Macroeconometrics

Module 4, 2020-2021

Professor: Valery Charnavoki
E-mail: vcharnavoki@nes.ru

Course description

This course provides a survey of recent developments in time series econometrics, with a strong emphasis on macroeconomic applications, rather than on econometric theory. We will begin with a quick overview of the simple univariate models and filters. Then, we will cover multivariate models: VAR and SVAR models, different methods of their identification, multivariate unit roots, cointegration and vector error-correction models. After that, we will study the models in data-rich environment: factors models and FA-VARs. And, finally, we will discuss different methods of estimation and inference of the dynamic stochastic general equilibrium models (DSGE), in particular, simulated method of moments, maximum likelihood and Bayesian methods.

Course requirements, grading, and attendance policies

There will be a few (maximum 4) home assignments (50% of the grade). The exam (50% of the grade) will contain questions on a published applied macroeconomic article handed out in advance. All these components (including all home assignments), as well as at least 70% attendance, are mandatory for getting a passing grade.

Course contents

1. **Univariate time series models:** business cycles and time series econometrics, the Wold representation theorem, stationary ARMA models, spectrum, data transformations and univariate filters

2. **Reduced-form Vector Autoregressions:** definition, estimation, inference and forecasting, Granger causality, impulse response functions, variance decomposition

3. **Structural Vector Autoregressions:** definition, impulse response functions, variance decomposition, historical decomposition, identification: short-run restrictions, long-run restrictions, sign restrictions, applications

4. **Unit roots, spurious regressions and cointegration:** definition, testing the unit roots, spurious regression, cointegration, testing and estimation of co-integrating relations, VECM representation of cointegrated VAR, applications

5. **Factor models and FAVAR:** static and dynamic factor models, principal components analysis, determining a number of static and dynamic factors, structural FAVAR and its identification, applications

6. **DSGE models and their estimation:** definition, approximating and solving DSGE, calibration, GMM and simulated GMM estimation, ML estimation, Bayesian estimation of DSGE models

Sample tasks for course evaluation

Problem 1: Spectra and Univariate Filters

For this exercise you may write your own code in MATLAB, Python, R, etc. or use any user-written code found in internet (with proper citations). You should understand every single line of the code used.

1. Download quarterly data on real GDP in Russia (non-adjusted for seasonality) from Rosstat database. Draw a plot illustrating dynamics of the (log) of GDP. Estimate and plot spectrum for unfiltered (log) of real GDP using:

   - sample periodogram
   - parametric method by fitting AR(8) model
   - nonparametric method with Bartlett kernel

2. Use the following four filters to extract business cycle component from log-transformed GDP series using:

   - first differences
   - Hodrick-Prescott filter
   - Baxter-King band-pass filter
   - Christiano-Fitzgerald band-pass filter

   Draw plots illustrating the filtered data. Interpret the results.

3. Estimate spectra (using three methods) for all series after applying each of the four filters and draw them. Discuss the differences with the spectrum for the unfiltered series.

Problem 2: Stylized facts of business cycles in the resource-rich economy

Download quarterly data on GDP (in current and constant prices), consumption (in constant prices), investment (in constant prices), government expenditures (in constant prices), net export (in current prices), price deflators of export and import, employment and real exchange rate in Russia from Rosstat and Bank of Russia database. Take logs of employment, real exchange rate and all series in constant prices and compute the ratio of net export to nominal GDP and log of terms of trade (ratio of export and import price deflators). Use band-pass filter (BK or CF) to extract business cycle components from these series. Similarly to Table 1 in Backus, Kehoe & Kydland (1992) and the tables in Mendoza (1995), compute the business cycle statistics of these macroeconomic variables: standard deviations, auto-correlations, correlations with (filtered) real GDP and terms of trade and report them in table. Interpret the results.

Problem 3: Structural VARs

For this exercise you may use any software (MATLAB, R, Python, etc.) or user-written code found in internet (with proper citations). You should understand every single line of the code used.

Consider the VAR model with three variables: (log difference of) real GDP, Δy_t, (log of) CPI inflation, Δp_t, and nominal interest rate, i_t. Download U.S. data from my.nes.

1. Choose lag length by information criteria and estimate VAR
2. Identify structural shocks using recursive (Cholesky) decomposition with the variables in order $(\Delta y_t, \Delta p_t, i_t)$, so the monetary policy shock is ordered the last and has no contemporaneous effect on output and inflation. Report impulse responses of the variables to this shock. Do you observe any 'puzzle'?
3. Identify structural shocks (supply shock, non-monetary demand shock and monetary shock) using a mix of long-run and short-run zero restrictions, such that:
   - Only supply shock has a long-run effect on real output,
   - Monetary policy shock has no contemporaneous effect on output.

   Report impulse responses of all variables to all shocks. Compare the results with those of recursive scheme. What is the problem with this identification scheme?
4. Identify structural shocks (supply shock, non-monetary demand shock and monetary shock) using sign restrictions, such that:
   - Positive supply shock has positive effect on output and negative effect on inflation.
   - Positive non-monetary demand shock has positive effects on all variables (output, inflation and interest rate).
   - Positive monetary policy shock has positive effects on output and inflation but negatively affects nominal interest rate.

Use Rubio-Ramirez, Waggoner and Zha (2010) procedure to impose sign restrictions. Report impulse responses (only point estimates, without standard errors) of the variables to all shocks. Compare the results with the first two schemes. What is the main problem of this sign identification.

Problem 4: Bayesian Estimation Using Dynare

Consider the following RBC model with a variable utilization rate of capital u_t and a second shock that represent exogenous variations in the price of imported oil p_t (this is adapted from Finn, 1995). The representative agent solves:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t + \theta \ln(1 - N_t)\right) \tag{1}$$

subject to

$$\begin{aligned}
&Y_t = Z_t N_t^{\alpha} (u_t K_t)^{1-\alpha},\\
&K_{t+1} = Y_t + (1 - \delta(u_t))K_t - C_t - p_t Q_t,\\
&\delta(u_t) = \frac{u_t^{\gamma}}{\gamma},\\
&\frac{Q_t}{K_t} = \frac{u_t^{\zeta}}{\zeta},\\
&\ln Z_t = (1 - \rho^Z) \ln \bar{Z} + \rho^Z \ln Z_{t-1} + \epsilon_t^Z, \epsilon_t^Z \sim N(0, \sigma^Z),\\
&\ln p_t = \rho^p \ln p_{t-1} + \epsilon_t^p, \epsilon_t^p \sim N(0, \sigma^p)
\end{aligned}$$

with K_0, Z_0 and p_0 given. C_t denotes consumption in period t, N_t are working hours, K_t is the stock of capital, and Q_t is the quantity of oil imported at the price p_t. A more intense utilization of capital increases the amount of energy required per unit of capital. Thus, if the price of oil rises, capital utilization will decrease.

1. Write down equilibrium conditions characterizing this model.

2. Write down the log-linear approximation of the model around the steady state.

3. Fix the following structural parameters as: $\beta = 0.99$, $\alpha = 0.7$, $\rho^p = 0.95$, $\rho^Z = 0.95$. Download from my.nes HP-filtered data on (log of) real GDP and (log of) real oil price in US (file USData.xls). Estimate the remaining structural parameters: θ, γ, ζ, σ^p, σ^Z and $\bar{Z}$ by Bayesian methods using Dynare. Use the following values as prior means of the estimated parameters: $\theta = 2$, $\gamma = 15$, $\zeta = 15$, $\sigma^p = 0.05$, $\sigma^Z = 0.001$ and $\bar{Z} = 1$. Choose appropriate prior distributions.

4. Plot impulse responses of the endogenous variables in the estimated model to oil price and productivity shocks, ϵ_t^p and ϵ_t^Z. Demonstrate that if the price of oil rises,

capital utilization will decrease. Interpret the results.

The Problems 5-7 are based on the following paper: Dario Caldara & Christophe Kamps (2017), *The Analytics of SVARs: A Unified Framework to Measure Fiscal Multipliers*, Review of Economic Studies

Problem 5.

This paper analyzes several approaches to identification of fiscal policy shocks and demonstrates that the estimated fiscal multipliers depend crucially on fiscal rules implied by these approaches.

1. What are the differences between fiscal rules and fiscal shocks? Give an example and provide an economic intuition.

2. What are the fiscal multipliers? Why are they so important? What is the formula for calculating the fiscal multipliers using SVAR? Why this formula requires two scaling factors: the standard deviation of the fiscal shock and the sample mean of the ratio of fiscal indicator (tax revenue of government spending) to GDP?

3. This paper discusses several approaches to identification of fiscal shocks. What are these approaches? Provide rationale for these identification schemes. Explain them briefly in a formal way. What are the implications of these schemes for the values of impact fiscal multipliers?

4. Discuss briefly the empirical results in the paper. In particular, what is the relation between contemporaneous elasticities of taxes (government spending) to output and impact tax (spending) multipliers? What is the economic intuition behind this relationship? Which non-fiscal proxies are used to identify the fiscal shocks in the proxy SVAR of Section 4? Why these non-fiscal variables are valid instruments? What are the estimated contemporaneous elasticities in the fiscal rules of this proxy SVAR? What are their implications for fiscal multipliers?

Problem 6.

Consider a simple SVAR model with two variables: output (gdp_t) and taxes (tr_t). The matrix L_0 of impact IRFs for any structural model can be written as:

$$L_0(\theta, \Sigma) = \begin{bmatrix} \sigma_{gdp}\cos(\theta) & -\sigma_{gdp}\sin(\theta) \\ \sigma_{tr}\cos(\theta - \varphi_{gdp,tr}) & -\sigma_{tr}\sin(\theta - \varphi_{gdp,tr}) \end{bmatrix} \tag{2}$$

where $\theta \in [-\pi, \pi]$ is a rotation angle in a Givens matrix, $\varphi_{gdp,tr} = \arccos(\rho_{gdp,tr})$ and the reduced-form covariance matrix Σ has the following structure:

$$\Sigma = \begin{bmatrix} \sigma_{gdp}^2 & \rho_{gdp,tr}\sigma_{gdp}\sigma_{tr} \\ \rho_{gdp,tr}\sigma_{gdp}\sigma_{tr} & \sigma_{tr}^2 \end{bmatrix}$$

1. Derive equation (1) using the reduced-form covariance matrix Σ and specific orthogonal (Givens) matrix with rotation angle θ.

2. Now assume for simplicity that $\sigma_{gdp} = \sigma_{tr} = \sigma$. Compute the rotation angle θ for the following identifications schemes: a) recursive Cholesky decomposition, b) Blanchard-Perotti approach with tax rule elasticity $\psi_{gdp}^{tr} = 2$ and c) penalty function approach. What are the corresponding impact IRFs matrices for these three schemes? What are the impact tax multipliers (ignore now the scaling factor tr/gdp)? Explain.

3. Keep an assumption that $\sigma_{gdp} = \sigma_{tr} = \sigma$. Lets try now the sign identification of tax shock. In particular, lets assume that the tax shock increases taxes and decreases output on impact. Determine the range of admissible orthogonal matrices, i.e. the range of admissible rotation angles $\theta \in [-\pi, \pi]$ in a Givens matrix for which these sign restrictions are satisfied. Assume that $0 < \rho_{gdp,tr} < 1$. What is the corresponding range of admissible tax multipliers (ignore again the scaling factor tr/gdp)?

Problem 7.

Download from my.nes the file *USData.xls* with data on the US economy for the period 1950Q1-2006Q4 used in the paper. The variables included are the logarithm of real per-capita gross domestic product (gdp_t), the logarithm of real per-capita federal tax revenue (tr_t), the logarithm of real per-capita government spending (g_t), consumer price inflation (π_t), and the 3-month T-bill rate (r_t).

1. Plot these five variables. Note, that gross domestic product, federal tax revenue and government spending have a linear trend. Extract a deterministic trend from these variables using OLS regression. Plot detrended variables.

2. Using any econometric software estimate the reduced-form VAR model with five variables: detrended gross domestic product (gdp_t), detrended federal tax revenue (tr_t), detrended government spending (g_t), consumer price inflation (π_t) and the 3-month T-bill rate (r_t). Note, that in contrast to paper which uses Bayesian techniques you must estimate the reduced-form VAR model using classical (frequentist) methods. Use information criteria to determine the number of lags. Report the estimated covariance matrix of reduced-form residuals.

3. Identify the fiscal (tax and spending) shocks using the recursive scheme (Cholesky decomposition) discussed in the paper, i.e. you need to order the variables in the VAR as follows: output first, federal tax revenue second, government spending third and then consumer price inflation and interest rate. Report the estimated short-run structural matrix A_0 and the impulse responses of output to fiscal shocks. Compute fiscal multipliers and plot them (as in Figure 2). What are the values of *impact* fiscal (tax and spending) multipliers under this simple rule? Explain.

4. Identify the fiscal (tax and spending) shocks by applying the Blanchard-Perotti approach. Use general fiscal rules discussed in the Section 3.3 and in the first column of Table 1. Report the estimated short-run structural matrix A_0 and the impulse responses of output to fiscal shocks. Compute fiscal multipliers and plot them (as in Figure 2). What are the values of *impact* fiscal (tax and spending) multipliers under this rule? Explain.

Course materials

Required textbooks and materials

1. Hamilton, James D., *Time Series Analysis*, Princeton University Press, 1994

2. DeJong, David N. & Dave, Chetan, *Structural Macroeconometrics*, Princeton University Press, 2nd ed., 2011

3. Kilian, Lutz & Lutkepohl, Helmut, *Structural Vector Autoregressive Analysis*, Cambridge University Press, 2017

Additional materials

1. Lutkepohl, Helmut, *New Introduction to Multiply Time Series Analysis*, Springer, 2007

2. Canova, Fabio, *Methods for Applied Macroeconomic Research*, Princeton University Press, 2007

3. Favero, Carlo A., *Applied Macroeconometrics*, Oxford University Press, 2001

I will also provide a reading list of papers applying models and methods discussed in the class, with the rate of about 2-3 per week.

Academic integrity policy

Cheating, plagiarism, and any other violations of academic ethics at NES are not tolerated.