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

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

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

Assume demand = supply or $\ln S_t = \ln D_t$ $\quad \mathrm{III}$

1.

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

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

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

$$\ln P_{Dt} = \frac{\beta_{20} - \beta_{10}}{\beta_{11} - \beta_{21}} + \frac{\beta_{22}}{\beta_{11} - \beta_{21}}\ln GDP_t - \frac{\beta_{12}}{\beta_{11} - \beta_{21}}\ln P_{x2t} - \frac{\beta_{13}}{\beta_{11} - \beta_{21}}\ln P_{x3t} - \frac{\beta_{14}}{\beta_{11} - \beta_{12}}\ln P_{x4t} + \frac{\varepsilon_{2t} - \varepsilon_{1t}}{\beta_{11} - \beta_{12}} \qquad \mathrm{IV}$$

Put value IV into II

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

$$= \beta_{20} + \frac{\beta_{21}(\beta_{20} - \beta_{10})}{\beta_{11} - \beta_{21}} + \frac{\beta_{11}\beta_{22}\ln GDP_t}{\beta_{11} - \beta_{21}} - \frac{\beta_{21}\beta_{12}\ln P_{x2t}}{\beta_{11} - \beta_{21}} - \frac{\beta_{21}\beta_{13}\ln P_{x3t}}{\beta_{11} - \beta_{21}} - \frac{\beta_{21}\beta_{14}\ln P_{x4t}}{\beta_{11} - \beta_{21}} + \frac{\beta_{21}(\varepsilon_{2t} - \varepsilon_{1t})}{\beta_{11} - \beta_{21}} + \varepsilon_{2t} \qquad \mathrm{V}$$

use π_{ij}

$$\pi_{20} = \beta_{20} + \frac{\beta_{21}(\beta_{20} - \beta_{10})}{\beta_{11} - \beta_{21}}, \quad \pi_{21} = \frac{\beta_{11}\beta_{22}}{\beta_{11} - \beta_{21}}, \quad \pi_{22} = -\frac{\beta_{21}\beta_{12}}{\beta_{11} - \beta_{21}}, \quad \pi_{23} = -\frac{\beta_{21}\beta_{13}}{\beta_{11} - \beta_{21}}, \quad \pi_{24} = -\frac{\beta_{21}\beta_{14}}{\beta_{11} - \beta_{21}}$$

$$w_{2t} = \frac{\beta_{21}(\varepsilon_{2t} - \varepsilon_{1t})}{\beta_{11} - \beta_{21}} + \varepsilon_{2t}$$

Put value IV into I

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

$$= \beta_{10} + \frac{\beta_{11}(\beta_{20} - \beta_{10})}{\beta_{11} - \beta_{21}} + \frac{\beta_{11}\beta_{22}\ln GDP_t}{\beta_{11} - \beta_{21}} - \frac{\beta_{11}\beta_{12}\ln P_{x2t}}{\beta_{11} - \beta_{21}} - \frac{\beta_{21}\beta_{13}\ln P_{x3t}}{\beta_{11} - \beta_{21}} - \frac{\beta_{21}\beta_{14}\ln P_{x4t}}{\beta_{11} - \beta_{21}} + \frac{\beta_{11}(\varepsilon_{2t} - \varepsilon_{1t})}{\beta_{11} - \beta_{21}} + \varepsilon_{2t} \qquad \mathrm{VI}$$

$$\pi_{10} = \beta_{10} + \frac{\beta_{11}(\beta_{20} - \beta_{10})}{\beta_{11} - \beta_{21}}, \quad \pi_{11} = \frac{\beta_{11}\beta_{22}}{\beta_{11} - \beta_{21}}, \quad \pi_{12} = -\frac{\beta_{11}\beta_{12}}{\beta_{11} - \beta_{21}}, \quad \pi_{13} = -\frac{\beta_{21}\beta_{13}}{\beta_{11} - \beta_{21}}, \quad \pi_{14} = -\frac{\beta_{21}\beta_{14}}{\beta_{11} - \beta_{21}}, \quad w_{1t} = \frac{\beta_{11}(\varepsilon_{2t} - \varepsilon_{1t})}{\beta_{11} - \beta_{21}} + \varepsilon_{2t}$$

From IV

$$\pi_{30} = \frac{\beta_{20} - \beta_{10}}{\beta_{11} - \beta_{21}}, \quad \pi_{31} = \frac{\beta_{22}}{\beta_{11} - \beta_{21}}, \quad \pi_{32} = -\frac{\beta_{12}}{\beta_{11} - \beta_{21}}, \quad \pi_{33} = -\frac{\beta_{13}}{\beta_{11} - \beta_{2}}, \quad \pi_{34} = -\frac{\beta_{14}}{\beta_{11} - \beta_{12}}, \quad W_{3t} = \frac{\varepsilon_{2t} - \varepsilon_{1t}}{\beta_{11} - \beta_{12}}$$

Therefore, reduced forms are

$$\ln S_t = \pi_{10} + \pi_{11} \ln GDP_t + \pi_{12} \ln P_{x2t} + \pi_{13} \ln P_{x3t} + \pi_{14} \ln P_{x4t} + W_t$$

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

$$\ln P_{Dt} = \pi_{30} + \pi_{31} \ln GDP_t + \pi_{32} \ln P_{x2t} + \pi_{33} \ln P_{x3t} + \pi_{34} \ln P_{x4t} + W_{3t}$$

2.

```
. g lnst=ln(st)

. g lndt=ln(dt)

. g pd=pm+t

. g lnpd=ln(pd)

. g lnpx2=ln(px2)

. g lnpx3=ln(px3)

. g lnpx4=ln(px4)

. g lngdp=ln(gdp)

. reg lnst lnpx2 lnpx3 lnpx4 lngdp
```

Source	SS	df	MS
Model	4.64569724	4	1.16142431
Residual	.529104674	17	.031123804
Total	5.17480192	21	.246419139

Number of obs	=	22
F(4, 17)	=	37.32
Prob > F	=	0.0000
R-squared	=	0.8978
Adj R-squared	=	0.8737
Root MSE	=	.17642

lnst	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
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
lngdp	.3438812	.1913463	1.80	0.090	-.0598242	.7475865
_cons	24.65741	5.309757	4.64	0.000	13.4548	35.86002

```
. predict lnsthat , xb

. reg lndt lnpx2 lnpx3 lnpx4 lngdp
```

Source	SS	df	MS
Model	3.4026552	4	.850663799
Residual	.54721789	17	.032189288
Total	3.94987309	21	.188089195

Number of obs	=	22
F(4, 17)	=	26.43
Prob > F	=	0.0000
R-squared	=	0.8615
Adj R-squared	=	0.8289
Root MSE	=	.17941

lndt	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
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
lngdp	.1265855	.194594	0.65	0.524	-.2839719	.5371429
_cons	27.18614	5.399879	5.03	0.000	15.79339	38.57889

```
. predict lndthat , xb

. reg lnpd lnpx2 lnpx3 lnpx4 lngdp
```

Source	SS	df	MS
Model	.17707359	4	.044268398
Residual	.111247189	17	.006543952
Total	.288320779	21	.013729561

Number of obs	=	22
F(4, 17)	=	6.76
Prob > F	=	0.0019
R-squared	=	0.6142
Adj R-squared	=	0.5234
Root MSE	=	.08089

lnpd	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
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
lngdp	.1632779	.0877392	1.86	0.080	-.0218357	.3483914
_cons	2.87652	2.434717	1.18	0.254	-2.260283	8.013322

```
. predict lndthat , xb
```

```
. reg lnpd lnpx2 lnpx3 lnpx4 lngdp

      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]
-------------+----------------------------------------------------------------
       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
       lngdp |   .1632779   .0877392     1.86   0.080    -.0218357    .3483914
       _cons |    2.87652   2.434717     1.18   0.254    -2.260283    8.013322
------------------------------------------------------------------------------

. predict lnpdhat , xb
```

3.

```
. reg lnst lnpdhat 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]
-------------+----------------------------------------------------------------
     lnpdhat |   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 lnpdhat 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]
-------------+----------------------------------------------------------------
     lnpdhat |  -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
------------------------------------------------------------------------------
```

4.

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

Multivariate regression
----------------------------------------------------------------------
Equation          Obs   Parms        RMSE    "R-sq"      F-Stat        P
----------------------------------------------------------------------
lnst               22       4    .1652258    0.9103       43.14   0.0000
lndt               22       2    .1391259    0.9069       92.53   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |  -1.111835   .4515147    -2.46   0.019    -2.027549   -.1961207
       lnpx2 |  -.4189546   .1431634    -2.93   0.006    -.7093034   -.1286059
       lnpx3 |  -.9424196   .2585266    -3.65   0.001    -1.466736   -.4181034
       lnpx4 |   -.521346   .3441643    -1.51   0.139    -1.219344    .1766516
       _cons |    41.4946   3.661911    11.33   0.000      34.0679     48.9213
-------------+----------------------------------------------------------------
lndt         |
        lnpd |  -2.181329   .2946999    -7.40   0.000    -2.779008    -1.58365
       lngdp |   .5776586   .0887536     6.51   0.000      .397658    .7576593
       _cons |   31.03578   3.761201     8.25   0.000     23.40771    38.66385
------------------------------------------------------------------------------
```

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) , 2sls 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      10.67   0.0000
lndt               22       2    .1454858    0.8982      77.04   0.0000
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |    2.10611   2.191774     0.96   0.343    -2.339013    6.551233
       lnpx2 |  -.7279628   .3442892    -2.11   0.041    -1.426214   -.0297119
       lnpx3 |  -1.122146    .528189    -2.12   0.041    -2.193363   -.0509293
       lnpx4 |  -1.428722   .8886357    -1.61   0.117    -3.230959    .3735147
       _cons |   18.59914   15.98447     1.16   0.252    -13.81886    51.01715
-------------+----------------------------------------------------------------
lndt         |
        lnpd |  -2.574157   .4354519    -5.91   0.000    -3.457295    -1.69102
       lngdp |   .5212921   .1027745     5.07   0.000     .3128558    .7297283
       _cons |   35.93499   5.494663     6.54   0.000      24.7913    47.07868
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
```

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) , 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
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      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
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
------------------------------------------------------------------------------
```

```
. reg3 (lnst lnpd lnpx2 lnpx3 lnpx4) (lndt lnpd lngdp) , 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 =  .00108981
Iteration 7:   tolerance =  .00042072
Iteration 8:   tolerance =  .00016231
Iteration 9:   tolerance =   .0000626
Iteration 10:  tolerance =  .00002414
Iteration 11:  tolerance =  9.310e-06
Iteration 12:  tolerance =  3.590e-06
Iteration 13:  tolerance =  1.384e-06
Iteration 14:  tolerance =  5.339e-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
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lnst         |
        lnpd |   2.212666   2.005956     1.10   0.270    -1.718936    6.144268
       lnpx2 |  -.8435967   .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
------------------------------------------------------------------------------
Endogenous variables:  lnst lnpd lndt
Exogenous variables:   lnpx2 lnpx3 lnpx4 lngdp
------------------------------------------------------------------------------
```

According to all approaches applied above, the most appropriated model is 2SLS. The reason is model of 2SLS does have consistency while being able to answer the bias of endogenity. On the other hand, the model of OLS is still lack behind in terms of consistency and does contain endogeneity bias. Compared to models of 3SLS and I3SLS, 2SLS has the highest performance. What makes 3SLS become disadvantaged is there is risk of inconsistency from specification error despite being more asymbtically efficient. Therefore, the most appropriated model is 2SLS.

5. β_{21} represents elasticity of domestic demand over domestic price
β_{22} represents elasticity of domestic demand over GDP or domestic economy