Macroeconometrics

Module 4, 2019-2020

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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, Bayesian methods and hybrid models (DSGE-VAR).

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: Juan Antolin-Diaz & Juan F. Rubio-Ramirez (2018), *Narrative Sign Restrictions for SVARs*, American Economic Review (forthcoming)

Problem 5.

This paper identifies structural vector autoregressions (SVARs) using narrative sign restrictions.

1. What are the sign restrictions based on narrative information? Give examples of these restrictions. Explain.

2. What are the main advantages of this identification method comparing to the traditional sign identification approach? And comparing to existing narrative information methods?

3. This paper proposes three types of the sign restrictions based on narrative information. What are these three types? What are the differences between them? Which type is the most restrictive?

4. The traditional sign identification approach provides a set of structural models with the same likelihood function. This complicates interpretation of the results, since two different structural models with different parameters are equally likely given the same sample of observed data. Does this problem exist for the sign restrictions based on narrative information? Explain why or why not.

5. This paper uses narrative information to revisit the results of Kilian (2009) and Kilian & Murphy (2012) regarding the relative importance of supply and demand shocks in the oil market. What are these narrative sign restrictions? What are the main economic implications of these restrictions regarding the effects of structural shocks? Which historical events in the oil market are the most important for identification?

Problem 6.

Download from my.nes a file *KilianData.xls* with data on the global oil market from Kilian (2009) for the period 1973M2-2008M9.

1. Estimate the SVAR model using three variables: $\Delta prod$ - the percent change in global crude oil production, rea - an index of real economic activity representing the global business cycle, rpo - the log of the real price of oil. Include 24 lags in this model. Using a recursive scheme as in Kilian (2009), identify a shock to the world

production of crude oil ('oil supply shock'), a shock to the demand for crude oil and other industrial commodities associated with the global business cycle ('aggregate demand shock'), and a shock to demand for oil that is specific to the oil market ('oil-market-specific demand shock'). Discuss the results. In particular, report the estimated structural matrix A_0, the impulse responses of three variables to identified shocks, their variance and historical decompositions.

2. Using recursively identified SVAR, compute the structural shocks and check whether the oil supply shock takes negative values in December 1978-January 1979 (Iranian Revolution), September-October 1980 (Iran-Iraq War), August 1990 (Persian Gulf War), December 2002 (Venezuela oil strike) and March 2003 (the start of the Iraq War). Explain the results.

3. Using recursively identified SVAR, check wether the oil supply shocks are the most important contributor to the observed unexpected movements in oil production growth in December 1978-January 1979 (Iranian Revolution), September-October 1980 (Iran-Iraq War), August 1990 (Persian Gulf War), December 2002 (Venezuela oil strike) and March 2003 (the start of the Iraq War). Check also whether the aggregate demand shocks are the least important contributor to the observed unexpected movements in the real price of oil in September-October 1980 (Iran-Iraq War) and August 1990 (Persian Gulf War). Explain the results.

Problem 7.

Consider the following bivariate supply and demand SVAR model:

$$\begin{pmatrix} 1 & 0 \\ -\alpha & 1 \end{pmatrix} \begin{pmatrix} \Delta y_t \\ \Delta p_t \end{pmatrix} = \begin{pmatrix} \beta & 0 \\ 0 & \gamma \end{pmatrix} \begin{pmatrix} \Delta y_{t-1} \\ \Delta p_{t-1} \end{pmatrix} + \begin{pmatrix} \epsilon_t^d \\ \epsilon_t^s \end{pmatrix}$$

where Δy_t are log-differences of GDP, Δp_t are log-differences of CPI, ϵ_t^d and ϵ_t^s denote orthogonal demand and supply shocks, α, β and γ are structural parameters.

1. Write down the conditions for a stability of SVAR-model in terms of restrictions on α, β and γ.

2. Compute the impulse responses $\mathbf{L}_k(\mathbf{\Theta})$ (see Section 2.1 in the paper) as functions of the structural parameters α, β and γ.

3. Compute the contribution of the demand shocks to the observed unexpected change in the CPI between periods t and $t+2$ as a function of the structural parameters α, β and γ and demand shocks ϵ_t^d, ϵ_{t+1}^d and ϵ_{t+2}^d, i.e. the historical decomposition $H_{2,1,t,t+2}(\mathbf{\Theta}, \epsilon_t, \epsilon_{t+1}, \epsilon_{t+2})$ (see Section 2.2 in the paper).

The Problems 8-10 are based on the following paper: Altig D., Christiano L., Eichenbaum M. & Linde J. (2011) *Firm-Specific Capital, Nominal Rigidities and the Business Cycle*, Review of Economic Dynamics

Problem 8.

This paper studies a business cycle model of the U.S. economy consistent with the observed inertia in inflation despite the fact that firms re-optimize prices frequently (on average once every 1.8 quarters).

1. What are the main differences between homogeneous and firm-specific capital? Why it is important for inflation inertia? Explain.

2. Are there any other propagation mechanisms generating inflation inertia?

3. The model is driven by three types of shocks: monetary policy shocks, neutral technology shocks and capital embodied shocks. What is the main difference between neutral and capital-embodied technology shocks? What are the predictions of this model regarding the effects of these two shocks on macroeconomic variables?

4. The log-linearized versions of the firm-specific and homogeneous capital models are observationally equivalent with respect to aggregate prices and quantities (i.e. we do not need to know which version of the model we are working with at the estimation stage). Why, then, do these models have so different implications regarding pricing behaviour of firms? Explain.

5. Why do we need a small value of the New Keynesian Phillips curve's parameter γ to account for inflation inertia observed in data? What is a role of the price elasticity of demand, $\frac{\lambda_f}{\lambda_f - 1}$, and the flexibility of capital utilization, σ_a, in determining γ? Explain.

Problem 9.

In the Section 4, the SVAR model is estimated and used to illustrate how major macroeconomic variables respond to monetary, neutral technology and capital embodied shocks in the United States.

1. Which method is used to identify the monetary, neutral technology and capital embodied shocks? Which restrictions does this identification scheme impose on the structural matrix C? Interpret these restrictions.

2. To compute the contribution of shock i to variance of each variable, the following formula is used:

$$\frac{\int_{\omega_1}^{\omega_2} f^i(\omega)d\omega}{\int_{\omega_1}^{\omega_2} f(\omega)d\omega},\ \omega_1 = \frac{2\pi}{32},\ \omega_2 = \frac{2\pi}{8}$$

where $f(\omega)$ denote the corresponding spectral density. Explain this formula.

3. Download from my.nes a file *USData.xls* with updated data on some of the variables used in the paper. Estimate the SVAR model using six variables: $d(RPI)$ - log-difference of the relative price of investment, $d(GDP/Hours)$ - log-difference of the labour productivity, $d(PGDP)$ - log-difference of the GDP deflator, CU - capacity utilization, $Hours$ - log of employment in per capita hours, and FFR - federal funds rate. Consider the SVAR with constant and without deterministic trend. Use information criteria to choose the lag length. Identify neutral technology and capital embodied shocks using the long-run restrictions discussed in the paper (you do not need to identify monetary shock in this exercise) and report their effects on the US economy. Discuss the results.

Problem 10.

In the Section 3.2 of the earlier (working paper) version of this paper, the authors discuss an estimation algorithm of the structural parameters of DSGE model.

1. What is a method used to estimate structural parameters? Sketch algorithm implementing this estimation method. (You do not need to write any code or to replicate the results of the paper. Just describe and explain the basic steps needed to implement this algorithm.)

2. What are advantages and disadvantages of this estimation method?

3. Could you suggest any alternative estimation algorithm of the DSGE model in the paper? Sketch the basic steps of this algorithm. What are advantages and disadvantages of this method?

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

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.