DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

Econometrics 2, Class 1

Problem Set #14
December 19, 2005

#14.1 Interpretation of IV and GMM estimations

We will go through this on the blackboard.

#14.2 Monetary policy rules for the US

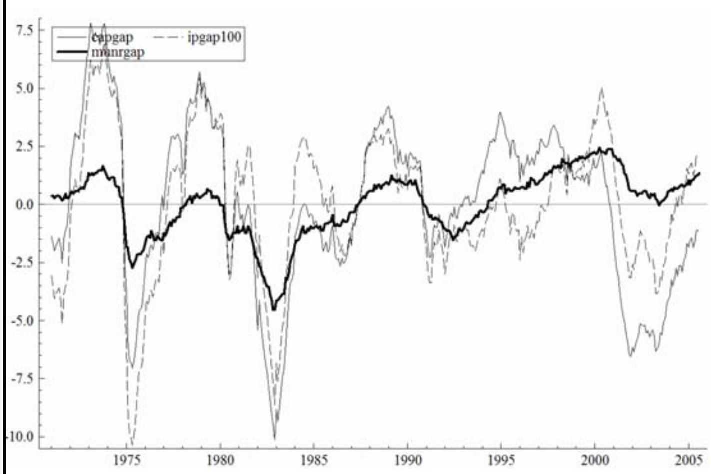
Now consider a particular data set for the estimation of monetary policy rules for the US, 1971 : 1 – 2005 : 8. The data file `MonetaryPolicy.xls` contains the following 11 variables:

ff	Average effective Federal funds rate.
fftarget	Target for the Federal funds rate.
bond	Average 10 years bond yield.
inf	Inflation from year to year.
infexcl	Inflation from year to year excluding food and energy.
caputil	Capacity utilization.
capgap	Measure of output gap: deviation of caputil from mean.
ip	Industrial production.
ipgap	Measure of output gap: deviation of ip from a smooth HP trend.
unr	Unemployment rate.
unrgap	Measure of output gap: deviation of unr from mean.

We want to estimate a monetary policy rule of the form (14.1) and we focus on the period with Greenspan as a chairman for the Federal Reserve Board: 1987 : 1 – 2005 : 8.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(1a) Graph of three measures of output gap



They generally follow each other.

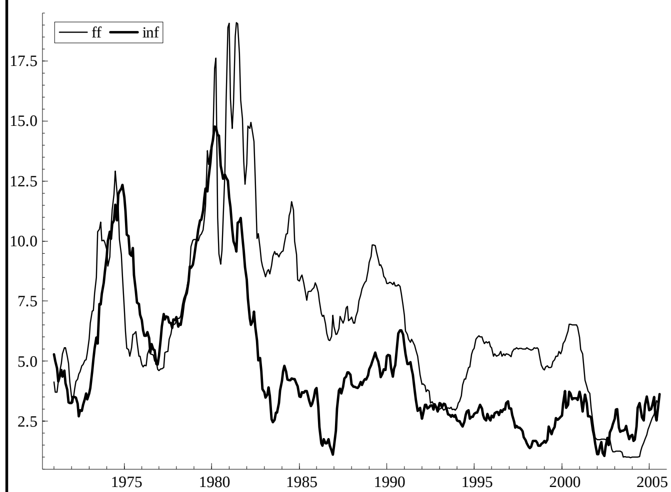
N.B. I have transformed ipgap and unrgap to aid comparison with capgap.

munrgap=-unrgap

ipgap100=ipgap*100

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(b) Inflation and policy instrument

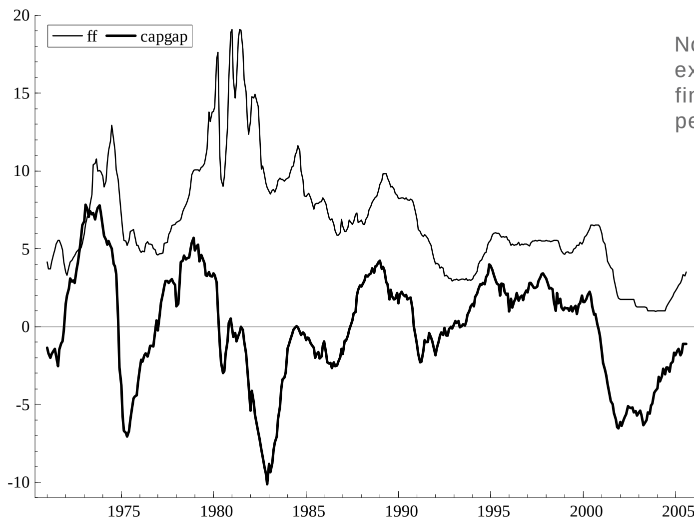


Generally seem to be low federal fund rates when inflation is low.

Not so obvious in the later period.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

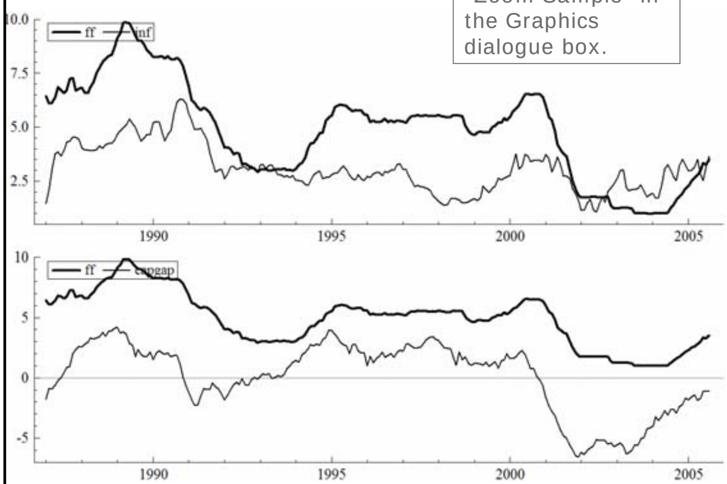
(c) Relation between output gap and policy instrument



No clear relationship, except perhaps in the final years of the period.

The Greenspan years 1987:1-2005:8

To see this choose “Zoom Sample” in the Graphics dialogue box.



There seems to be greater correlation between the output gap and the policy instrument than between inflation and the policy instrument.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(2) The instruments

First, we measure inflation by the variable inf and the output gap by the variable capgap. As instruments we take lag one and two of all variables, i.e.

$$z_t = (1, \mathsf{ff}_{t-1}, \mathsf{ff}_{t-2}, \mathsf{bond}_{t-1}, \mathsf{bond}_{t-2}, \mathsf{inf}_{t-1}, \mathsf{inf}_{t-2}, \mathsf{infexcl}_{t-1}, \mathsf{infexcl}_{t-2},$$
$$\mathsf{capgap}_{t-1}, \mathsf{capgap}_{t-2}, \mathsf{ipgap}_{t-1}, \mathsf{ipgap}_{t-2}, \mathsf{unrgap}_{t-1}, \mathsf{unrgap}_{t-2})'.$$

The Ox program `MonetaryPolicy.ox` estimates the model by GMM, where the weights matrix is based on a heteroskedasticity and autocorreelation consistent (HAC) estimator.

For this exercise you need to use OxEdit...

The code

```
//load the procedures for GMM estimation
#include <oxstd.h>
#include <Z:\Econometrics 2\PS14\gmm.ox>

//**********************************************************************
//  Specify moment conditions
//  theta[0][],theta[1][],...,theta[k-1][] denote the k parameters
//  y[][0],y[][1],...,y[][p]               denote the p model variables
//  z                                      denote the k instruments
mom(const theta)
  {
  //simple taylor rule (no smoothing)
  ufunc = y[][0]-theta[0][]-theta[1][]*y[][1]-theta[2][]*y[][2];

  //interest rate smoothing
  //ufunc = y[][0] - theta[0][]*(1-theta[3][])
  //                 - theta[1][]*(1-theta[3][])*y[][1]
  //                 - theta[2][]*(1-theta[3][])*y[][2]
  //                 - theta[3][]                *y[][3];

  return ufunc.*z;
  }
//**********************************************************************
```

These files include the procedures needed for GMM estimation.

// signifies a comment

.* signifies that the two vectors are multiplied together row by row. These are the moment conditions: $E[u_t z_t] = 0,$

Here we have defined the residuals from the simple Taylor rule:

$$r_t = \alpha_0 + \alpha_1 \cdot E[\pi_{t+12} - \pi^* \mid \mathcal{I}_t] + \alpha_2 \cdot E[y_t \mid \mathcal{I}_t] + \epsilon_t,$$

The code (cont.)

```
//this is the main program block
main()
  {
  decl t1,t2;
  t1=timer();

  //import data
  decl data    = loadmat("MonetaryPolicyData.xls");

  //extract the 8 data series
  decl ff        = data[][ 0];  // Federal funds rate (effective)
  decl fftarget = data[][ 1];  // Federal funds rate (target)
  decl bond      = data[][ 2];  // bond rate (10Y constant maturity)
  decl inf       = data[][ 3];  // inflation CPI
  decl infexcl   = data[][ 4];  // inflation CPI excluding food and energy
  decl caputil   = data[][ 5];  // capacity utilization
  decl capgap    = data[][ 6];  // Output gap based on caputil
  decl ip        = data[][ 7];  // Industrial production
  decl ipgap     = data[][ 8];  // Output gap based on ip
  decl unr       = data[][ 9];  // unemployment rate
  decl unrgap    = data[][10];  // Output gap based on unr
```

This code just reads the data into the specified arrays.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

The code (cont.)

```
//Exercise set, simple taylor rule, lags: 1-2
y      = (ff~lags(inf,{-12})~capgap) [192:rows(ff)-1-12][];  //start: 12=1972:1, 192=1987:1
z      = (ones(rows(ff),1)~
          lags(ff      ,{1,2})~
          lags(bond    ,{1,2})~
          lags(inf     ,{1,2})~
          lags(infexcl ,{1,2})~
          lags(capgap  ,{1,2})~
          lags(ipgap   ,{1,2})~
          lags(unrgap  ,{1,2})  )[192:rows(ff)-1-12][];
gmm("hac",1,13,0,0);
//gmm("hc",1,0,0,0);
//gmm("iid",0,0,0,0);
```

Here we define *y* (model variables) and *z* (instruments). Use *capgap* to get the same results as me.

You need to use these when answering question (4).

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

The code (cont.)

```
//Model (M1)-(M3) simple taylor rule lags: 1-6,9,12
//y     = (ff~lags(inf,{-12})~capgap) [192:rows(ff)-1-12][];  //start: 12=1972:1, 192=1987:1
//z     = (ones(rows(ff),1)~
//         lags(ff      ,{1,2,3,4,5,6,9,12})~
//         lags(inf     ,{1,2,3,4,5,6,9,12})~
//         lags(capgap  ,{1,2,3,4,5,6,9,12})  )[192:rows(ff)-1-12][];
//gmm("iid",0,0,0,0);
//gmm("hc",1,0,0,0);
//gmm("hac",1,13,0,0);

//Model (M4)-(M6) Interest rate smoothing
//y     = (ff~lags(inf,{-12})~capgap~lags(ff,{1}))[192:rows(ff)-1-12][];
//z     = (ones(rows(ff),1)~
//         lags(ff      ,{1,2,3,4,5,6,9,12})~
//         lags(inf     ,{1,2,3,4,5,6,9,12})~
//         lags(capgap  ,{1,2,3,4,5,6,9,12})  )[192:rows(ff)-1-12][];
//gmm("iid",1,0,0,0);
//gmm("hc",1,0,0,0);
//gmm("hac",1,13,0,0);
```

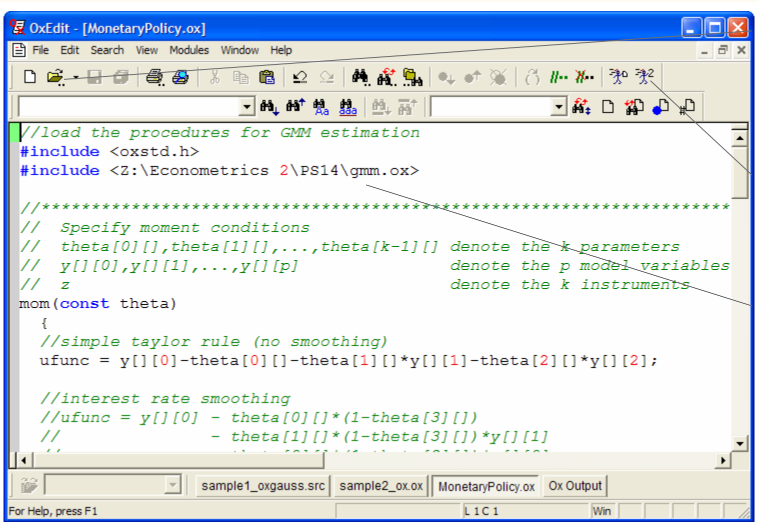
We will use this code later for questions (7) onwards.

The code (cont.)

```
//graph
SetDrawWindow("Data and estimated policy rule");
DrawTMatrix(0,(y[][0]       )' ,{"Actual"}     , 1988,1, 12,  0,2);
DrawTMatrix(0,(y[][0]-ufunc)' ,{"Predicted"} , 1988,1, 12,  0,3);
ShowDrawWindow();

t2=timer();
print("\nElapsed time: ",timespan(t1,t2),"\n");
}
```

Finally, the program draws a graph of the actual and predicted values of the federal funds rate and displays how much time it has used reaching these results!

OxEdit



Here you can open, save etc.

Use this to run the program.

The first thing you need to do is to change this to the directory where you have placed your files!

(3) The results

```
****************
* One-step GMM *
****************

                    Estimate     Std.error      t-ratio
Theta 1             -0.13447        2.1382    -0.062889
Theta 2               1.6833       0.67117       2.5079
Theta 3              0.41710       0.11821       3.5285

Observations             212
Criteria func.      1.877631


**************************
* Two-step efficient GMM *
**************************

                    Estimate     Std.error      t-ratio
Theta 1               1.1378       0.90572       1.2563
Theta 2               1.3147       0.27053       4.8599
Theta 3              0.44276      0.071385       6.2024

Observations             212
Criteria func.      0.047440
J-statistic        10.057252    [0.610938]  in a Chi2(12)
```

We get the results of one-step, two-step and iterated GMM (next slide). One-step GMM uses the identity matrix as the weight. Two-step GMM uses two iterations, where the second is based on the estimates from the first. (See p. 13 in the GMM note.)

We concentrate on the results from "iterated GMM" for the remainder of this exercise. This means that the iteration process continues until the estimates stabilize.

The results (cont.)

```
**********************************
* Iterated GMM, 22 iterations *
**********************************

                    Estimate     Std.error      t-ratio
Theta 1               1.8595       0.50198       3.7044
Theta 2               1.1090       0.15559       7.1276
Theta 3              0.47347      0.040123       11.800

Observations             212
Criteria func.      0.044132
J-statistic         9.355903    [0.672268]  in a Chi2(12)

***************************
Details:
Based on HAC estimator (Bartlett kernel [bandwidth=13]) of the optimal weight.
Kernel weights:
  1.000  0.923  0.846  0.769  0.692  0.615  0.538  0.462  0.385  0.308  0.231
  0.154  0.077  0.000  0.000  0.000  0.000

Elapsed time:  2.54
```

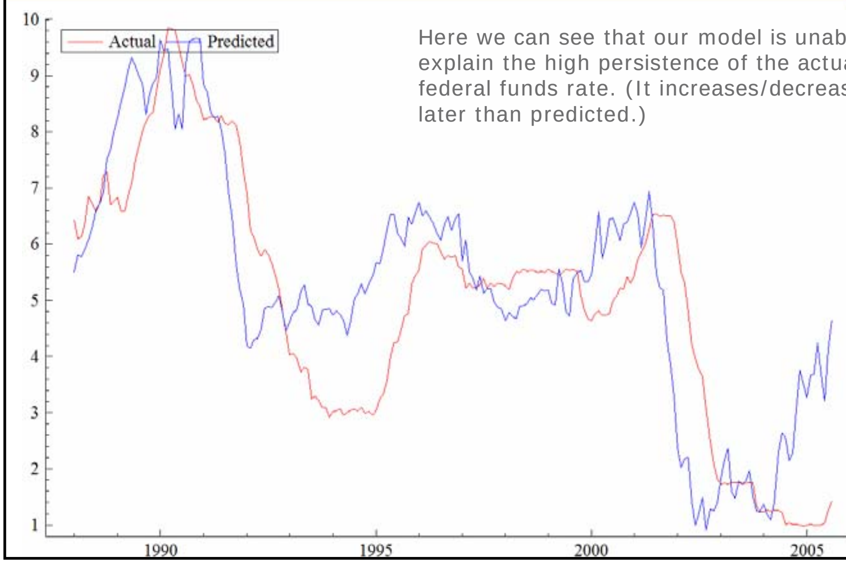
The Hansen test for no overidentification (accepted). We have 12 overidentifying moment conditions.

We allow for autocorrelation up to lag 12, because *u* includes a 12-month forecast and will thus automatically be autocorrelated. This is done using a HAC estimator of the weight matrix.

The coefficients have the expected signs and magnitudes and are significant.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

Actual vs. predicted federal funds rate



Here we can see that our model is unable to explain the high persistence of the actual federal funds rate. (It increases/decreases later than predicted.)

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(4) Estimation under assumption of IID errors, and with an HC estimator

```
*********************************
* Iterated GMM, 4 iterations *
*********************************

                  Estimate    Std.error      t-ratio
Theta 1            0.67075      0.43358       1.5470
Theta 2             1.4017      0.13940       10.055
Theta 3            0.40025     0.039373       10.166

Observations              212
Criteria func.       0.518215
J-statistic        109.861526   [6.37357e-018] in a Chi2(12)


***************************
Details:
Based on IID estimator of the optimal weight.

Elapsed time:  1.22
```

The assumption of IID errors changes the magnitude of the estimates, and we now find that the model is overidentified.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

Allowing for heteroskedasticity but no autocorrelation

```
**********************************
* Iterated GMM, 28 iterations *
**********************************

                  Estimate    Std.error      t-ratio
Theta 1             1.3429      0.29565       4.5423
Theta 2             1.1797     0.094742       12.451
Theta 3            0.49412     0.025624       19.284

Observations              212
Criteria func.       0.356254
J-statistic         75.525894    [2.92214e-011] in a Chi2(12)


****************************
Details:
Based on HC estimator of the optimal weights.

Elapsed time:  1.63
```

Again, the magnitude of the estimates is affected, and the model is overidentified.

We ought, of course, to take account of autocorrelation!

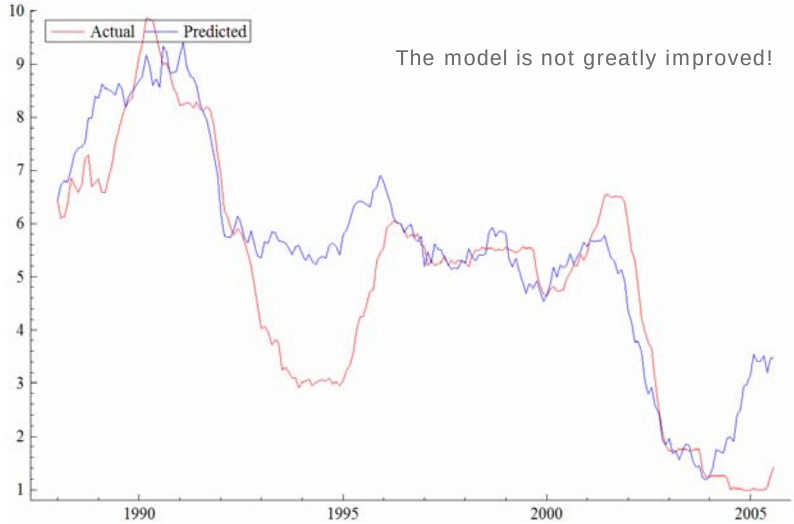
DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(5) Using a measure of inflation excluding food and energy prices, *infexcl*

```
**********************************
* Iterated GMM, 26 iterations *
**********************************

                  Estimate    Std.error      t-ratio
Theta 1             1.7941      0.23740       7.5571
Theta 2             1.2194     0.072030       16.929
Theta 3            0.35142     0.022323       15.743

Observations              212
Criteria func.       0.044112
J-statistic          9.351769    [0.672627] in a Chi2(12)


****************************
Details:
Based on HAC estimator (Bartlett kernel [bandwidth=13]) of the optimal weight.
Kernel weights:
  1.000  0.923  0.846  0.769  0.692  0.615  0.538  0.462  0.385  0.308  0.231
  0.154  0.077  0.000  0.000  0.000  0.000

Elapsed time:  2.81
```

This is a robustness test. *infexcl* might be the relevant inflation target, since food and energy price changes are often temporary and volatile.

Using *infexcl* (cont.)



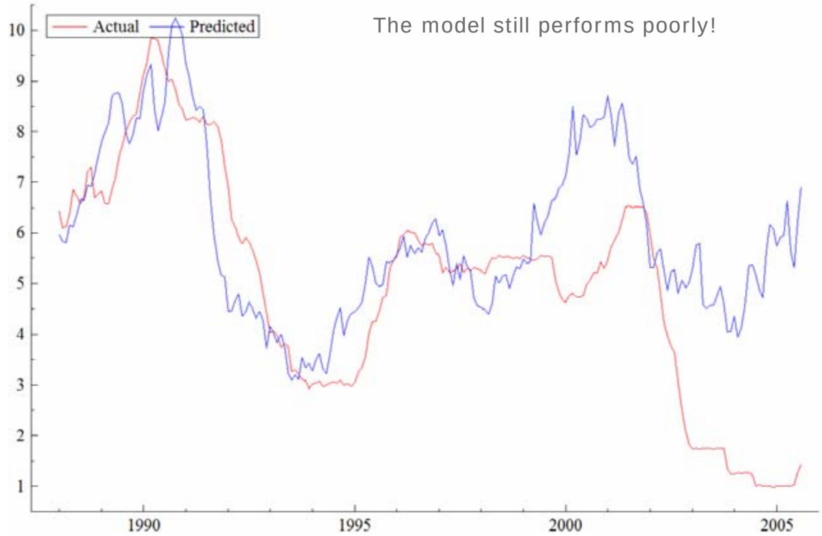
The model is not greatly improved!

(6) Using a different measure of the output gap, *unrgap*

```
*********************************
* Iterated GMM, 58 iterations *
*********************************

                  Estimate    Std.error      t-ratio
Theta 1             1.4572      0.37317       3.9049
Theta 2             1.2140      0.12192       9.9568
Theta 3            -1.2030      0.13114      -9.1738

Observations              212
Criteria func.       0.049606
J-statistic         10.516430    [0.57075] in a Chi2(12)


***************************
Details:
Based on HAC estimator (Bartlett kernel [bandwidth=13]) of the optimal weight.
Kernel weights:
  1.000  0.923  0.846  0.769  0.692  0.615  0.538  0.462  0.385  0.308  0.231
  0.154  0.077  0.000  0.000  0.000  0.000

Elapsed time:  3.83
```

Another robustness check. Note the negative coefficient for the output gap. This is because low unemployment means that there is a positive gap.

Using *unrgap* (cont.)



The model still performs poorly!

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(7) Adding lags

```
**********************************
* Iterated GMM, 41 iterations *
**********************************

                  Estimate    Std.error      t-ratio
Theta 1             1.1959      0.75062       1.5932
Theta 2             1.3333      0.21426       6.2231
Theta 3            0.35512     0.062007       5.7272

Observations              212
Criteria func.       0.046618
J-statistic          9.883077    [0.987334] in a Chi2(22)


***************************
Details:
Based on HAC estimator (Bartlett kernel [bandwidth=13]) of the optimal weight.
Kernel weights:
  1.000  0.923  0.846  0.769  0.692  0.615  0.538  0.462  0.385  0.308  0.231
  0.154  0.077  0.000  0.000  0.000  0.000

Elapsed time:  5.73
```

These are the results presented on p. 21 of the GMM note, which can be obtained using the example given in *MonetaryPolicy.ox*.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

More lags (cont.)

The model still performs poorly.

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(8) Allowing for interest rate smoothing

Now we extend the model to allow for interest rate smoothing. In particular we consider a model of the form

$$r_t = (1-\rho) \cdot \{\alpha_0 + \alpha_1 \cdot E[\pi_{t+12} - \pi^* \mid \mathcal{I}_t] + \alpha_2 \cdot E[y_t \mid \mathcal{I}_t]\} + \rho \cdot r_{t-1} + \epsilon_t, \quad (14.2)$$

where the actual interest rate depends on the lagged dependent variable.

We noted previously that the federal funds rate was more highly persistent that our model could explain. It is thus natural to add a lag of the dependent variable.

The moment conditions are the same, i.e. $E[u_t z_t] = 0$, with the residuals appropriately redefined.

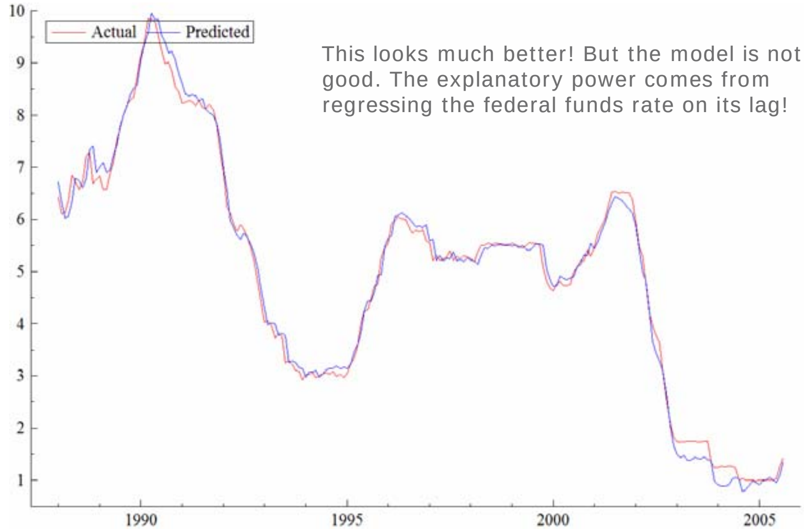
(9) Estimation of the new model

```
**********************************
* Iterated GMM, 110 iterations *
**********************************

                  Estimate     Std.error      t-ratio
Theta 1           -0.83545      0.73142       -1.1422
Theta 2             1.7385      0.24586        7.0710
Theta 3             1.0714      0.15584        6.8750
Theta 4            0.92838      0.010849       85.575

Observations              212
Criteria func.       0.048828
J-statistic         10.351625    [0.973976] in a Chi2(21)


***************************
Details:
Based on HAC estimator (Bartlett kernel [bandwidth=13]) of the optimal weight.
Kernel weights:
  1.000  0.923  0.846  0.769  0.692  0.615  0.538  0.462  0.385  0.308  0.231
  0.154  0.077  0.000  0.000  0.000  0.000

Elapsed time: 14.44
```

Note that the coefficient to the lagged interest rate is close to one, and that the coefficient to the new information is below 1/10!

If you want to replicate these results yourself, note that you need to change the code in two places!

Interest rate smoothing (cont.)



This looks much better! But the model is not good. The explanatory power comes from regressing the federal funds rate on its lag!

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(10) Why is the lagged dependent variable so important?

- The coefficient to the lagged interest rate is close to unity.
- This could reflect that the time series for the interest rate is close to behaving as a unit root process.
- Assumptions 1 and 2 in the GMM note (LLN and CLT) are thus violated.
- This means that the tools used here and not valid!
- The literature has focussed on the “success” of the Taylor-rule empirically (since the coefficients support the theory), but the tools used to demonstrate this are invalid given the data. ☺

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

(11) Are the results still sensitive to the chosen specification?

See the results presented in the GMM note. What doesn’t change is the importance of the lagged federal funds rate.

(12) Repeat the exercise for 1971:1 to 1987:12

I will let you try this yourselves!

DEPARTMENT OF ECONOMICS
UNIVERSITY OF COPENHAGEN

Finally…

- Thank you for this semester!
- As ever, you are always welcome to send an e-mail if you have any questions.
- GOOD LUCK WITH THE EXAM!