihood:                -430.75
No. Observations:                 758   AIC:                             865.5
Df Residuals:                     756   BIC:                             874.8
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          5.6568      0.020    280.924      0.000         5.617     5.696
expr           0.0172      0.007      2.335      0.020         0.003     0.032
==============================================================================
Omnibus:                        7.070   Durbin-Watson:                   1.673
Prob(Omnibus):                  0.029   Jarque-Bera (JB):                6.678
Skew:                           0.187   Prob(JB):                       0.0355
Kurtosis:                       2.733   Cond. No.                         3.74
==============================================================================
```

Comments:

- RNS

  Negative coefficient shows that people from southern states tend to have lower wage than non-southern resident.
- MRT

  Positive coefficient shows that married people tend to have higher wage, possibly because the demand of financial stability.
- SMSA

Positive coefficient shows that people who live in urban areas have a tendency to have higher wage.

- KWW

  The data shows strong positive correlation between the result of "Knowledge of the World of Work" test score with high wage.

- EXPR

  The graph shows strong correlation between experience in years to higher wage.

e. Bivariate least squares model relating log wages to schooling and its 95 confidence interval:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.253
Model:                            OLS   Adj. R-squared:                  0.252
Method:                 Least Squares   F-statistic:                     255.7
Date:                Thu, 25 Sep 2014   Prob (F-statistic):           8.52e-50
Time:                        14:47:14   Log-Likelihood:                -323.05
No. Observations:                 758   AIC:                             650.1
Df Residuals:                     756   BIC:                             659.4
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          4.3915      0.082     53.481      0.000         4.230     4.553
s              0.0966      0.006     15.991      0.000         0.085     0.108
==============================================================================
Omnibus:                        1.749   Durbin-Watson:                   1.733
Prob(Omnibus):                  0.417   Jarque-Bera (JB):                1.697
Skew:                           0.021   Prob(JB):                        0.428
Kurtosis:                       3.228   Cond. No.                         83.2
==============================================================================
```

Note: using python statsmodels we can automatically calculate the range of 95% confidence level, which is **0.085** (lower boundaries) and **0.108** (upper boundaries).

f. Multivariate least squares model relating log wages to the variables in b:

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.433
Model:                            OLS   Adj. R-squared:                  0.426
Method:                 Least Squares   F-statistic:                     63.38
Date:                Thu, 25 Sep 2014   Prob (F-statistic):          4.21e-86a
Time:                        15:47:24   Log-Likelihood:                -218.67
No. Observations:                 758   AIC:                             457.3
Df Residuals:                     748   BIC:                             503.6
Df Model:                           9
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          3.4149      0.123     27.838      0.000         3.174     3.656
rns           -0.0877      0.027     -3.203      0.001        -0.142    -0.034
mrt            0.1007      0.027      3.716      0.000         0.047     0.154
smsa           0.1368      0.027      5.144      0.000         0.085     0.189
med            0.0059      0.005      1.258      0.209        -0.003     0.015
iq             0.0042      0.001      3.998      0.000         0.002     0.006
kww           -0.0023      0.002     -1.174      0.241        -0.006     0.002
age            0.0497      0.006      8.342      0.000         0.038     0.061
s              0.0479      0.008      6.159      0.000         0.033     0.063
expr           0.0022      0.007      0.310      0.757        -0.012     0.016
==============================================================================
Omnibus:                       12.122   Durbin-Watson:                   1.798
Prob(Omnibus):                  0.002   Jarque-Bera (JB):               18.748
Skew:                          -0.104   Prob(JB):                     8.49e-05
Kurtosis:                       3.742   Cond. No.                     1.19e+03
==============================================================================

Warnings:
[1] The condition number is large, 1.19e+03. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Note: using python statsmodels we can automatically calculate the range of 95% confidence level, which is **0.033** (lower boundaries) and **0.063** (upper boundaries).

g. Generate a variable that is age raised to the power of two (i.e., is age squared), then re-estimate f. including age-squared:

```
Results
==============================================================================
Dep. Variable:                     lw   R-squared:                       0.438
Model:                            OLS   Adj. R-squared:                  0.430
Method:                 Least Squares   F-statistic:                     58.21
Date:                Thu, 25 Sep 2014   Prob (F-statistic):           1.06e-86
Time:                        16:14:55   Log-Likelihood:                -215.09
No. Observations:                 758   AIC:                             452.2
Df Residuals:                     747   BIC:                             503.1
Df Model:                          10
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          4.8628      0.557      8.728      0.000         3.769     5.957
rns           -0.0847      0.027     -3.103      0.002        -0.138    -0.031
mrt            0.1118      0.027      4.095      0.000         0.058     0.165
smsa           0.1400      0.027      5.281      0.000         0.088     0.192
med            0.0056      0.005      1.207      0.228        -0.004     0.015
iq             0.0041      0.001      3.880      0.000         0.002     0.006
kww           -0.0020      0.002     -1.037      0.300        -0.006     0.002
age           -0.0838      0.050     -1.660      0.097        -0.183     0.015
s              0.0511      0.008      6.519      0.000         0.036     0.066
expr           0.0037      0.007      0.515      0.606        -0.010     0.018
a              0.0029      0.001      2.664      0.008         0.001     0.005
==============================================================================
Omnibus:                       14.225   Durbin-Watson:                   1.795
Prob(Omnibus):                  0.001   Jarque-Bera (JB):               22.965
Skew:                          -0.121   Prob(JB):                     1.03e-05
Kurtosis:                       3.818   Cond. No.                     2.46e+04
==============================================================================
```

```
Warnings:
[1] The condition number is large, 2.46e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
```

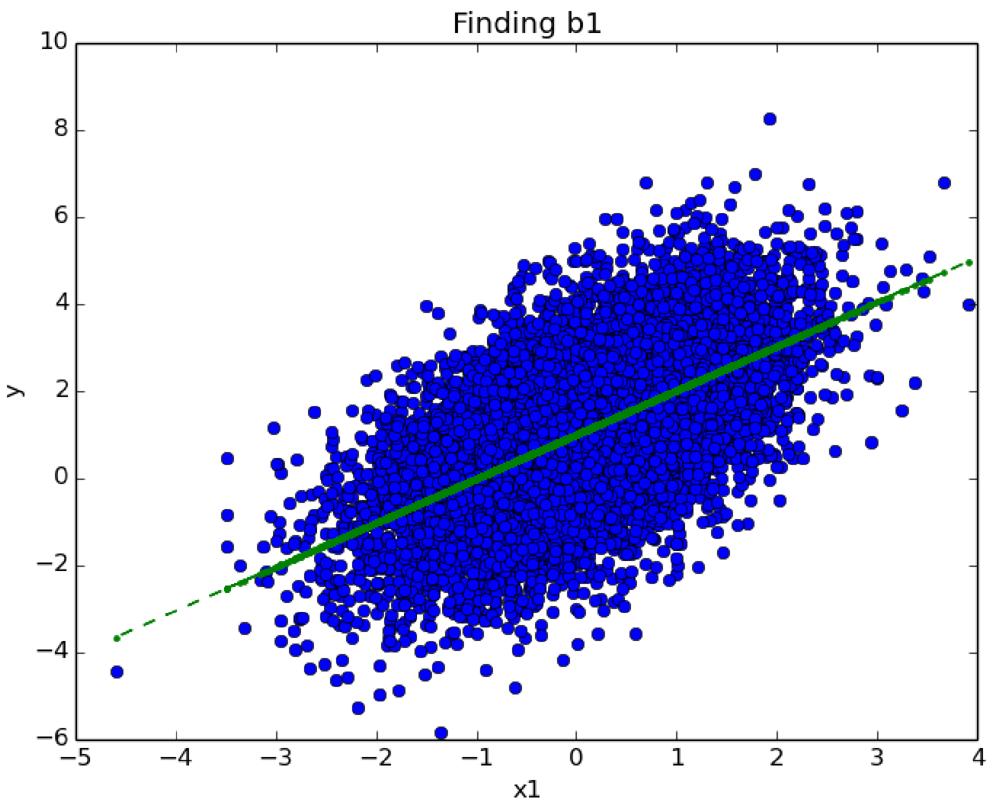
Note: by including age square into the equation, the coefficient of original age variable is getting smaller while some other variables' coefficients also changed. This shows that in multivariate regression adding new variables affect the whole coefficient, mostly one with high correlation with the one to be included (in this one age and age square).

h. The difference of estimates of the returns to schooling in e. and f. results shows that multivariable might have correlation to each other. Moreover, it can also be assumed that the covariance of the schooling and the unknown error might not be zero.

ANSWERS:

2. Solution are described in the following sections:

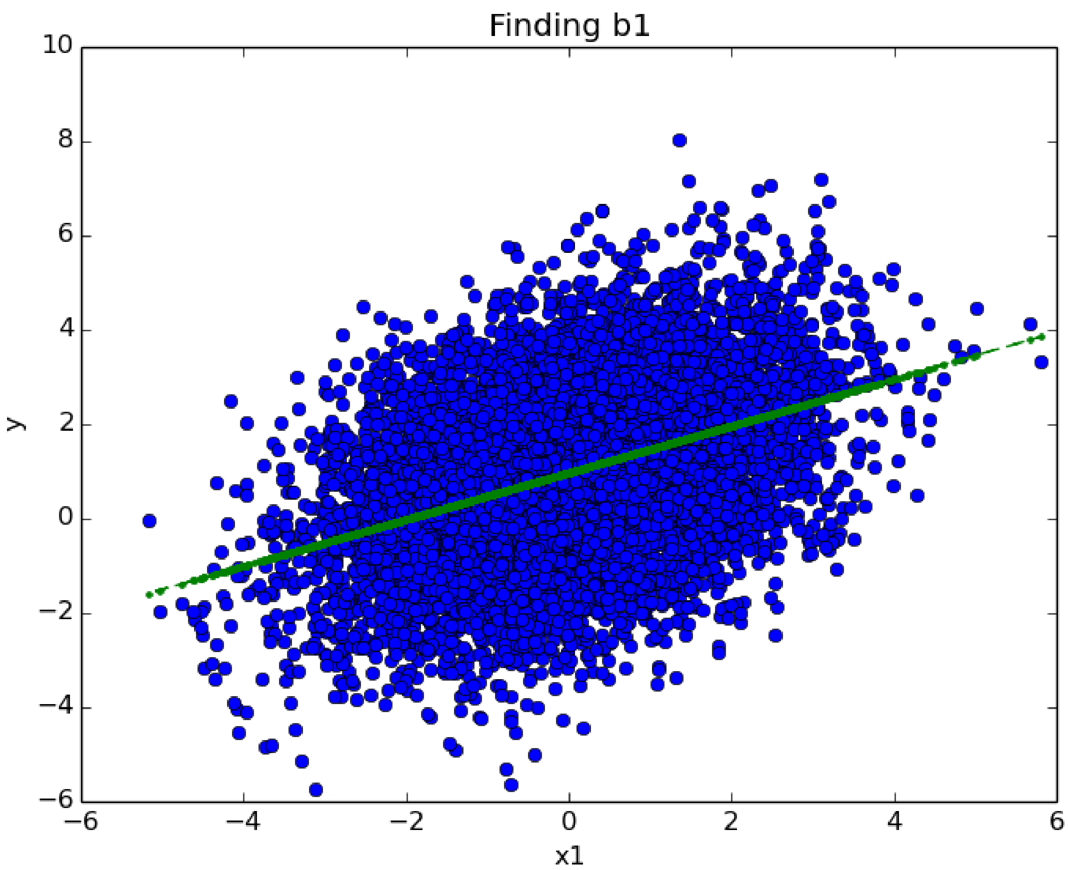
    a. simulation of DGP assuming 10,000 observations and estimate the least squares value for b_1 based on equations in problem 2a:




```
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.342
Model:                            OLS   Adj. R-squared:                  0.342
Method:                 Least Squares   F-statistic:                     5202.
Date:                Thu, 25 Sep 2014   Prob (F-statistic):               0.00
Time:                        17:09:09   Log-Likelihood:                -17503.
No. Observations:               10000   AIC:                         3.501e+04
Df Residuals:                    9998   BIC:                         3.502e+04
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
```

```
const          1.0101      0.014     72.509      0.000       0.983     1.037
x1             1.0143      0.014     72.122      0.000       0.987     1.042
==============================================================================
Omnibus:                        1.133   Durbin-Watson:                   2.017
Prob(Omnibus):                  0.567   Jarque-Bera (JB):                1.109
Skew:                          -0.002   Prob(JB):                        0.574
Kurtosis:                       3.051   Cond. No.                         1.02
==============================================================================
```

b. simulation of DGP assuming 10,000 observations and estimate the least squares value for b_1 based on equations in problem 2b:




```
                            OLS Regression Results
==============================================================================
Dep. Variable:                      y   R-squared:                       0.160
Model:                            OLS   Adj. R-squared:                  0.160
```

```
Method:                 Least Squares   F-statistic:                     1906.
Date:                Thu, 25 Sep 2014   Prob (F-statistic):               0.00
Time:                        17:15:39   Log-Likelihood:                -18896.
No. Observations:               10000   AIC:                         3.780e+04
Df Residuals:                    9998   BIC:                         3.781e+04
Df Model:                           1
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          0.9779      0.016     61.073      0.000         0.947     1.009
x1             0.4957      0.011     43.663      0.000         0.473     0.518
==============================================================================
Omnibus:                        0.328   Durbin-Watson:                   1.976
Prob(Omnibus):                  0.849   Jarque-Bera (JB):                0.359
Skew:                          -0.005   Prob(JB):                        0.836
Kurtosis:                       2.972   Cond. No.                         1.41
==============================================================================
```

c. **Comments:**

To find all variables that are relevant in the real world is impossible, and what's more it may also lead to add unnecessary process as follows:

- If we limit to the data being used in this problem 2, (data are random variables and independent), the overuse of many more statistical model might result in these problems:
  - Model might show that predictors have correlation to each other (although it should be totally independent)
  - Covariance to new unknown errors might not be zero.
- Every time you add more predictor, by default the value of R-squared increases. Too many predictors and higher order polynomials may lead to model new random noise in the data, as known as *overfitting*, where it could produce higher R values and make it harder to make predictions.

ANSWERS:

3. Solution are described in the following sections:
   a. Reading dta data process is attached in the source code.
   b. Treating the years 70-78 of the NLSW data as a training set and estimate the model presented in class both as a linear and a logit:

- Get the data year 70-78 and fit the linear and logit model

```
...
df_sliced2 = df[df['year'] >=70]
df_sliced = df_sliced2[df['year'] <=78]
x= df_sliced[['year','age','grade','south','black','smsa']]
y = df_sliced.union
X = sm.add_constant(x)
#Least square regression
model_linear = sm.OLS(y, X)
results_linear = model_linear.fit()
print(results_linear.summary())
#Logit square regression
model_logit = sm.Logit(y, X)
results_logit = model_logit.fit()
print(results_logit.summary())
```

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                  union   R-squared:                       0.045
Model:                            OLS   Adj. R-squared:                  0.045
Method:                 Least Squares   F-statistic:                     204.8
Date:                Thu, 25 Sep 2014   Prob (F-statistic):          2.98e-256
Time:                        18:16:49   Log-Likelihood:                -13562.
No. Observations:               26200   AIC:                         2.714e+04
Df Residuals:                   26193   BIC:                         2.720e+04
Df Model:                           6
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const          0.1714      0.052      3.277      0.001         0.069     0.274
```

```
year          -0.0029      0.001     -3.183      0.001        -0.005    -0.001
age            0.0044      0.001      5.240      0.000         0.003     0.006
grade          0.0121      0.001     11.283      0.000         0.010     0.014
south         -0.1421      0.005    -26.236      0.000        -0.153    -0.131
black          0.1442      0.006     24.148      0.000         0.132     0.156
smsa           0.0159      0.006      2.781      0.005         0.005     0.027
==============================================================================
Omnibus:                     4332.120   Durbin-Watson:                   1.987
Prob(Omnibus):                  0.000   Jarque-Bera (JB):             6880.188
Skew:                           1.252   Prob(JB):                         0.00
Kurtosis:                       2.815   Cond. No.                     1.90e+03
==============================================================================

Warnings:
[1] The condition number is large, 1.9e+03. This might indicate that there are
strong multicollinearity or other numerical problems.
Optimization terminated successfully.
         Current function value: 0.506056
         Iterations 6

                           Logit Regression Results
==============================================================================
Dep. Variable:                  union   No. Observations:                26200
Model:                          Logit   Df Residuals:                    26193
Method:                           MLE   Df Model:                            6
Date:                Thu, 25 Sep 2014   Pseudo R-squ.:                 0.04368
Time:                        18:16:49   Log-Likelihood:                -13259.
converged:                       True   LL-Null:                       -13864.
                                        LLR p-value:                1.894e-258
==============================================================================
                 coef    std err          z      P>|z|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const         -1.5927      0.318     -5.016      0.000        -2.215    -0.970
year          -0.0180      0.006     -3.270      0.001        -0.029    -0.007
age            0.0269      0.005      5.293      0.000         0.017     0.037
grade          0.0744      0.007     11.265      0.000         0.061     0.087
```

south	-0.9013	0.035	-25.440	0.000	-0.971	-0.832
black	0.8535	0.036	23.994	0.000	0.784	0.923
smsa	0.0890	0.036	2.445	0.014	0.018	0.160

==

c. Treat the years 80-88 of the NLSW data as a set of attributes on individuals that you would like to classify as union/non-union, using a threshold of 0.25 and both the linear and the logit classifiers estimated in b.:

   The output of the calculation:

- Using the coefficient from year 70-78 to predict year 80-88:

```
...
df_sample2 = df[df['year'] >=80]
df_sample = df_sample2[df['year'] <=88]
y_hat_linear = []
y_hat_logit = []
var= df_sample[['year','age','grade','south','black','smsa']]
X_pred = sm.add_constant(var)
#linear
y_hat_linear = results_linear.predict(X_pred)
#logit
y_hat_logit = results_logit.predict(X_pred)
...
```

```
Output:
    LINEAR: Estimated number of people which is Union : 4308
    LOGIT : Estimated number of people which is Union : 3749
```

d. For both models, summarize the accuracy of your support vector machine (with a threshold of 0.2) in a table by comparing your union prediction to what was actually observed.   It might look something like the table below.

- Now comparing prediction based on data year 70-78 with the actual linear and logit model from actual observation (year 80-88):

```
...
df_sample2 = df[df['year'] >=80]
df_sample = df_sample2[df['year'] <=88]
y_act = df_sample.union
var= df_sample[['year','age','grade','south','black','smsa']]
X_pred = sm.add_constant(var)

#linear regression
model_linear_act = sm.OLS(y_act, X_pred)
results_linear_act = model_linear_act.fit()
#Logit square regression
model_logit_act = sm.Logit(y_act, X_pred)
results_logit_act = model_logit_act.fit()

 #Actual value from the data
##############################
union_count_real = 0
for people in df_sample.union:
 if float(people) == 1: union_count_real += 1
print 'REAL DATA : Actual number of people which is Union : %d' %
union_count_real

...
```

Because there might be misunderstanding to this questions, the middle column stating the number of union student predicted using coefficient in 80-88 were added

SVM	Number of Union Members (Predicted using 70-78 training data)	Number of Union Members (predicted using 80-88 actual data)	Number of Union Members (Actual)
Linear	9217	9968	3323
Logit	8230	9421	