Macroeconometrics - handout 5

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May 10th or 17th, 2007

This classes is based on:

Clarida R., Gali J., Gertler M., [1998], *Monetary Policy Rules in Practice: Some International Evidence*, European Economic Review, Vol. 42, pp.1033-1067.
Clarida R., Gali J., Gertler M., [2000], *Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory*, Quarterly Journal of Economics, Vol. CXV, issue 1, pp. 147-180.

You can find link to this article as well as the data for the classes on the web pages:
www.wne.uw.edu.pl/pwojcik or www.wne.uw.edu.pl/krosiak.

The datafile **cgg.wf1** will be used during the classes - can be also downloaded from here (click on Chapter 7).

The datafile contains monthly data for the US and German economy.

1 Introduction

CGG (2000) estimate a forward-looking monetary policy reaction function for the postwar United States economy, before and after Paul Volckers appointment as Fed Chairman in 1979. Their results point to substantial differences in the estimated rule across periods. In particular, interest rate policy in the Volcker-Greenspan period appears to have been much more sensitive to changes in expected inflation than in the pre-Volcker period. They then compare some of the implications of the estimated rules for the equilibrium properties of inflation and output, using a simple macroeconomic model, and show that the Volcker-Greenspan rule is stabilizing.

Lets consider central bank reaction functions - a central bank's policy rule can be specified by assuming that central banks set their instrument - the interest rate - to react to the contemporaneous output gap (the difference between current and potential output) and to deviation of future expected inflation from its target. Future inflation is the relevant variable because the existence of lags between monetary action and their effect on the economy makes reacting to contemporaneous targets useless. The literature takes the relevant horizon for future inflation to be about one year. So CGG propose a simple baseline forward-looking specification for policy reaction function.

$$r_t^* = \bar{r} + \alpha_1 E_t(\pi_{t+12} - \pi^*) + \alpha_2 E_t(y_t - y_t^*), \tag{1}$$

$$r_t = (1-\rho)r_t^* + \rho r_{t-1} + \nu_t, \tag{2}$$

where r_t^* is the target interest rate at time t and $\bar{r}$ is the equilibrium value for r^*. The partial adjustment mechanism introduced by equation (2) is justified by the empirical observation of tendency of central banks to smooth interest rates. Moreover, a constant target rate of inflation is assumed in the estimated version of the rule. The empirical model for the policy rates becomes:

$$r_t = (1-\rho)[\bar{r} + \alpha_1 E_t(\pi_{t+12} - \pi^*) + \alpha_2 E_t(y_t - y_t^*)] + \rho r_{t-1} + \nu_t \tag{3}$$

from which, by assuming $\alpha_0 = \bar{r} - \alpha_1 \pi^*$ and eliminating the unobserved forecast variables, we obtain:

$$r_t = (1-\rho)\alpha_0 + \alpha_1(1-\rho)\pi_{t+12} + \alpha_2(1-\rho)(y_t - y_t^*) + \rho r_{t-1} + \epsilon_t \tag{4}$$

where

$$\epsilon_t = \nu_t - \alpha_1(1-\rho)(\pi_{t+12} - E_t\pi_{t+12}) - \alpha_2(1-\rho)(y_t - E_t y_t^*). \tag{5}$$

Then, since $E_t[\epsilon_t|u_t] = 0$, where u_t includes all the variables in the central bank's information set at the time interest rates are chosen, we derive the following set of orthogonality conditions:

$$\begin{aligned} E_t[f_t|u_t] &= 0 \\ f_t &= r_t - (1-\rho)\alpha_0 - \alpha_1(1-\rho)(\pi_{t+12} - \alpha_2(1-\rho)(y_t - y_t^*) - \rho r_{t-1} \end{aligned} \tag{6}$$

GMM can be used in this framework to estimate the parameters of interest $\alpha_0, \alpha_1, \alpha_2$ and ρ. The J-test for the validity of over-identifying restrictions can then assess if the simple specification of the monetary policy rule in equation (6) omits important variables which enter the central bank rule. Obvious candidates for the role of omitted variables are monetary aggregates, foreign interest rates, long-term interest rates, exchange rate fluctuations and possibly stock markets overvaluation. Moreover the estimation of parameters of interest allows some relevant consideration on monetary policy.

Given equation (1), one can write an equilibrium relation for the real interest rate as follows:

$$rr_t^* = \bar{rr} + (\alpha_1 - 1)E_t(\pi_{t+12} - \pi^*) + \alpha_2 E_t(y_t - y_t^*), \tag{7}$$

where $\bar{rr}$ is the equilibrium real interest rate, independent from monetary policy. Equation (7) illustrates the critical role of parameter α_1. If $\alpha_1 > 1$ the target real interest rate is adjusted to stabilize inflation, while with $0 < \alpha_1 < 1$ it instead moves to accomodate inflation: the central bank raises the nominal rate in response to an expected rise in inflation but it does not increase it sufficiently to keep the real rate from declining. Clarida, Gali and Gertler (2000) have shown that $0 < \alpha_1 < 1$ are consistent with the possibility of persistent, selffulfilling fluctuations in inflation and output. Therefore the value of one for α_1 is crucial discriminatory criterion to judge central bank behaviour. Clarida, Gali and Gertler show that in the pre-October 1979 period the Fed rule features rules $\alpha_1 < 1$, while the post-October 1979 period features $\alpha_1 > 1$. Finally, it is possible to use the fitted values for the parameters α_0 and α_1 to recover an estimate of the central banks' constant target inflation rate π^*. The empirical model does not separately identify the equilibrium inflation rate and of the equilibrium real interest rate but it does provide a relation between them conditional upon α_0 and α_1. Given that $\alpha_0 = \bar{r} - \alpha_1\pi^*$ and $\bar{rr} = \bar{r} - \pi^*$, we have then:

$$\pi^* = \frac{\bar{rr} - \alpha_0}{\alpha_1 - 1} \tag{8}$$

which establishes a relation between the target rate of inflation and the equilibrium real interest rate defined by the parameters α_0 and α_1 in the policy rule. Clarida, Gali and Gertler (1998) set the real interest rate to the average in the sample and use equation (8) to recover the implied value for π^*.

2 Data

The CGG database contains monthly data for the US and German economy that should enable replication of the reaction function estimated by the authors, as well as testing for a number of over-identifying restrictions. The following variables for the sample 1979:1-1996:12 are available:

```
ger10y:  redemption yield on German 10-year government bonds;
gercp:  German consumer price index;
pcm:  IMF world commodity price index (in US Dollars);
us10y:  redemption yield on US 10-year government bonds;
usa3m:  redemption yield on US 3-month government bonds;
uscp:  US consumer price index;
usff:  US average Federal Funds rate;
usagap1-usagap3:  US output gap measures;
```

3 Estimation

3.1 Estimation of a baseline policy rule for the Fed

We concentrate first on the US case, trying to replicate the results in Clarida, Gali and Gertler (1998). A series of empirical problems must be solved in order to perform GMM estimation of the monetary policy rule. The first issue we take is the measurement of the output gap. Clarida, Gali and Gertler take as the measurement the deviation of the logarithm of industrial production from a quadratic trend (USAGAP1). This is easily obtained by taking the residuals of an OLS regression of the logarithm of industrial production on a constant, a linear trend and a quadratic trend. Such measurement of the cycle would be correct only if the logarithm of industrial production features a deterministic quadratic trend. To check the robustness of the definition of the cycle to alternative de-trending methods we will compare the original proposal (USGAP1) of the authors with the difference between industrial production and a Hodrick-Prescott filter with the penalty parameter set to 14400 (USGAP2) and with the demeaned capacity utilization rate (USGAP3)[1]. The USAGAPs are calculated for the period 1981:10-1997:12, as we want to start estimation of the policy rule from 1982:10 (the beginning of the interest rate targeting regime).

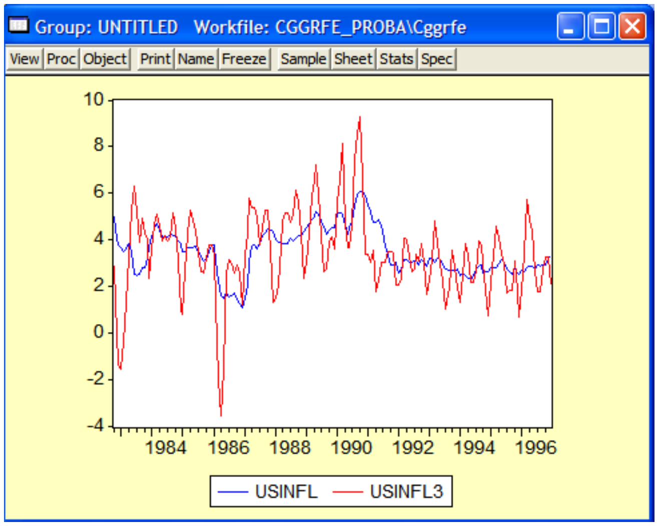
First, we need to calculate inflation rates based on price levels:

```
genr usinfl=100*(log(uscp)-log(uscp(-12)))
```

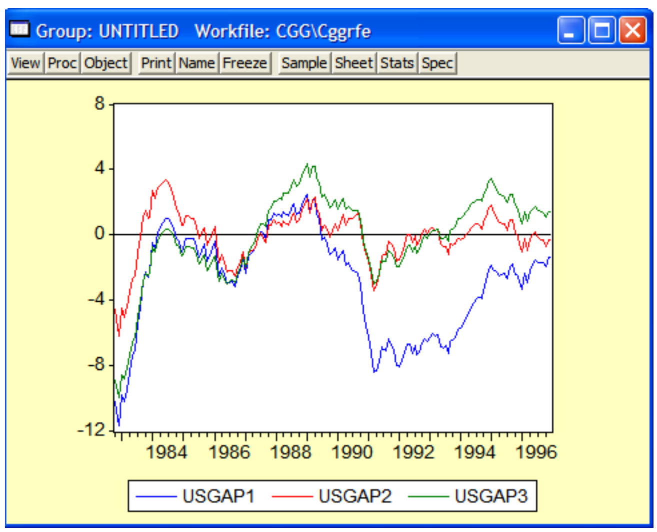
Task: Calculate yearly German inflation rate and quarterly inflation rates for US and Germany.

[1]Capacity utilization rate is the ratio of actual output to the potential output. Demeaned means that the series represent surplus over the average (mean) value.

Task: Plot US or German yearly and quarterly inflation rate in one figure.



Task: Plot a figure of alternative output gaps (USAGAP1, USAGAP2, USAGAP3). How would You interpret them?



One can observe that the three different measures do not show evident discrepancies as far as the location of the turning points in the cycle is concerned up to 1990, from 1990 onwards USGAP1 signals a persistent recession, not shared by the other two measures. Obviously, such a difference does show up in a corresponding difference in policy rates. To keep the results comparable with those of Clarida, Gali and Gertler, we keep USGAP1 as the relevant measure for the gap. Checking robustness to different de-trending choices will be the exercise at the end of this class.

The second empirical problem is the choice of the instruments. Here we follow Clarida, Gali and Gertler, by taking as instruments the constant, the first six lags, the ninth and the twelfth lag of output gap, the first six lags, the ninth and the twelfth lag of the federal fund rate, the first six lags, the ninth and the twelfth lag of inflation, the first six lags, the ninth and the twelfth lag of the logarithm IMF commodity price index. We then implement estimation by GMM, using the correction for heteroscedasticity and autocorrelation of unknown form with a lag truncation parameter of 12 and choosing Bartlett weights to ensure positive definiteness of the estimated variance-covariance matrix.

Task: Generate new variable DLPCM as the lag logarithm of the IMF commodity price index (PCM).

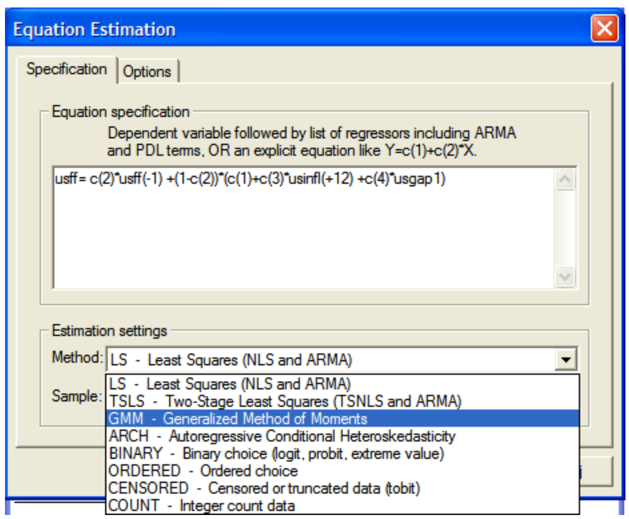
Lets then change the estimation sample period:

```
smpl 1982:10 1997:12
```

Lets estimate equation (4). Choose "Quick/Estimate Equation". In the specification window put:

```
usff=c(2)*usff(-1)+(1-c(2))*(c(1)+c(3)*usinfl(+12) +c(4)*usgap1)
```

As an estimation method choose GMM.



The starting point of GMM estimation is a theoretical relation that the parameters should satisfy. The idea is to choose the parameter estimates so that the theoretical relation is satisfied as closely as possible. The theoretical relation is replaced by its sample counterpart and the estimates are chosen to minimize the weighted distance between the theoretical and actual values. GMM is a robust estimator in that (unlike e.g. MLE) it does not require information of the exact distribution of an error term. In fact, many common estimators in econometrics can be considered as special cases of GMM (i.e. OLS).

The theoretical relation that the parameters should satisfy are usually called *ortgogonality conditions* between some (possibly nonlinear) function of the parameters $f(\theta)$ and a set of instrumental variables z_t:

$$E(f(\theta)'Z) = 0, \tag{9}$$

where θ are the parameters to be estimated. The GMM estimator selects parameter estimates so that the sample correlations between the instruments and the function f are as close to zero as possible, as defined by the criterion function:

$$J(\theta) = (m(\theta))' A m(\theta), \tag{10}$$

where $m(\theta) = f(\theta)'Z$ and A is a weighting matrix. Any symmetric positive definite matrix A will yield a consistent estimate. However, a necessary (but not sufficient) condition to obtain an asymptotically efficient estimate is to set A equal to the inverse of the covariance matrix of the sample moments m.

To obtain GMM estimates in Eviews one needs to write the moment conditions as an orthogonality condition between an expression including the parameters and a set of instrumental variables. If the equation is specified either by listing variable names or by an expression with an equal sign, Wviews will interpret the moment condition as an orthogonality condition between the instruments and the residuals defined by the equation. One must also provide the list of instruments. For the GMM estimator to be identified, there has to be at least as many instruments as there are parameters to estimate[2].

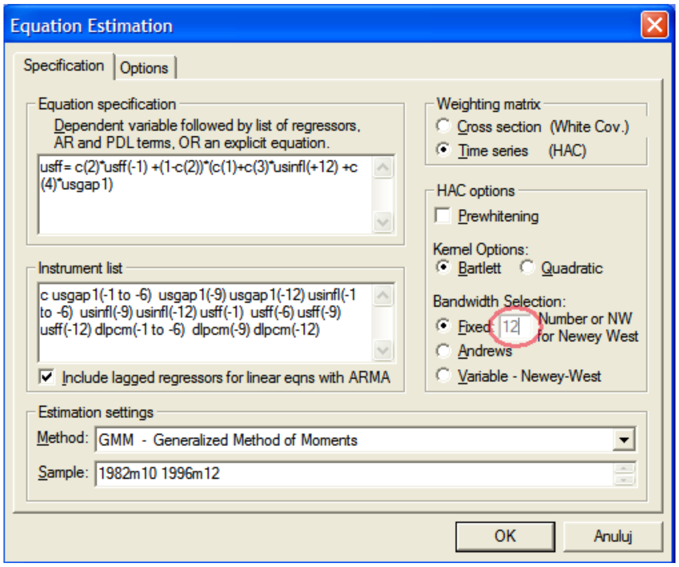
As mentioned before we follow the choice of intruments done by CGG, so in the instruments list window paste:

```
c usgap1(-1 to -6) usgap1(-9) usgap1(-12) usinfl(-1 to -6) usinfl(-9) usinfl(-12)
usff(-1) usff(-6) usff(-9) usff(-12) dlpcm(-1 to -6) dlpcm(-9) dlpcm(-12)
```

On the right hand side of the Equation Specification dialog are options for selecting the weighting matrix A in the objective function. Checking *Weighting Matrix: Cross section (White Cov)* will result in GMM estimates robust to heteroskedasticity of unknown form. Checking *Weighting Matrix: Time Series (HAC)* will result in GMM estimates robust to heteroskedasticity and autocorrelation of unknown form. For the latter one has to additionally specify the kernel type and bandwidth. The *Kernel Options* determine the functional form of the kernel used to weight the autocovariances in computing the weighting matrix. The *Bandwidth Selection* option determines how the weights given by the kernel change with the lags of the autocovariances in the computation of the weighting matrix. Selecting *Fixed* bandwidth one may either enter a number for the bandwidth or type `nw` to use Newey and West's fixed bandwidth selection criterion. The *Prewhitening* option runs a preliminary VAR(1) prior to estimation to "soak up" the correlation in the moment conditions.

Getting back to our estimation, as other options are concerned, please check if Bandwidth Selection is set to Fixed and put there 12 instead of nw (due to monthly data).

[2] Eviews will always include the constant term in the instrument list.



Below table reports estimation results:

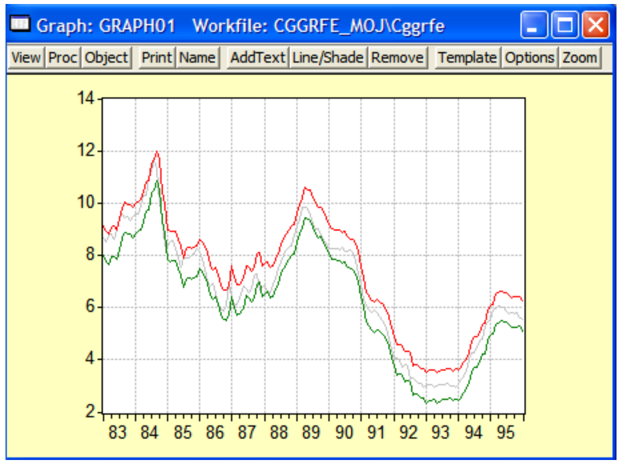
	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	2.875915	0.991193	2.901469	0.0042
C(2)	0.929660	0.012591	73.83463	0.0000
C(3)	1.730939	0.251907	6.871330	0.0000
C(4)	0.665200	0.100715	6.604758	0.0000

R-squared	0.983168	Mean dependent var	6.713957
Adjusted R-squared	0.982866	S.D. dependent var	2.191514
S.E. of regression	0.286865	Sum squared resid	13.74269
Durbin-Watson stat	1.065714	J-statistic	0.061173

Thus we have estimated $\alpha_0 = 2.88$, $\alpha_1 = 1.73$, and $\alpha_2 = 0.66$, while $\rho = 0.93$. The estimates are in line with those obtained by Clarida, Gali and Gertler, with $\alpha_1 > 1$, with some slight differences. Such differences can be explained by their choice of a second-order lag in the adjustment, while here only first-order dynamics is assumed.

The statistic for the validity of instruments has a χ^2 distribution with 29 degrees of freedom (33 instruments for 4 parameters) and takes the value of 10.45[3] and does not allow us to reject the null of validity of instruments ($\chi^2_{0.05}(29)$=42.577). If we follow the practice suggested by Clarida, Gali and Gertler to derive an estimate for the inflation target by using the estimated parameters and the average real interest rate over the sample as a proxy for the real equilibrium interest rate, we get a point estimate of 0.5 with a rather wide confidence interval (as the 95% confidence interval for α_0 spans 0.89-4.85). Overall, the rule is rather successful in explaining the Fed behaviour as illustrated in below figure, where the observed policy rates are reported with 95% confidence interval from the estimated equation.

[3] 0.0611 x 171 as the reported J-statistic in E-Views is divided by the number of observations.



3.2 Does the Fed care for long-term interest rates?

Within the GMM framework it is easy to check the importance of omitted variables in the policy rule. In fact if there are such variables, then the orthogonality condition should be violated and the test for the validity of instruments should then reject the null hypothesis. There is a rather wide range of literature concentrating on the importance of long-term interest rates for the Fed explicitly related to their signalling role for 'inflation scares'. The behaviour of long-term interest rates could be informative on agents' expectations for inflation and on the effects of monetary policy on such expectations. Some authors concentrate on the collapse of bond prices in 1994, relating it to movements in the term premium generated by a rise in expected inflation, unmatched by any movement in the same direction in actual inflation. Looking at the 1994 data we see clearly that the Fed reacted lately to the increase in long-term interest rates and it took several tightening steps in the target federal funds rate to convince markets of the central bank determination in fighting inflation. In fact only after several tightening movements in the policy rate the long-term interest rate started reverting its upward trend.
All this discussion shows that there are serious theoretical and policy reasons for the central bank to monitor long-term interest rates, and the omission of long-term interest rates from the rule seems an obvious candidate for putting our testing procedure at work.

Then next step is re-estimating of the the baseline model by including the level of contemporaneous long-term interest rates among instruments.

Task: Reestimate the model adding US10Y and one period lagged US10Y to the instruments set.

Check if your results are the same as in the table below:

The point estimates of the parameters are slightly modified but the tests for validity of instruments do not reject the null (0.067 x 171 = 11.45). In the light of this evidence we can conclude that the long-term interest rate affects the Fed behaviour as a leading indicator for future inflation but not as an independent argument of the monetary policy rule.

Task: Estimate the model using different gap measures and different instruments - do the results change substantially?

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	4.237480	1.101947	3.845447	0.0002
C(2)	0.949171	0.007868	120.6351	0.0000
C(3)	1.487264	0.276588	5.377180	0.0000
C(4)	0.868331	0.116234	7.470530	0.0000

R-squared	0.984451	Mean dependent var	6.713957
Adjusted R-squared	0.984172	S.D. dependent var	2.191514
S.E. of regression	0.275716	Sum squared resid	12.69519
Durbin-Watson stat	1.172223	J-statistic	0.067136

Task: Estimate the model for two separate periods - prior and after October 1979. Calculate targeted inflation for both periods. What are Your conclusions?