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Course: Econometrics 512 (Homework 3)

Impact of Human Capital Development and Capital Accumulation on Economic Growth: Evidence from OLS and IV Regression Analysis

Problem 1

Question 1a:

The estimated results on the impact of capital accumulation and human capital development on economic growth are reported in Table 2. Based on t-statistics and standard error, the result shows that both human capital development captured as labor in our model and capital accumulation captured by capital are highly statistically significant. Specifically, a 1% increase in both capital and labor will lead to 52% and 47% increase in output respectively. Finally, the R-squared shows that 96% variation of the model can be explained by labor and capital.

Table 1: **Multiple Regression Result**

```
. * Problem 1a: Run the multiple regression
.
. reg lnoutput lnlabor lncapital

      Source |       SS           df       MS      Number of obs   =        51
-------------+----------------------------------   F(   2,     48)   =    645.93
       Model |  91.9246133         2  45.9623067   Prob > F          =    0.0000
    Residual |  3.41551772        48  .071156619   R-squared         =    0.9642
-------------+----------------------------------   Adj R-squared     =    0.9627
       Total |  95.340131         50  1.90680262   Root MSE          =    .26675

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |   .4683318   .0989259     4.73   0.000      .269428    .6672357
   lncapital |   .5212795    .096887     5.38   0.000      .326475    .7160839
       _cons |   3.887599   .3962281     9.81   0.000     3.090929    4.684269
------------------------------------------------------------------------------
```

Question 2a:

In this section, we carried out a sensitivity analysis by examining the individual impact of capital on output and the impact of capital on labor. The objective here is to see the relationship that exists between the residuals coming from individual's regression analysis. We interpret the results as follows.

Case 1: impact of capital on output

In this subsection, we show that capital has a strong significant impact on output. In particular, a 1% increase in capital will lead to a 96% increase in output. Intuitive, capital is one the factors that derives output growth.

Case 2: impact of capital on labour

In this subsection, we show that capital has a strong significant impact on labor. In particular, a 1% increase in capital will lead to a 94% increase in output. Intuitive, capital accumulation is one the factors that derives human capital development.

Table 2a: Simple Regression Result for case 1

```
. * problem 1b: Regress lnoutput on lncapital to predict the first residual.
. *Similarly, regress  lnlabour on lncapital to predict the second residual
.
. reg lnoutput lncapital

      Source |       SS           df       MS      Number of obs   =        51
-------------+----------------------------------   F(1, 49)        =    883.41
       Model |  90.3298259         1  90.3298259   Prob > F        =    0.0000
    Residual |   5.0103051        49  .102251124   R-squared       =    0.9474
-------------+----------------------------------   Adj R-squared   =    0.9464
       Total |   95.340131        50  1.90680262   Root MSE        =    .31977

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lncapital |   .9617962   .0323595    29.72   0.000     .8967674    1.026825
```

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```
       _cons |   3.391633    .458073     7.40   0.000     2.471101    4.312165
------------------------------------------------------------------------------

. predict e1, residuals
```

Table 2b: Simple Regression Result for case 2

```
. reg  lnlabor lncapital

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  1,    49) =  582.21
       Model |  86.3937937     1  86.3937937           Prob > F      =  0.0000
    Residual |  7.27102154    49  .148388195           R-squared     =  0.9224
-------------+------------------------------           Adj R-squared =  0.9208
       Total |  93.6648153    50  1.87329631           Root MSE      =  .38521

------------------------------------------------------------------------------
     lnlabor |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lncapital |   .9406082   .0389823    24.13   0.000     .8622704    1.018946
       _cons |  -1.059006   .5518237    -1.92   0.061    -2.167937    .0499254
------------------------------------------------------------------------------

. predict e2, residuals
```

Case 3: Impact of innovation 2 (Case 2 residual) on innovation 1 (Case 1 residual)

In this subsection, we show that the innovation coming from the impact of capital on labor has a strong significant impact on innovation 1. In particular, a 1% increase in innovation 2 will lead to capital will lead to a 46% increase in output. Specifically, the two residuals are closely related.

Table 2c: Simple Regression Result for case 3

```
. reg e1 e2

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  1,    49) =   22.88
       Model |  1.59478739     1  1.59478739           Prob > F      =  0.0000
    Residual |  3.41551769    49  .069704443           R-squared     =  0.3183
-------------+------------------------------           Adj R-squared =  0.3044
       Total |  5.01030508    50  .100206102           Root MSE      =  .26402

------------------------------------------------------------------------------
          e1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          e2 |   .4683318   .0979112     4.78   0.000     .2715719    .6650918
       _cons |  -9.90e-10   .0369696    -0.00   1.000    -.0742933    .0742933
------------------------------------------------------------------------------
```

Question 1c

In this section, we alternatively test for our result in Question 1b of case 3 to see if we will arrive at the same result. The result that emerges from this analysis shows that using another approach the estimated paraments are the same. *The reason why this occurs is that we examined the innovations (residuals) coming from the impact of capital on labor on output, which is similar to our analysis in Question 1b. However, the result here is insignificant, indicating that the innovation 2 as described in Question 1b does not determine output growth*.

Table 3: Simple Regression Result for impact of innovation 2 on output growth.

```
. * problem 1c: The next procedure is to regress lnoutput on the second residual
>
.
. reg lnoutput e2

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  1,    49) =    0.83
       Model |  1.59478745     1  1.59478745           Prob > F      =  0.3657
    Residual |  93.7453436    49  1.91317028           R-squared     =  0.0167
-------------+------------------------------           Adj R-squared = -0.0033
       Total |   95.340131    50  1.90680262           Root MSE      =  1.3832

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

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```
          e2 |   .4683318   .5129548     0.91   0.366    -.5624894    1.499153
       _cons |   16.94139   .1936831    87.47   0.000     16.55217    17.33061
------------------------------------------------------------------------------
```

Note: The raw results and the **STATA codes** that produced all the results are given in the appendix section of this research paper. Comment on how we implement the econometrics are also given.

Problem 2

In this section of the research paper, we assumed that capital accumulation correlated with the residual of the regression model in Question 1a. Therefore, we took a step backward to see how this problem can be solved. In addressing this problem, we carried IV-Regression analysis replacing capital accumulation with a variable that does not correlate with the error term called lnoutlab in this model.

Question 2a

In this section, we examined the impact of capital and labor on output using the Generalized Method of Moment (GMM). The result shows that capital has a strong significant impact on output. The implication is that a 1% increase in capital will lead to a 138% increase in output. However, labor is insignificant in this model suggesting that labor does not drive output growth. As a result of this problem, we proceed to carry out IV-regression using our instrumental variable.

Table 4a: **GMM Result**

```
. * problem 2: IV regression
.
.
. * problem 2a: Instrumental Variable regression. lnoutlab is used as an
. *instrument in this regression. In that case, we replace lncapital with
. *lnoutlab and lnoutput is regressed on lnlabor lnoutlab
.
. ivregress gmm lnoutput lnlabor (lncapital = lnoutlab)

Instrumental variables (GMM) regression             Number of obs =        51
                                                    Wald chi2(2)  =    335.04
                                                    Prob > chi2   =    0.0000
                                                    R-squared     =    0.9048
GMM weight matrix: Robust                           Root MSE      =    .42193
```

lnoutput	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lncapital	1.385655	.4317705	3.21	0.001	.5394005	2.23191
lnlabor	-.3792855	.4425238	-0.86	0.391	-1.246616	.4880453
_cons	2.044667	1.018963	2.01	0.045	.0475363	4.041798

```
Instrumented:  lncapital
Instruments:   lnlabor lnoutlab
```

After considering the instrumental variable, the result shows that both labor and the instrumental variable have a highly significant impact on output growth. In particular, a 1% increase in labor and the instrument variable will lead to a 100% increase in output growth. By implication, after introducing the instrumental variable, labor has a full impact on output. Furthermore, we predict a new variable from this estimation to see if two-stage will support our result.

Table 4a: IV-Regression Result

```
.
. reg lnoutput lnlabor lnoutlab

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  2,    48) =       .
       Model |  95.340131      2  47.6700655           Prob > F      =  0.0000
    Residual | 2.0810e-11     48  4.3354e-13           R-squared     =  1.0000
-------------+------------------------------           Adj R-squared =  1.0000
       Total |  95.340131     50  1.90680262           Root MSE      =  6.6e-07

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |          1   6.83e-08   1.5e+07   0.000     .9999999           1
    lnoutlab |          1   2.81e-07   3.6e+06   0.000     .9999996    1.000001
       _cons |  -6.02e-07   1.64e-06    -0.37   0.715    -3.89e-06    2.69e-06
------------------------------------------------------------------------------

.
. * problem 2b: To perform two stage least squares, predict lncapital_hat
. *and thereafter regress lnoutput on lnlabour and lncapital_hat
.
. predict lncapital_hat
(option xb assumed; fitted values)
```

Question 2b:
In this section, we examined the impact of labor and the predicted variable on output. The result indicates that the predicted variable has a great impact on output growth using two stages least square. On the other hand, labor is insignificant to the model. However, IV-regression result is more robust compares to two staged-least squares

Table 5: Staged Least square Result

```
. reg lnoutput lnlabor lncapital_hat

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  2,    48) =       .
       Model |  95.340131      2  47.6700655           Prob > F      =  0.0000
    Residual | 4.0460e-11     48  8.4292e-13           R-squared     =  1.0000
-------------+------------------------------           Adj R-squared =  1.0000
       Total |  95.340131     50  1.90680262           Root MSE      =  9.2e-07

------------------------------------------------------------------------------
     lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
      lnlabor |   2.09e-07   3.96e-07     0.53   0.600    -5.87e-07    1.01e-06
lncapital_hat |   .9999998   3.92e-07   2.5e+06   0.000      .999999    1.000001
        _cons |   1.38e-06   2.28e-06     0.60   0.548    -3.21e-06    5.96e-06
------------------------------------------------------------------------------
```

Question 2c:

In this section, we carried out a reduced form regression to see the ratio of the impact of labor and the instrumental variable on output to the impact of labor and the instrumental variable on capital. The results of the two regression are robust, hence, the predictive power the coefficient is high.

Table 6a: Reduced form 1 regression Result

```
. * problem 2c: Regress lnoutput on lnlabor and lnoutlab and generate the
. *first coefficient. Similarly, Regress lncapital on lnlabor and lnoutlab and
. *generate the second coefficient
.
. reg lnoutput lnlabor lnoutlab

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  2,    48) =       .
       Model |  95.340131     2  47.6700655           Prob > F      =  0.0000
    Residual | 2.0810e-11    48  4.3354e-13           R-squared     =  1.0000
-------------+------------------------------           Adj R-squared =  1.0000
       Total |  95.340131    50  1.90680262           Root MSE      =  6.6e-07

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |          1   6.83e-08   1.5e+07   0.000      .9999999           1
    lnoutlab |          1   2.81e-07   3.6e+06   0.000      .9999996    1.000001
       _cons |  -6.02e-07   1.64e-06    -0.37   0.715     -3.89e-06    2.69e-06
------------------------------------------------------------------------------

. mat beta = e(b)

. svmat beta, names(matcol)
```

Table 6b: Reduced form 2 regression Result

```
. reg lncapital lnlabor lnoutlab

      Source |       SS           df       MS      Number of obs   =        51
-------------+----------------------------------   F(2, 48)        =    471.62
       Model |  92.9197874         2  46.4598937   Prob > F        =    0.0000
    Residual |  4.72858879        48  .098512266   R-squared       =    0.9516
-------------+----------------------------------   Adj R-squared   =    0.9496
       Total |  97.6483762        50  1.95296752   Root MSE        =    .31387

------------------------------------------------------------------------------
   lncapital |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```


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```
     lnlabor |   .9954032   .0325471    30.58   0.000     .9299629    1.060843
    lnoutlab |   .7216804   .1341345     5.38   0.000     .4519849    .9913759
       _cons |  -1.475596   .7796798    -1.89   0.064    -3.043248    .0920548
------------------------------------------------------------------------------

. mat gamma = e(b)

. svmat gamma, names(matcol)
```

Table 6c: Ratio of the two Reduced form regression Result

```
. * Take the ratio of the two coefficients derived
.
. scalar alpha_hat1 = betalnoutlab/gammalnoutlab

. display alpha_hat1
1.3856551
```

Question 2d

In this section, we check using a different approach if we are going to arrive at the ratio of the reduced form regression model, we estimated in Question 2c. The results from this analysis are fairly robust and give the ratio of the reduced form regression.

Table 7a: Simple Regression Result 1

```
. * problem 2d: Check using another approach, if we will arrive at the same
. * alpha_hat1. The procedure is as follows
.
. * regress lnoutlab on lnlabor and predict the first residuals
.
. reg lnoutlab lnlabor

      Source |       SS       df       MS              Number of obs =      51
-------------+------------------------------           F(  1,    49) =    0.35
       Model |  .039343945     1  .039343945           Prob > F      =  0.5557
    Residual |  5.47531704    49  .111741164           R-squared     =  0.0071
-------------+------------------------------           Adj R-squared = -0.0131
       Total |  5.51466099    50   .11029322           Root MSE      =  .33428

------------------------------------------------------------------------------
    lnoutlab |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |  -.0204951   .0345397    -0.59   0.556    -.0899052     .048915
       _cons |   4.999017     .42371    11.80   0.000      4.14754    5.850494
------------------------------------------------------------------------------

. predict e_z, residuals
```

Table 7b: Simple Regression Result 2

```
. * regress lnoutput on lnlabor and predict the second residuals
.
. reg lnoutput lnlabor

      Source |       SS           df       MS      Number of obs   =        51
-------------+----------------------------------   F(1, 49)        =    804.22
       Model |  89.8648125         1  89.8648125   Prob > F        =    0.0000
    Residual |  5.47531855        49  .111741195   R-squared       =    0.9426
-------------+----------------------------------   Adj R-squared   =    0.9414
       Total |   95.340131        50  1.90680262   Root MSE        =    .33428

------------------------------------------------------------------------------
    lnoutput |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |   .9795049   .0345397    28.36   0.000     .9100948    1.048915
       _cons |   4.999017     .42371    11.80   0.000      4.14754    5.850494
```


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```
. predict e_y, residuals
```

Table 7c: Simple Regression Result 3

```
. * regress lnoutlab on lnlabor and predict the third residuals
.
. reg lncapital lnlabor

      Source |       SS           df       MS      Number of obs   =        51
-------------+----------------------------------   F(1, 49)        =    582.21
       Model |  90.0681184         1  90.0681184   Prob > F        =    0.0000
    Residual |   7.5802578        49  .154699139   R-squared       =    0.9224
-------------+----------------------------------   Adj R-squared   =    0.9208
       Total |  97.6483762        50  1.95296752   Root MSE        =    .39332

------------------------------------------------------------------------------
   lncapital |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlabor |   .9806122   .0406402    24.13   0.000     .8989427    1.062282
       _cons |   2.132096   .4985469     4.28   0.000     1.130229    3.133964
------------------------------------------------------------------------------

. predict e_t, residuals
```

Table 7c: **Covariance Results from the Residuals of the three Regression result**

```
. * Estimate the first covariance using the second and the first residuals
.
. corr e_y e_z, covariance
(obs=51)

             |      e_y      e_z
-------------+------------------
         e_y |  .109506
         e_z |  .109506  .109506

. scalar scov1 = r(cov_12)

.
. * Estimate the second covariance using the third and the first residuals
.
. corr e_t e_z, covariance
(obs=51)

             |      e_t      e_z
-------------+------------------
         e_t |  .151605
         e_z |  .079029  .109506

. scalar scov2 = r(cov_12)

.
. * Finally, divide the first covariance by the second covariance.
.
. scalar alpha_hat2 = scov1/scov2
```

Table 7d: **Ratio of the two Covariance Result**

```
. scalar scov2 = r(cov_12)

.
. * Finally, divide the first covariance by the second covariance.
.
. scalar alpha_hat2 = scov1/scov2
```


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```
. display alpha_hat2
1.3856551
```

Note: The raw results and the **STATA codes** that produced all the results are given in the appendix section of this research paper. Comment on how we implement the econometrics are also given.