Assignment 2
Simultaneous Equation Models

From the data set `assign2.dta`:

Demand and Supply Equations

$$\ln S_t = \beta_{10} + \beta_{11}\ln P_{Dt} + \beta_{12}\ln P_{X2t} + \beta_{13}\ln P_{X3t} + \beta_{14}\ln P_{X4t} + \varepsilon_{1t} \quad (1)$$

$$\ln D_t = \beta_{20} + \beta_{21}\ln P_{Dt} + \beta_{22}\ln GDP_t + \varepsilon_{2t} \quad (2)$$

Equilibrium condition can be achieved by $D_t = S_t$ through the price P_{Dt} mechanism.

where: S_t = Domestic Supply at time t

D_t = Domestic Demand at time t

P_{Dt} = Domestic Price at time $t = P_{Mt} + T_t$

T_t = Tariff at time t

P_{X2t} = Price of Input 2 at time t

P_{X3t} = Price of Input 3 at time t

P_{X4t} = Price of Input 4 at time t

GDP_t = Gross Domestic Product (Representing Income) at time t

Endogenous variables in this system include S_t, D_t, and P_{Dt}
Exogenous variables in this system include P_{X2t}, P_{X3t}, P_{X4t}, and GDP_t

a. State reduce form models of this system. Estimate reduce form models using OLS and prediction of the endogenous variables.

b. Estimate structural form using predicted endogenous variables as independent variables in the structural form models.

c. Estimate this system equations model using OLS, 2SLS, 3SLS, and I3SLS. Determine whether there exists endogeneity bias in the estimated results. Concerning on the asymptotic property, which model is the most appropriated model? Why? What do β_{21} and β_{22} mean?

Additional Issue:

If equilibrium doesn't hold $D_t \neq S_t$, when $D_t > S_t$; then $Q_t = S_t$ but when $D_t < S_t$; then $Q_t = D_t$, where Q_t is transaction quantity at time t.

$$\ln Q_t = \beta_{10} + \beta_{11}\ln P_{Dt} + \beta_{12}\ln P_{X2t} + \beta_{13}\ln P_{X3t} + \beta_{14}\ln P_{X4t} + \varepsilon_{1t} \quad (3)$$

$$\ln Q_t = \beta_{20} + \beta_{21}\ln P_{Dt} + \beta_{22}\ln GDP_t + \varepsilon_{2t} \quad (4)$$

d. Generate lnQ_t and estimate the above system equations (model (3) and model (4)) using OLS, 2SLS, and 3SLS using Q_t, and P_{Dt} as endogenous variables and P_{X2t}, P_{X3t}, P_{X4t}, and GDP_t as exogenous variables.

e. What are the problems, in term of economic concept and econometric technique, of the estimated results in **d**?

$$\ln S_t = \beta_{10} + \beta_{11}\ln P_{Dt} + \beta_{12}\ln P_{X2t} + \beta_{13}\ln P_{X3t} + \beta_{14}\ln P_{X4t} + \varepsilon_{1t}$$

$$\ln D_t = \beta_{20} + \beta_{21}\ln P_{Dt} + \beta_{22}\ln GDP_t + \varepsilon_{2t}$$

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a) For reduced form

As equilibrium condition $\ln S_t = \ln D_t$

$$\beta_{10} + \beta_{11}\ln P_{D_t} + \beta_{12}\ln P_{x2t} + \beta_{13}\ln P_{x3t} + \beta_{14}\ln P_{x4t} + \epsilon_{1t} = \beta_{20} + \beta_{21}\ln P_{Dt} + \beta_{22}\ln GDP_t + \epsilon_{2t}$$

$$(\beta_{11} - \beta_{21})\ln P_{Dt} = \beta_{20} - \beta_{10} - \beta_{12}\ln P_{x2t} - \beta_{13}\ln P_{x3t} - \beta_{14}\ln P_{x4t} + \beta_{22}\ln GDP_t + \epsilon_{2t} - \epsilon_{1t}$$

$$\ln P_{Dt} = \left(\beta_{20} - \beta_{10} - \beta_{12}\ln P_{x2t} - \beta_{13}\ln P_{x3t} - \beta_{14}\ln P_{x4t} + \beta_{22}\ln GDP_t + \epsilon_{2t} - \epsilon_{1t}\right) \times \frac{1}{(\beta_{11} - \beta_{21})}$$

$$\ln P_{Dt} = \frac{\beta_{20} - \beta_{10}}{\beta_{11} - \beta_{21}} - \frac{\beta_{12}}{\beta_{11} - \beta_{21}}\ln P_{x2t} - \frac{\beta_{13}}{\beta_{11} - \beta_{21}}\ln P_{x3t} - \frac{\beta_{14}}{\beta_{11} - \beta_{21}}\ln P_{x4t} + \frac{\beta_{22}}{\beta_{11} - \beta_{21}}\ln GDP + \frac{\epsilon_{2t} - \epsilon_{1t}}{\beta_{11} - \beta_{21}}$$

$$= \Pi_0 + \Pi_1\ln GDP_t - \Pi_2\ln P_{x2t} - \Pi_3\ln P_{x3t} - \Pi_4\ln P_{x4t} + W_t$$

Substitute $\ln P_{Dt}$ in $\ln S_t$ & $\ln D_t$ For $\ln S_t$

$$\ln S_t = \Pi_{10} + \Pi_{11}\ln GDP_t + \Pi_{12}\ln P_{x2t} + \Pi_{13}\ln P_{x3t} + \Pi_{14}\ln P_{x4t} + W_{1t}$$

$$\ln D_t = \Pi_{20} + \Pi_{21}\ln GDP_t + \Pi_{22}\ln P_{x2t} + \Pi_{23}\ln P_{x3t} + \Pi_{24}\ln P_{x4t} + W_{2t}$$

```
. reg lndt lngdp lnpx2 lnpx3 lnpx4

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(4, 17)        =     26.43
       Model |   3.4026552         4  .850663799   Prob > F        =    0.0000
    Residual |  .54721789         17  .032189288   R-squared       =    0.8615
-------------+----------------------------------   Adj R-squared   =    0.8289
       Total |  3.94987309        21  .188089195   Root MSE        =    .17941

------------------------------------------------------------------------------
        lndt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .1265855    .194594     0.65   0.524    -.2839719    .5371429
       lnpx2 |  -.4887365   .1541691    -3.17   0.006    -.8140049   -.1634682
       lnpx3 |  -.7243134   .2830597    -2.56   0.020    -1.321517   -.1271097
       lnpx4 |   -.577921   .4293997    -1.35   0.196    -1.483875    .3280333
       _cons |   27.18614   5.399879     5.03   0.000     15.79339    38.57889
------------------------------------------------------------------------------
```

```
. reg lnst lngdp lnpx2 lnpx3 lnpx4

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(4, 17)        =     37.32
       Model |  4.64569724         4  1.16142431   Prob > F        =    0.0000
    Residual |  .529104674        17  .031123804   R-squared       =    0.8978
-------------+----------------------------------   Adj R-squared   =    0.8737
       Total |  5.17480192        21  .246419139   Root MSE        =    .17642

------------------------------------------------------------------------------
        lnst |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .3438812   .1913463     1.80   0.090    -.0598242    .7475865
       lnpx2 |  -.4503744   .1515961    -2.97   0.009    -.7702142   -.1305347
       lnpx3 |  -.9242052   .2783356    -3.32   0.004    -1.511442   -.3369685
       lnpx4 |  -.3883793   .4222332    -0.92   0.371    -1.279214    .5024549
       _cons |   24.65741   5.309757     4.64   0.000      13.4548    35.86002
------------------------------------------------------------------------------
```

```
. reg lnpd lngdp lnpx2 lnpx3 lnpx4

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(4, 17)        =      6.76
       Model |   .17707359         4  .044268398   Prob > F        =    0.0019
    Residual |  .111247189        17  .006543952   R-squared       =    0.6142
-------------+----------------------------------   Adj R-squared   =    0.5234
       Total |  .288320779        21  .013729561   Root MSE        =    .08089

------------------------------------------------------------------------------
        lnpd |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lngdp |   .1632779   .0877392     1.86   0.080    -.0218357    .3483914
       lnpx2 |   .1318015   .0695123     1.90   0.075    -.0148567    .2784596
       lnpx3 |   .0939842    .127627     0.74   0.472    -.1752851    .3632535
       lnpx4 |   .4939641   .1936093     2.55   0.021     .0854842    .9024439
       _cons |    2.87652   2.434717     1.18   0.254    -2.260283    8.013322
------------------------------------------------------------------------------

. predict y2hat, xb
```

b)

```
. reg lnst y2hat lnpx2 lnpx3 lnpx4

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(4, 17)        =     37.32
       Model |  4.64569773         4  1.16142443   Prob > F        =    0.0000
    Residual |  .529104183        17  .031123775   R-squared       =    0.8978
-------------+----------------------------------   Adj R-squared   =    0.8737
       Total |  5.17480192        21  .246419139   Root MSE        =    .17642

------------------------------------------------------------------------------
        lnst |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       y2hat |   2.106112   1.171903     1.80   0.090    -.3663879    4.578612
       lnpx2 |   -.727963   .1840856    -3.95   0.001     -1.11635   -.3395762
       lnpx3 |  -1.122146   .2824139    -3.97   0.001    -1.717988   -.5263052
       lnpx4 |  -1.428722   .4751381    -3.01   0.008    -2.431176   -.4262679
       _cons |   18.59912   8.546622     2.18   0.044     .5673274    36.63092
------------------------------------------------------------------------------

. reg lndt y2hat lngdp

      Source |       SS           df       MS      Number of obs   =        22
-------------+----------------------------------   F(2, 19)        =     44.99
       Model |  3.26129847         2  1.63064924   Prob > F        =    0.0000
    Residual |  .688574614        19  .036240769   R-squared       =    0.8257
-------------+----------------------------------   Adj R-squared   =    0.8073
       Total |  3.94987309        21  .188089195   Root MSE        =    .19037

------------------------------------------------------------------------------
        lndt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       y2hat |  -2.574157   .5697943    -4.52   0.000     -3.76675   -1.381563
       lngdp |   .5212927   .1344816     3.88   0.001     .2398194     .802766
       _cons |   35.93498   7.189835     5.00   0.000     20.88648    50.98347
------------------------------------------------------------------------------
```

c)

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) (lnpd lngdp lnpx2 lnpx3 lnpx4), 2sls nodfk inst(lnpx2 lnpx3 lnpx4 lngdp)

Two-stage least-squares regression
----------------------------------------------------------------------
Equation             Obs   Parms        RMSE    "R-sq"       F-Stat        P
----------------------------------------------------------------------
lnst                  22       4     .329951    0.6424        13.81   0.0000
lndt                  22       2    .1454858    0.8982        89.20   0.0000
lnpd                  22       4    .0808947    0.6142         8.75   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |    2.10611   1.926677     1.09   0.279    -1.758314    5.970534
       lnpx2 |  -.7279628   .3026471    -2.41   0.020    -1.334996   -.1209295
       lnpx3 |  -1.122146    .464304    -2.42   0.019    -2.053422   -.1908703
       lnpx4 |  -1.428722   .7811544    -1.83   0.073    -2.995519    .1380753
       _cons |   18.59914   14.05113     1.32   0.191    -9.583858    46.78215
-------------+----------------------------------------------------------------
lndt         |
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.385831   -1.762483
       lngdp |   .5212921   .0955104     5.46   0.000     .3297225    .7128617
       _cons |   35.93499   5.106302     7.04   0.000     25.69304    46.17693
-------------+----------------------------------------------------------------
lnpd         |
       lngdp |   .1632779   .0771271     2.12   0.039     .0085806    .3179752
       lnpx2 |   .1318015   .0611047     2.16   0.036     .0092409     .254362
       lnpx3 |   .0939842   .1121904     0.84   0.406    -.1310411    .3190096
       lnpx4 |   .4939641   .1701921     2.90   0.005     .1526021    .8353261
       _cons |    2.87652   2.140235     1.34   0.185    -1.416249    7.169288
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
------------------------------------------------------------------------------
```

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) (lnpd lngdp lnpx2 lnpx3 lnpx4), 3sls inst(lnpx2 lnpx3 lnpx4 lngdp)

Three-stage least-squares regression
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
lnst               22      4    .2963642    0.6266      57.47   0.0000
lndt               22      2     .135203    0.8982     178.41   0.0000
lnpd               22      4    .0732203    0.5909      36.62   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |   2.171576   1.926095     1.13   0.260    -1.603501    5.946652
       lnpx2 |  -.7990055   .2985983    -2.68   0.007    -1.384247   -.2137635
       lnpx3 |  -1.329743   .4560002    -2.92   0.004    -2.223487   -.4359989
       lnpx4 |  -1.171403    .775654    -1.51   0.131    -2.691657     .348851
       _cons |   17.84948   14.04122     1.27   0.204    -9.670808    45.36976
-------------+----------------------------------------------------------------
lndt         |
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.367304    -1.78101
       lngdp |   .5212921   .0955104     5.46   0.000     .3340951     .708489
       _cons |   35.93499   5.106302     7.04   0.000     25.92682    45.94316
-------------+----------------------------------------------------------------
lnpd         |
       lngdp |   .1577055   .0770217     2.05   0.041     .0067456    .3086653
       lnpx2 |    .164339   .0568235     2.89   0.004     .0529671     .275711
       lnpx3 |   .1990003   .1024634     1.94   0.052    -.0018243     .399825
       lnpx4 |   .3429611   .1609238     2.13   0.033     .0275562     .658366
       _cons |   3.169164   2.130477     1.49   0.137    -1.006495    7.344823
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
------------------------------------------------------------------------------
```

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) (lnpd lngdp lnpx2 lnpx3 lnpx4), 3sls ireg3 inst(lnpx2 lnpx3 lnpx4 lngdp)

Iteration 1:   tolerance =   .1059484
Iteration 2:   tolerance =  .04569793
Iteration 3:   tolerance =  .01846611
Iteration 4:   tolerance =  .00725496
Iteration 5:   tolerance =  .00281814
Iteration 6:   tolerance =  .00108982
Iteration 7:   tolerance =  .00042071
Iteration 8:   tolerance =  .00016231
Iteration 9:   tolerance =   .0000626
Iteration 10:   tolerance =  .00002414
Iteration 11:   tolerance = 9.318e-06
Iteration 12:   tolerance = 3.589e-06
Iteration 13:   tolerance = 1.383e-06
Iteration 14:   tolerance = 5.336e-07

Three-stage least-squares regression, iterated
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
lnst               22      4    .3022006    0.6117      54.83   0.0000
lndt               22      2     .135203    0.8982     178.41   0.0000
lnpd               22      4    .0760315    0.5589      34.91   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |   2.212666   2.005956     1.10   0.270    -1.718936    6.144268
       lnpx2 |  -.8435966   .3049354    -2.77   0.006    -1.441259   -.2459342
       lnpx3 |  -1.460044   .4623671    -3.16   0.002    -2.366267   -.5538216
       lnpx4 |  -1.009892   .7998393    -1.26   0.207    -2.577548     .557764
       _cons |   17.37893   14.61488     1.19   0.234    -11.26571    46.02357
-------------+----------------------------------------------------------------
lndt         |
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.367304    -1.78101
       lngdp |   .5212921   .0955104     5.46   0.000     .3340951     .708489
       _cons |   35.93499   5.106302     7.04   0.000     25.92682    45.94316
-------------+----------------------------------------------------------------
lnpd         |
       lngdp |   .1546852   .0822301     1.88   0.060    -.0064828    .3158532
       lnpx2 |   .1819748    .055389     3.29   0.001     .0734143    .2905352
       lnpx3 |   .2559202   .0970792     2.64   0.008     .0656484     .446192
       lnpx4 |   .2611159   .1606733     1.63   0.104    -.0537981    .5760298
       _cons |    3.32778   2.266592     1.47   0.142    -1.114658    7.770218
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
------------------------------------------------------------------------------
```

```
. hausman twostage ols

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   twostage        ols         Difference          S.E.
-------------+----------------------------------------------------------------
        lnpd |     2.10611    -1.111835        3.217945        1.873023
       lnpx2 |   -.7279628    -.4189546       -.3090082         .266645
       lnpx3 |   -1.122146    -.9424196       -.1797266        .3856712
       lnpx4 |   -1.428722     -.521346        -.907376        .7012511
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivregress
            B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.95
                Prob>chi2 =      0.5659
```

For supply side

Prob > chi 2 = 0.5659 which > 0.05

H_0 is not rejected at 5% level significance. Therefor, endogeneity bias not occur.

```
. ivregress 2sls lndt lngdp (lnpd=lngdp lnpx2 lnpx3 lnpx4)

Instrumental variables (2SLS) regression          Number of obs   =         22
                                                  Wald chi2(2)    =     178.41
                                                  Prob > chi2     =     0.0000
                                                  R-squared       =     0.8982
                                                  Root MSE        =      .1352

------------------------------------------------------------------------------
        lndt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.367304    -1.78101
       lngdp |   .5212921   .0955104     5.46   0.000     .3340951     .708489
       _cons |   35.93499   5.106302     7.04   0.000     25.92682    45.94316
------------------------------------------------------------------------------
Instrumented:  lnpd
Instruments:   lngdp lnpx2 lnpx3 lnpx4

. est store twostage

. hausman twostage ols

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |   twostage        ols         Difference          S.E.
-------------+----------------------------------------------------------------
        lnpd |   -2.574157    -2.352055       -.2221026         .253181
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from ivregress
            B = inconsistent under Ha, efficient under Ho; obtained from regress

    Test:  Ho:  difference in coefficients not systematic

                  chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.77
                Prob>chi2 =      0.3804
```

For Demand

Prob > chi = 0.3804 > 0.05

H_0 is not rejected at 5% level significance, therefor endogeneity bias not exist.

Concerning on asymtotic property, 3SLS will be the most appropriate due to the property that have more asymtotic normality. But if one of the equation have specification error will spread to all other equation, therefor inconsistent will occur.

β_{21} means that the change in P_{D_t} by 1% will change D_t to change by β_{21} % in the opposite direction.

β_{22} means that the change in P_{D_t} by 1% will change S_t by β_{22}% in the same direction

S_t always more than D_t, therefor $Q_t > D_t$

d)

```
. g lnQ = lndt

. reg lnQ lnpd lnpx2 lnpx3 lnpx4
```

Source	SS	df	MS		
				Number of obs =	22
				F(4, 17) =	48.95
Model	3.63435347	4	.908588368	Prob > F =	0.0000
Residual	.315519616	17	.018559977	R-squared =	0.9201
				Adj R-squared =	0.9013
Total	3.94987309	21	.188089195	Root MSE =	.13624

lnQ	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnpd	-1.353506	.3722912	-3.64	0.002	-2.138972	-.5680403
lnpx2	-.3864994	.1180437	-3.27	0.004	-.6355499	-.137449
lnpx3	-.6782817	.2131651	-3.18	0.005	-1.128021	-.2285427
lnpx4	-.3606189	.2837767	-1.27	0.221	-.9593355	.2380976
_cons	40.10218	3.019386	13.28	0.000	33.73183	46.47253

```
. reg lnQ lnpd lngdp
```

Source	SS	df	MS		
				Number of obs =	22
				F(2, 19) =	92.53
Model	3.58210899	2	1.79105449	Prob > F =	0.0000
Residual	.367764099	19	.019356005	R-squared =	0.9069
				Adj R-squared =	0.8971
Total	3.94987309	21	.188089195	Root MSE =	.13913

lnQ	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnpd	-2.181329	.2946999	-7.40	0.000	-2.798143	-1.564515
lngdp	.5776586	.0887536	6.51	0.000	.3918952	.7634221
_cons	31.03578	3.761201	8.25	0.000	23.1635	38.90807

```
. reg3 (lnQ lnpd lnpx2 lnpx3 lnpx4) (lnQ lnpd lngdp) (lnpd lngdp lnpx2 lnpx3 lnpx4), 2sls nodfk inst(lngdp lnpx2 lnpx3 lnpx4)

Two-stage least-squares regression
----------------------------------------------------------------------
Equation             Obs   Parms        RMSE    "R-sq"     F-Stat        P
----------------------------------------------------------------------
lnQ                   22       4    .2329302    0.7665      20.29   0.0000
2lnQ                  22       2    .1454858    0.8982      89.20   0.0000
lnpd                  22       4    .0808947    0.6142       8.75   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnQ          |
        lnpd |   .7752765   1.360145     0.57   0.571    -1.952829    3.503382
       lnpx2 |  -.5909191   .2136549    -2.77   0.008    -1.019457   -.1623815
       lnpx3 |  -.7971771   .3277773    -2.43   0.018    -1.454615   -.1397392
       lnpx4 |  -.9608797    .551459    -1.74   0.087    -2.066967    .1452071
       _cons |   24.95604   9.919453     2.52   0.015     5.060137    44.85194
-------------+----------------------------------------------------------------
2lnQ         |
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.385831   -1.762483
       lngdp |   .5212921   .0955104     5.46   0.000     .3297225    .7128617
       _cons |   35.93499   5.106302     7.04   0.000     25.69304    46.17693
-------------+----------------------------------------------------------------
lnpd         |
       lngdp |   .1632779   .0771271     2.12   0.039     .0085806    .3179752
       lnpx2 |   .1318015   .0611047     2.16   0.036     .0092409     .254362
       lnpx3 |   .0939842   .1121904     0.84   0.406    -.1310411    .3190096
       lnpx4 |   .4939641   .1701921     2.90   0.005     .1526021    .8353261
       _cons |    2.87652   2.140235     1.34   0.185    -1.416249    7.169288
------------------------------------------------------------------------------
Endogenous variables:  lnQ lnpd
Exogenous variables:   lngdp lnpx2 lnpx3 lnpx4
```

```
. reg3 (lnQ lnpd lnpx2 lnpx3 lnpx4) (lnQ lnpd lngdp) (lnpd lngdp lnpx2 lnpx3 lnpx4), 3sls inst(lngdp lnpx2 lnpx3 lnpx4)

Three-stage least-squares regression
----------------------------------------------------------------------
Equation             Obs   Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
lnQ                   22       4    .2056595    0.7644      81.74   0.0000
2lnQ                  22       2     .135203    0.8982     178.41   0.0000
lnpd                  22       4    .0732203    0.5909      36.62   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnQ          |
        lnpd |   .7879239   1.360114     0.58   0.562    -1.877851    3.453699
       lnpx2 |  -.6046439   .2134422    -2.83   0.005    -1.022983   -.1863049
       lnpx3 |  -.8372831   .3273419    -2.56   0.011    -1.478861   -.1957047
       lnpx4 |  -.9111679   .5511692    -1.65   0.098     -1.99144    .1691039
       _cons |   24.81121   9.918929     2.50   0.012     5.370467    44.25195
-------------+----------------------------------------------------------------
2lnQ         |
        lnpd |  -2.574157   .4046743    -6.36   0.000    -3.367304    -1.78101
       lngdp |   .5212921   .0955104     5.46   0.000     .3340951     .708489
       _cons |   35.93499   5.106302     7.04   0.000     25.92682    45.94316
-------------+----------------------------------------------------------------
lnpd         |
       lngdp |   .1577055   .0770217     2.05   0.041     .0067456    .3086653
       lnpx2 |    .164339   .0568235     2.89   0.004     .0529671     .275711
       lnpx3 |   .1990003   .1024634     1.94   0.052    -.0018243     .399825
       lnpx4 |   .3429611   .1609238     2.13   0.033     .0275562     .658366
       _cons |   3.169164   2.130477     1.49   0.137    -1.006495    7.344823
------------------------------------------------------------------------------
Endogenous variables:  lnQ lnpd
Exogenous variables:   lngdp lnpx2 lnpx3 lnpx4
------------------------------------------------------------------------------
```

e) Due to quantity demand equal to Q_t, in economic concept, the higher price of input should not reflect quantity demand which is about consumer decision. In addition, measure quantity demand instead supply may cause a measurement error which is specification bias, estimator will be biased.

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