Course Syllabus

Title of the course	**Time Series Econometrics**		
Title of the Academic Programme	Master's in Applied Economics and Mathematical Methods		
Type of the course	Elective		
Prerequisites	Introduction into Mathematical Economics, Econometrics, Macroeconomics I		
ECTS workload	3		
Total indicative study hours	Directed Study	Self-directed study	Total
	36	78	114
Course Overview	Time series analysis is one of the natural extensions of Econometrics I and other corresponding econometrics related courses. The focus of the course is adopting and extending techniques and results from the baseline econometrics courses to the case of time series related theoretical and empirical problems. The course is supposed to provide the students with a set of tools that are useful for both theoretical and empirical modeling of dynamic economic data coming in the form of both univariate and multivariate time series. The course content covers (but not limited to) an overview of the crucial theoretical results of contemporary time series econometrics and of the approaches towards empirical application of these results to empirical data and tasks, including estimation of dynamic economic models and practical forecasting.		
Intended Learning Outcomes (ILO)	After mastering this course, the students will be able to statistically describe and analyze various dynamic economic data coming in the form of time series, to construct and analyze models of the corresponding economic processes, to construct relevant predictions of the data. The practical skills of doing the corresponding empirical research are supposed to be practiced by analyzing relevant empirical data using statistical software. The skills of writing an analytical economic paper are developed and tested by completing the report on a group empirical project. In addition, the students are going to develop teamwork organization and coordination skills by completing the group project task.		
Teaching and Learning Methods	The course is delivered via lectures, practice sessions, group homework assignment and an exam. During the lectures the students are delivered new material and perform checking activities, including those based on interactive teaching technologies (Mentimeter, Wooclap). The activities that take place during the lectures are not graded and are designed to check the students' understanding of the new material and recall the previously discussed points. The practice sessions include quizzes (graded) based on interactive testing systems (Wooclap). The quizzes are designed to motivate the students to get prepared for the practice sessions and revise the material delivered in the lectures step-wise.		

	The homework assignment is a group empirical project task. Firstly, it is designed to help the students develop the practical skills of empirical work with real-life economic time series data using relevant and contemporary software. Also the students are to improve their ability to find and process statistical data, pose relevant data analysis questions, answer them via performing statistical analysis and report the conclusions in form a self-standing written analytical paper. Secondly, the homework assignment has a project component. The students are supposed to work in teams (strictly more than 4 people, up to 8 people) so that they improve their teamwork and communication skills. The exam is a traditional self-standing written individual closed-book work scheduled and held according to examination week schedule. The exam covers the material of all the course, including essential questions from the theoretical work and empirical project results. The content and materials of the course are supported via an interactive classroom system (Padlet), where the students can access all the necessary material and ask and answer questions.

Content and Structure of the Course

№	Topic / Course Chapter	Total	Directed Study		Self-directed Study
			Lectures	Tutorials	
1	Inroduction to the course	6	2	0	4
2	Stationarity	20	6	2	12
3	Linear modeling	24	6	4	14
4	Prediction	18	4	2	12
5	Stationary linear regression	18	4	2	12
6	Structural breaks and stability	16	2	2	12
Total study hours		114	24	12	78

Indicative Assessment Methods and Strategy	The resulting gradefor the course, **GR**, is determined according to the following rule: $$\mathbf{GR} = 0.67 \times \mathbf{GF} + 0.264 \times \mathbf{GH} + 0.066 \times \mathbf{GQ},$$ rounded to the ceiling, where **GF** is the grade for the final exam (on the scale from 0 to 10), **GH** is the grade for the homework assignment (HWA, same scale), and **GQ** is the average grade for the quizzes (same scale). The HWA is a group empirical project. The students are offered a task to work with an actual real-life sample of economic time series of their choice and perform a series of empirical exercises (the details are announced in the task that is to be distributed before the third lecture of the course). Students report their results in a form of a written report and are graded accordingly to the 1) fullness of the task completion, 2) their demonstrated control of the empirical software mastering, 3) their ability to produce and empirical research report, and 4) their skill of organization and coordination of teamwork.

There are 5 graded quizzes held during practice sessions, the grade for the quizzes is

$$\mathbf{GQ} = 0.2x(\mathbf{Q1}+...+\mathbf{Q5}),$$

rounded to the ceiling, where **Qi**s are the grades for each quiz.

The quizzes are held during practice sessions and are based on the material of the lectures. Each quiz consists of several (10-15) multiple-choice type of questions (including multiple choice, TRUE-FALSE, matching, filling the blanks, etc.) and is an individual closed-book work in the interactive system (Wooclap). The students are graded according to the number of correct answers given on the scale from 0 to 10. For each quiz the grade is

$$\mathbf{Qi} = \min\{10; \text{number of correct answers given in quiz i}\}.$$

The final exam is held according to the schedule of the examination week. The exam is a written individual 80-minute closed-book work, during which the students are given a task to answer questions showing their control of the material studied in the course. The exam task will contain several questions covering different topics from the course, including the material covered in the lectures, in practice sessions, in the HWA and mandatory self-directed study. Each question will be assigned a weight (announced in the task) and graded separately with percentage points according to which extent the answer to the question is full, correct, *and not excessive*. The total points for the test will, thus, be the weighted average of the points for all the questions from 0 to 100, and the resulting grade, **GF**, will be determined accordingly by the following scale rule:

points	Below 20	[20;30)	[30;40)	[40;50)	[50;60)	[60;70)	[70;75)	[75;80)	[80;85)	85 and above
GF	1	2	3	4	5	6	7	8	9	10

Readings / Indicative Learning Resources

<u>Mandatory:</u>

[T] Tsay R. S. Financial Time Series //Wiley StatsRef: Statistics Reference Online. – 2014. – C. 1-23.

<u>Recommended:</u>

[H] Hamilton J. D. Time series analysis. – Princeton, NJ : Princeton university press, 1994. – T. 2. – C. 690-696.

[MF] edX MOOC "Macroeconomic forecasting" materials according to the course schedule and content: https://www.edx.org/course/macroeconometric-forecasting-0

Indicative Self- Study Strategies

Type	+/–	Hours
Reading for seminars / tutorials (lecture materials, mandatory and optional resources)	+	12
Assignments for seminars / tutorials / labs	+	12
E-learning / distance learning (MOOC / LMS)	+	12
Fieldwork	-	-
Project work	+	20

	Other (please specify)	-	-
	Preparation for the exam	+	16
Academic Support for the Course	Academic support for the course is provided during office hours and distance consultations, and via interactive classroom support, where students can find: • all the materials used in the classroom (lectures and practice sessions slides, set of the questions and answer keys to the quizzes, suggested readings lists and links, selected questions from the classroom discussions and Q&As sessions, etc.); • guidelines and recommendations for doing the course, including HWA recommendations and self-directed studying; • samples of assessment materials (including sample quizzes and sample examination tasks). The interactive classroom also provides the students with the possibility to ask questions (either anonymously or directly) about any part of the course and/or leaving comments to any of the content posted on the interactive classroom. The students are encouraged to contribute to the questions posted on the interactive classroom by either voting for them (indicating increased interest in the question and its importance) or answering to each other.		
Facilities, Equipment and Software	Lectures are delivered in a classroom equipped with a computer connected to the Internet and projective equipment. The tutorials are delivered in a regular classroom equipped with a computer and projective equipment and the ability to connect individual devices (laptops, notebooks, smartphones or tablets) to the Internet.		
Course Instructor	Vladimir Pyrlik (Владимир Николаевич Пырлик) доцент департамента экономики СПбШЭМ НИУ ВШЭ CERGE-EI teaching fellow		

Intended Learning Outcomes (ILO) Delivering

Programme ILO(s)	Course ILO(s)	Teaching and Learning Methods for delivering ILO(s)	Indicative Assessment Methods of Delivered ILO(s)
	Knowledge of time series economic data properties	• Lectures • Non-graded checking activities (show of hands questions, polls, discussions, exit-ticket questions) • Graded quizzes • In-class discussions of empirical examples	• Checking activities during lectures • Quizzes • HWA • Exam
	Knowledge and understanding the main requirements for and properties of time series statistical modeling approaches, including univariate linear modeling and prediction, multivariate stationary regression analysis and structural breaks and stability testing.	• Lectures • Non-graded checking activities (show of hands questions, polls, discussions, exit-ticket questions) • Graded quizzes • In-class discussions of empirical examples • Project HWA • Interactive classroom discussions	• Checking activities during lectures • Quizzes • HWA • Exam
	Skills of economic time series data finding and accessing	• In-class discussions of empirical examples • Project HWA • Interactive classroom discussions	• Checking activities during practice sessions • HWA
	Skills of empirical time series data analysis techniques application	• In-class discussions of empirical examples • Project HWA • Interactive classroom discussions	• Checking activities during practice sessions • HWA
	Critical analysis of economic events and context using real-life time series economic data	• Lectures • Non-graded checking activities (show of hands questions, polls, discussions, exit-ticket questions) • In-class discussions of empirical examples • Project HWA	• Checking activities during lectures • Quizzes • HWA • Exam
	Teamwork organization and coordination	• Project HWA	• HWA
	Skills of writing an analytical report on an empirical research project based on real-life economic time series data and prediction problem related research question	• Project HWA	• HWA

Course Content

1. *Introduction to the course.*

Lecture (2 hours):

The place of the course in the sequence of the econometrics and statistics-related courses and in the programme in general. The importance of the course for professional work of an economist in business or academia.

Organizational details of the course. Game rules (materials, technologies, tasks, grading).

Introduction into Time Series. The main questions of time series analysis and econometrics. The differences between time series type of data and random samples or cross-sectional data.

Checking the students understanding via an interactive poll.

Practice session (1 hour):

Quiz (not graded) on the properties of TS data and questions of TSE. Discussion of real-life economic time series data examples, their properties and potential questions and practical tasks they can be used for.

2. *Stationarity:*

Lectures (6 hours):

Part I. The importance of stationarity and ergodicity for time series econometrics. Examples of probability, statistics and econometrics methods and tools that cannot be applied right away to TS data and require adjustment.

Stationarity. The concept in general. The difference between strict and weak stationarity.

Approaches towards testing for weak stationarity in the data. Examples of real-life economic time series analysis and performing essential judgment and visual analysis to test for the data stationarity.

Engaging the students and checking the students understanding via several show-of-hands questions, a pair discussions activity, and self-summary.

Part II. Formal testing for stationarity. Recap on the general conventional testing approach, general scheme of a conventional test application. Main approaches towards formal testing for a TS stationarity. ADF test and its properties. KPSS test and its properties. Examples of real-life economic TS data, formal tests of stationarity and discussion of accordance of the test results and essential judgment.

Stationary transformations of the data. Types of transformations. Detrending transformations. Difference transformations. Growth rates and percentage changes transformations. Log-differences. Comparison of the transformations, their essential meaning and technical properties. Numerical and essential differences between the growth rates and log-differences. Simulated data examples of differencing transformations application. Introducing the intuition behind the concept of a unit root. A few real-life economic TS examples and their transformations.

Engaging the students into self-directed study and preparation for the upcoming practice sessions and quizzes by suggesting a (non-graded) take-home poll that summarizes the topic and provides the important points of the lecture that are to appear on the graded quiz later.

Practice sessions (4 hours):

Part I. Quiz on essential judgment and visual analysis of stationarity of real-life economic TS. Discussion of several real-live economic TS from different fields (macroeconomic indicators, financial markets, commodity markets, demographics, public policy indicators, consumers surveys, etc.), discussing the main types of non-stationarity in these data.

Performing an exit ticket activity to check for the students understanding and collect their opinion on the class and questions.

Part II. Quiz on formal tests for stationarity and differencing transformations. Discussion of the quiz results and considering more real-life examples of the economic TS focusing on the formal tests of stationarity and stationary transformations.

3. *Linear modeling*

Lectures (6 hours):

Basic important linear time series processes and their properties. White noise, random walks, autoregressive process, moving average, ARMA. Stationarity conditions and moments of stationary processes.

Examples of important cases of ARMA processes. The illustration of unit root.

Wold's theorem and ARMA representation of a stationary process. Box-Jenkins modeling approach and its contemporary version.

Estimating ARMA model. Conditional Quasi Maximum Likelihood estimation. In-sample diagnostics technique. Testing for residual autocorrelation. Information criteria. Choosing relevant order of the model.

Engaging students and checking the understanding by a short non-graded quiz on the previous material.

The HWA task is released and discussed.

Practice sessions (2 hours):

Quiz on the linear representation of a stationary TS, ARMA estimation and in-sample diagnostics. Discussing an empirical example of ARMA model specification, estimation and diagnostics on a sample of real-life economic TS.

4. *Prediction*

Lecture (4 hours):

General prediction problem. Prediction uncertainty. Loss function. Conditional expectation as the best MSE predictor.

Predicting from an ARMA model. Static vs dynamic prediction. Long-run prediction convergence.

Comparing alternative predictors. Prediction loss functions. Diebold-Mariano test. Model confidence set approach.

Practice session (2 hours):

Quiz on predicting from ARMA model and comparing alternative predictors. Discussion of an empirical example on constructing and evaluating different predictors from an ARMA model for a real-life economic TS.

5. *Stationary TS regression.*

Lecture (4 hours):

Recap on iid regression. Properties of the OLS estimated, required results from the probability and statistics.

The corresponding versions of the theorems for stationary and ergodic time series. Long-run variance of a TS. Estimation of the LR variance.

Heteroskedasticity and autocorrelation correction for the regression coefficients estimates standard errors. Empirical example discussion.

Engagements students and checking understanding by a short (non-graded) interactive poll.

Upcoming students' evaluations are announced.

Practice session (2 hours):

Quiz on the S&ETS theorems and HAC correction. Discussion of another empirical example of a stationary TS regression.

6. *Stability and structural breaks.*

Lecture (2 hours):

A review of stability testing approaches. General idea of a structural break testing, the challenge of non-identified under the true null model and the idea of sup-statistics and sup-tests. Examples of structural break testing. Discussion of an empirical example of a real-life economic policy evaluation analysis.

Practice session: (2 hours):

Quiz on the stability and structural breaks testing. Discussing the technique of stability tests. Considering another empirical example.

Announcing the rules and deadlines for the student's evaluation and giving the exam preparation recommendations. Q&As regarding the ongoing HWA.

Assessment Methods and Criteria

Assessment Methods

Types of Assessment	Forms of Assessment	Modules			
		1	**2**	**3**	**4**
Formative Assessment	Quiz	5			
	Project	1			
Summative Assessment	Exam	1			

Assessment Criteria

Quizzes

In-class participation is graded via quizzes containing several questions (at least 10, up to 15) on the studied material. The grade corresponds to the number of correct answers. The questions are posed in such a way that answering at least the majority of them requires a student to respond effectively to all of the aspects of the topic and have a good control of the advanced essential and/or technical details. Answering only the simplest questions (mostly the TRUE-FALSE or the simplest multiple choice types) will indicate that the student only controls the basic understanding of the lectures coverage.

Project Homework Assignment

Grades	Assessment Criteria
«Excellent» (8-10)	A well-structured, analytical presentation of project work in form of a written self-stending analytical report. Shows strong evidence and broad background knowledge. In a group report all members of the project team are expected to contribute more or less equally and each contribution builds on the previous one clearly. The individual contributions of particular memners of the team are indicated directly in the report and are to be verified by the team leader (a team member delegated to the job on the stage of the team assembling). Answers to follow-up questions reveal a good range and depth of the performed analysis and clear understanding of the research question.
«Good» (6-7)	Clearly organized analysis, showing evidence of a good overall knowledge of the research question. No more than one third of individual members have significantly lesser contribution to the final result than the other members of the team. There must be evidence that the group has met to discuss the topic and is presenting the results of an actual teamwork. The key points and questions are addressed appropriately, a few technical details or essential comments might be missing.
«Satisfactory» (4-5)	Takes a very basic approach to the topic, using broadly appropriate material but lacking focus. The presentation of project work is largely unstructured, and some points are irrelevant to the topic. Knowledge of the topic is limited and there may be evidence of basic misunderstanding. In a group presentation, most of the work is done by one or two students and the individual contributions do not add up.

«Fail» (1-3)	Fails to demonstrate any appropriate knowledge and appropriate teamwork organization.
«Absent» (0)	No attempt to perform the task was indicated

Written Exam

Grades	Assessment Criteria
«Excellent» (8-10)	Has a clear argument, which addresses the topics of all he questions and responds effectively to all aspects of the course covered by the examination task. Fully satisfies all the requirements of the task; rare minor errors occur (in calculations or non-crucial or essential for the course);
«Good» (6-7)	Responds to most aspects of the topic with a clear, explicit argument. Covers the requirements of the task; may produce occasional errors.
«Satisfactory» (4-5)	Generally addresses the task; the format may be inappropriate in places; display little evidence of (depending on the assignment): independent thought and critical judgement include a partial superficial coverage of the key issues, lack critical analysis, may make frequent errors.
«Fail» (1-3)	Fails to demonstrate any appropriate knowledge.
«Absent» (0)	Didn’t attend the exam

Recommendations for students about organization of self-study

Self-study is organized in order to:

- Systemize theoretical knowledge received at lectures and revisiting the discussed examples;
- Completing the take-home reviews of the lectures and sample quizzes and polls;
- Enhancing critical thinking and personal development skills by studying the real-life examples and answering the extra questions posed during the classes;
- Development of research skills and teamwork skills via working on the HWA task;
- Obtaining skills of efficient independent professional activities by initiating and participating in the discussions started on the virtual classroom or organizing self-study groups for the quizzes or exam preparations.

Self-study, which is not included into a course syllabus, but aimed at extending knowledge about the subject, is up to the student's own initiative (see the suggested MOOC in the recommended readings section above). Students are encouraged to ask the instructor to recommend relevant resources for self-study and/or define relevant methods. Tasks for self-study and its content can vary depending on individual characteristics of a student and her aims. Self-study can be arranged individually or in groups both offline and online depending on the objectives, topics and difficulty degree. Assessment of self-study is made in the framework of teaching load for seminars or tests only to the degree of the mandatory self-study. The self-study behind the syllabus of the course is not to be formally assessed during the course.

In order to show the outcomes of self-study it is recommended:

- Actively participate in the checking activities during the lectures
- Complete take-home polls and sample quizzes on time
- Ask questions on the interactive classroom and contribute to answering the questions of other students
- Leave comments and suggestions on the course content when asked by the instructor

Recommendations for the project HWA report:

The report is to be prepared as the main outcome of the project HWA. The report is supposed to be a self-standing written work and should be able to be read accordingly. Different subsections of the main part of the report can be prepared by different members of the team, and the introduction and conclusion must indicate and present the results of the teamwork and discussion. The report as a whole must give a concise answer to a particular research question that is to be posed by the team and correspond to the data they choose to work with. The main part of the report must contain the answers to the particular parts of the task, including (for each part) the essential analysis of the problem, descriptive analysis of the corresponding data and/or calculations results, connection with the main research question and previous and next parts of the task. It is not strictly required to include the corresponding codes the students compose to perform the analysis, however, it can be done for extra points. In case the team decides to include the codes, they must constitute a separate section (e.g. an appendix) and must be provided with relevant comments so that the code is understandable by a potential reader who is not expected to be very experienced in time series econometrics, but is familiar with basic programming and data processing. The conclusion must revisit the initial problem and research question and summarize the results of the analysis and make the conclusions on how they answer the question at hand. The final part of the conclusion must be prepared by the m\team leader and

indicate the contributions of all the team members to both the actual empirical work and the report preparation, including the discussions and other team effort.

Special conditions for organization of learning process for students with special needs

The following types of comprehension of learning information (including e-learning and distance learning) can be offered to students with disabilities (by their written request) in accordance with their individual psychophysical characteristics:

1. *for persons with vision disorders:* a printed text in enlarged font; an electronic document; audios (transferring of learning materials into the audio); an individual advising with an assistance of a sign language interpreter; individual assignments and advising.
2. *for persons with hearing disorders: a* printed text; an electronic document; video materials with subtitles; an individual advising with an assistance of a sign language interpreter; individual assignments and advising.
3. *for persons with muscle-skeleton disorders: a* printed text; an electronic document; audios; individual assignments and advising.

The corresponding material appropriate for the students with special needs is not to be provided by the instructor by default. The students are supposed to address the instructor about it directly or via the study affairs office or any other convenient and appropriate way. The necessary material will be provided on demand.

Appendix A List of sample materials

Disclaimer. This is an approximate list of materials of the same types that are used in the actual teaching process of the course. The actual materials of the same types will have the same format and functionality; however, the actual content might be different (list of the topics, content of the questions, grade points, etc.). The actual content of the materials is to be revealed during the actual teaching process according to the dates announced on the first lecture.

The content of the interactive classroom, lecture slides, practice sessions presentations, Wooclap quizzes and any other course material listed below or posted on the listed platforms is developed by the course instructor and must not be redistributed, shared or used without his clear written permission. For detail please contact Vladimir Pyrlik at vpyrlik@cerge-ei.cz

The following materials are or can be used during the teaching process of the course:

- The interactive classroom based on the Padlet platform. The information on the service can be accessed at https://padlet.com/about

  The classroom can be accessed at https://padlet.com/vpyrlik/tse19

  The course's padlet is open to anyone with the link and does not require (but allows for) a sign-up. The posts and comments, however, are subject for moderation by the course instructor prior to publishing.

- The platform above contains examples of presentation slides, practice sessions presentations, sample quizzes, and other material used in the course.

  An example of a lecture slides can be also accessed at
  https://vpyrlik.github.io/tse19lec01/slides.html

  An example of practice session presentation is available at
  https://vpyrlik.github.io/tse19pra01/slides.html

- The quizzes are held on the interactive learning platform Wooclap, http://wooclap.com

  The graded quizzes are only revealed during the practice sessions when they take place.

  A non-graded sample quiz of the same type con be accessed at
  https://www.wooclap.com/TS1309

- Other types of interactive material includes polls, quizzes, questionnaires, etc. developed either in Wooclap or other interactive systems (Metnimeter, PollEv or others). The exact links to the activities are distributed during the classes in real-time when they take place.

  A sample "stretching question" can be accessed at
  https://www.wooclap.com/STRETCH
  (however, it might not be open and accessible before the actual class takes place)

  A sample poll used during the lecture can be accessed on the corresponding lecture slide, see
  https://vpyrlik.github.io/tse19lec00/slides.html#13

- A sample exam task is in **Appendix B** below.

Appendix B A sample final exam task

Disclaimer. This is a sample final exam task. The actual list of topics covered, and questions content and points might be different on the actual exam. This sample task is listed here to provide the students with the information regarding the format of the task in general and of the separate problems or questions.

Time Series Econometrics (Fall 2019)

Sample Final Exam

Vladimir Pyrlik

September 2019

Dear students! This exam work is an **80**-minute 100% individual written closed-book work. That means you are NOT allowed to use any printed or handwritten material, and any communication with anyone inside or outside the classroom is not allowed, neither is sharing any parts of your work. Should you have any questions, address them directly to the instructors. You are allowed to use a personal calculator that is NOT in your smartphone or other communication-type or wearable device.

Each question below has a fixed points value indicated in the brackets right next to the question number, i.e., for example, "3. [6p] ..." means that answering Question 3 would bring you *at most* 6 test points. Carefully and *really briefly* answer the questions of the problems. Please be informed and keep in mind that the fully correct answers are to be short and clear, while either excessive or irrelevant answers indicate your low control of the material and will be penalized with lower or negative points.

The following scale is used to transform the *test points* into the *grade*:

test points	below 20	[20;30)	[30;40)	[40;50)	[50;60)	[60;70)	[70;75)	[75;80)	[80;85)	85 and above
grade	1	2	3	4	5	6	7	8	9	10

Do your best to manage your time & effort wisely!

1 Problem I: time series properties and univariate prediction.

You are working with annual data on Electricity Generation (EG) in China in 1985 – 2017. The data is rather simple as it includes generation in all regions of China (including Hong Kong) and from all the sources (like hydro, coal, nuclear and all others). Your goal is to examine the properties of the time series at hand and construct and evaluate a few prediction techniques based on these data only. Answer the following questions.

0. [1p] Sign your name on the paper you are working on and number the pages. *Thanks & good luck!*
1. [16p] Based on the Figure 1, page 3 & Table 1 (page 4) perform a brief analysis of the data in levels, log-levels & first differences of log-levels. Based on the autocorrelation plots (Panels [D] & [E] of Figure 1), suggest reasonable ARMA specifications for the first diffs of the logs series – which orders you would use, briefly explain your choice.
2. [24p] Say you estimated some specifications, see Table 2 (page 4). Based on these results *only*, which of the specifications has a better *fit*? Explain. In addition to these outputs, what other diagnostic tools would you use to analyze the estimated specifications (still not talking about prediction power, just the fit)?
3. [16p] Based on Table 2, do the AR(1) & AR(2) estimates contradict stationarity of the first diffs of the logs series? What are the long-run forecasts for the first diffs of the logs series from these models?
4. [24p] In Table 3 (page 4) you can find the tail of the dataset. Your models are estimated on the data up to 2015. Based on the data and the estimates of AR(1) & AR(2), fill in the following table (*redraw it into your solutions, use* ***static forecasts***), compare the three predictors in terms of *mean absolute prediction error* (MAPE). Interpret the results.

1

Year	actual Δ log EG	Naive		AR(1)		AR(2)	
		forecast	*error*	*forecast*	*error*	*forecast*	*error*
2016	0.05334						
2017	0.05734						
	MAPE						

2 Problem II: vector models & cointegration.

Now you are working with quarterly data on short-term natural rate of unemployment & house prices in the US in 1975Q2 – 2019Q1, the series are in % changes to the previous quarter. The unemployment rate is not seasonally adjusted and includes unemployment from all sources. The house prices includes data on all the purchases. You are making an attempt to analyze the joint dynamics of the two series by constructing and estimating a relevant *restricted vector autoregressive* model. Answer the following questions.

a. [8p] Based on the visual analysis of the data (Figure 2, page 5) and stationarity test results (Table 4, page 5), make a brief conclusion about the stationarity of the series. Explain why you think the data is stationary, or what kind of non-stationarity you suspect.

b. [16p] You still make an attempt to estimate a VAR model for these data. See the estimation results in Table 2 & Figure 3, page 6. Make a brief diagnostics of these results. Explain if it is reasonable or not to make conclusions based on these estimates. What would you change in either data, model specification or estimation technique to improve the results? What is the main purpose of the restricted model?

c. [24p] Instead of estimating the restricted model, you further decide to switch to a structural VAR model. Write down a reasonable specification (in general form) for such a model. Suggest a reasonable identification approach, explain your intuition. Say, you manage to estimate this model, what tool would you use to explore how shocks in the dynamics of either series effect them?

d. [24p] You decide to move your analysis further and switch to the initial integrated data on unemployment rate and house process. What tool(s) would you use to explore a long-run relationship between the two processes? Briefly explain why it cannot be done in the plain VAR models as above. Without any prior analysis, tests or estimates, do you expect any long-run relationship between the two processes? Explain your intuition.

Appendix

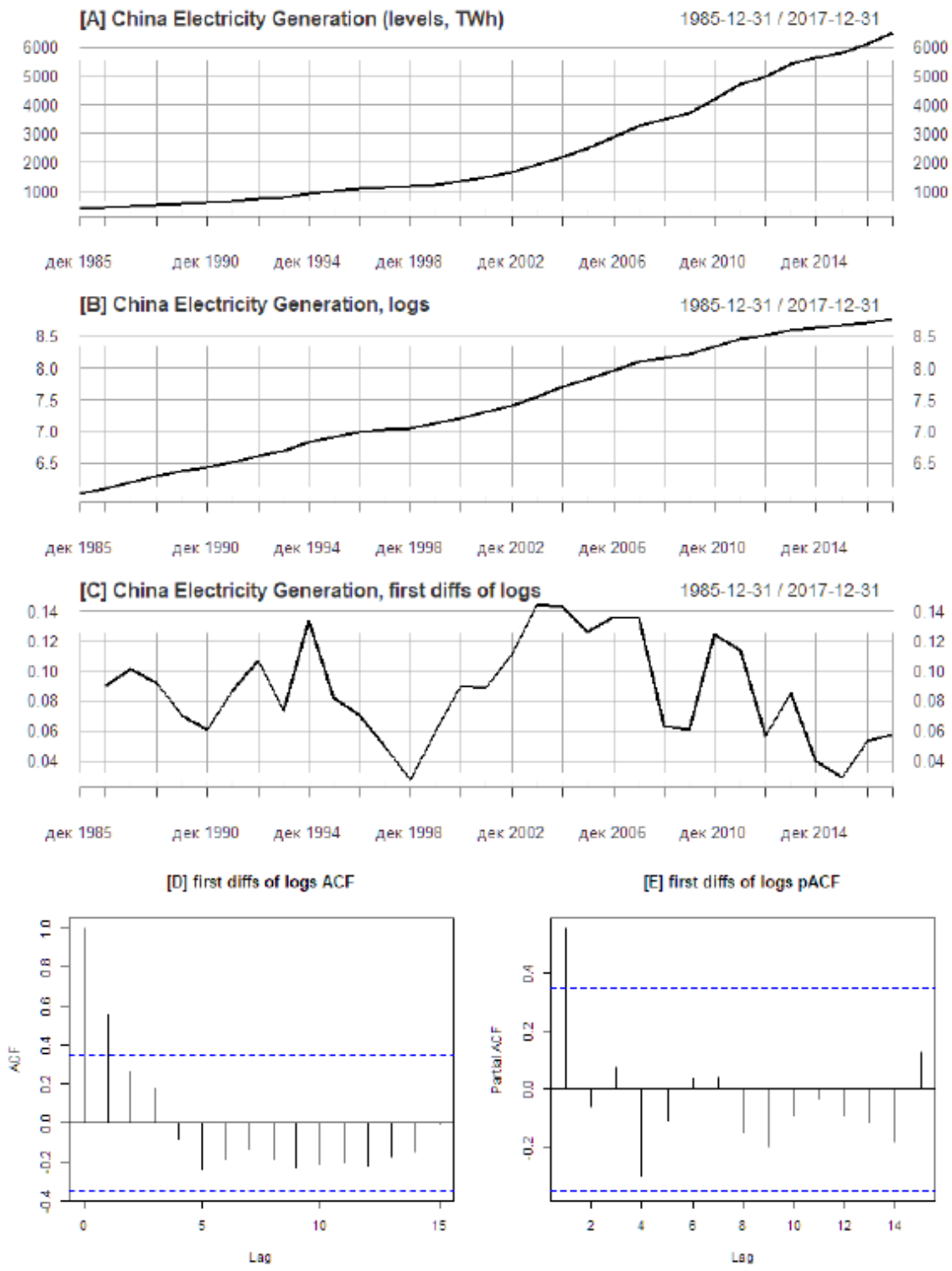

Figure 1: Problem I data: China Electricity Generation

Data	Test	P-value
log EG	ADF	0.238
	KPSS	<0.01
Δ log EG	ADF	0.497
	KPSS	>0.1

Table 1: Stationarity tests results for China Electricity Generation in logs & first diffs of logs

	Dependent variable:						
	Δ log EG						
	AR(1)	AR(2)	MA(1)	MA(2)	ARMA(1,1)	ARMA(2,1)	ARMA(1,2)
ar1	0.535***	0.568***			0.268	−0.104	0.530
	(0.159)	(0.183)			(0.490)	(0.651)	(0.450)
ar2		−0.070				0.245	
		(0.188)				(0.438)	
ma1			0.558***	0.591***	0.338	0.709	0.082
			(0.144)	(0.174)	(0.512)	(0.597)	(0.468)
ma2				0.072			−0.148
				(0.162)			(0.295)
intercept	0.086***	0.087***	0.088***	0.088***	0.087***	0.087***	0.087***
	(0.011)	(0.010)	(0.008)	(0.008)	(0.009)	(0.010)	(0.010)
Observations	30	30	30	30	30	30	30
Log Likelihood	64.182	64.251	64.160	64.259	64.346	64.566	64.465
σ^2	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Akaike Inf. Crit.	−122.363	−120.502	−122.321	−120.517	−120.692	−119.132	−118.929
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 2: A few ARMA estimates for the first differences of log EG **in 1986-2015**

Year	EG (TWh)	Δ log EG
2013	5431.6370	0.08530
2014	5649.5830	0.03934
2015	5814.5730	0.02879
2016	6133.1600	0.05334
2017	6495.1400	0.05734

Table 3: Tail of the Energy Generation dataset, **2013 − 2017**

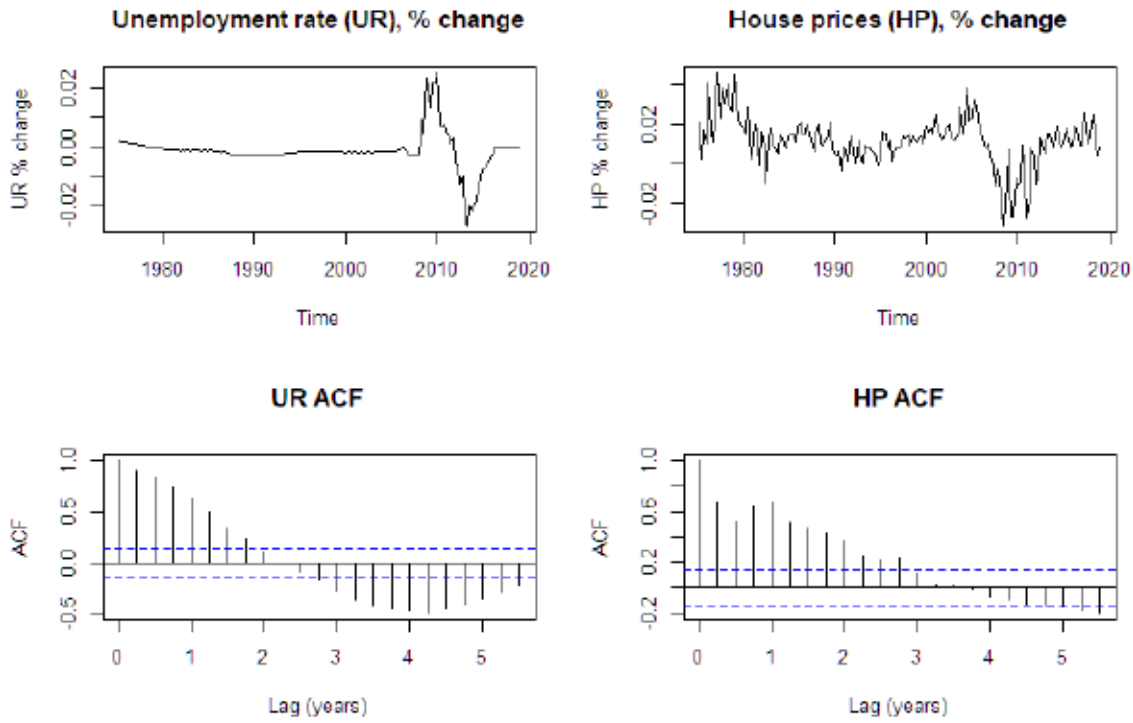

Figure 2: Problem II data: US unemployment rate & house prices, % change, quarterly

Data	Test	P-value
% change of UR	ADF	<0.01
	KPSS	>0.1
% change of HP	ADF	0.461
	KPSS	0.019

Table 4: Stationarity tests results for US unemployment and house prices, % changes

	Dependent variable:	
	(1) UR % change (ur_t)	(2) HP % change (hp_t)
ur_{t-1}	0.688***	−0.382*
	(0.074)	(0.212)
ur_{t-2}	0.359***	0.190
	(0.092)	(0.262)
ur_{t-3}	0.019	0.573**
	(0.091)	(0.261)
ur_{t-4}	−0.188**	−0.435**
	(0.073)	(0.209)
hp_{t-1}	−0.056**	0.463***
	(0.026)	(0.075)
hp_{t-2}	−0.034	−0.156**
	(0.027)	(0.078)
hp_{t-3}	−0.002	0.347***
	(0.027)	(0.078)
hp_{t-4}	0.088***	0.226***
	(0.026)	(0.076)
intercept	−0.0002	0.001
	(0.0003)	(0.001)
Observations	173	172
R^2	0.829	0.631
Adjusted R^2	0.821	0.613
Residual Std. Error	0.003 (df = 164)	0.008 (df = 163)
F Statistic	99.526*** (df = 8; 164)	34.846*** (df = 8; 163)
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 5: VAR estimation results for Unemployment rate & house prices % changes

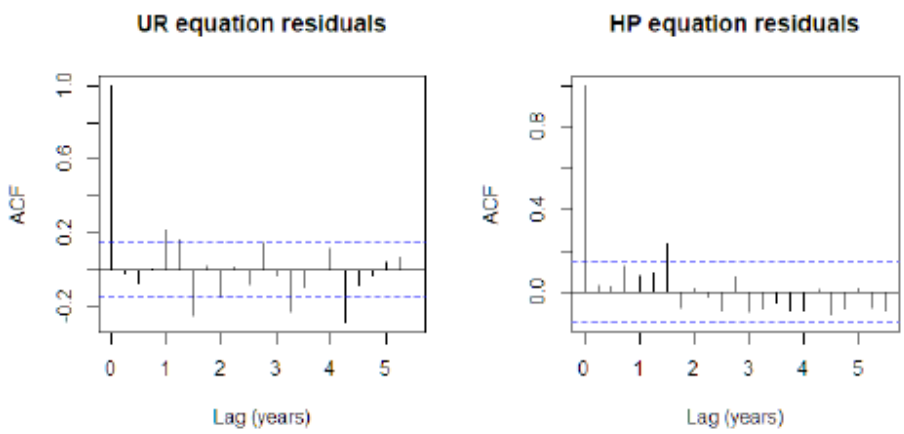

Figure 3: ACFs of VAR residuals

Appendix C Non-Discrimination and Anti-Harassment Policy

This course is developed and organized with the support of CERGE-EI Graduate Teaching Fellows program (https://www.cerge-ei.cz/teaching-fellows) and CERGE-EI foundation (https://www.cerge-ei.cz/donors/foundation).

The CERGE-EI Foundation is committed to maintaining an environment free of all forms of harassment, discrimination, bullying and sexual misconduct. All staff and fellows are responsible for ensuring a community free of such prohibited misconduct. Discrimination or harassment can be based on race, color, religion, nationality, gender, disability, age, sexual orientation, or other identifiable group characteristic. The CERGE-EI Foundation expressly expects that all individuals in all the programs it supports will be treated with respect and evaluated strictly on merit.

Any individual who is participating in a course or program supported by the CERGE-EI Foundation and who believes she/he has been subjected to or has observed discrimination or harassment may submit a written complaint.

The written complaint should identify the parties involved; describe the behavior, including when and where it occurred; and identify by name or description any witnesses. Written complaints should be treated as confidential and should be provided directly and only to one of the designated members of the Harassment Redressal Committee. The complaining individual should select one of the listed Foundation officials and address their complaint to him or her.

CERGE-EI Foundation Discrimination and Harassment Redressal Committee

The Committee consists of five members, all of whom are responsible for upholding foundation standards and governance. The committee is made up of: two Board Directors, the Teaching Fellows Pedagogical Mentor, the Administrative Director and the External Relations Director.

Prior to submitting a formal complaint, an individual may solicit anonymous advice by sending a request to info@cerge-ei-foundation.org with an anonymous email to which a response may be sent.

If the individual subsequently wishes to pursue the complaint at a formal level, the recipient of the email will make a determination as to whether there appears to be cause to initiate a formal review process. If they so determine, two other committee members from among the five listed will be selected to join the initial reviewer in making a formal investigation.

The purpose of the investigation is to gather facts relating to the incident(s) outlined in the written complaint and to determine whether it is more likely than not that the alleged behavior occurred and, if so, whether this constitutes harassment or discrimination. It may include written statements, interviews and any other sources that the investigators deem appropriate.

Note: Adversarial hearings, including confrontation, cross-examination by the parties, and active advocacy by attorneys or other outside advocates, are neither appropriate nor permitted during the investigation process.

At the conclusion of the investigation, a determination will be made as to whether any allegations in the complaint were substantiated and whether Foundation policy was violated. Three outcomes are possible:

1) A Finding of "No Violation" of the Foundation's Non-Discrimination/Anti-Harassment Policy

If it is determined that the behavior investigated did not violate Foundation policy, both parties will be so informed. If retaliatory behavior occurs after the issuance of this determination, either party may bring a new complaint.

2) A Finding of "Inappropriate Behavior Not Rising to the Level of a Violation" of the Foundation's Non-Discrimination/Anti-Harassment Policy

There may be a determination that the behavior was inappropriate and unprofessional but did not rise to the level of violating Foundation policy. Such inappropriate behavior may merit ongoing monitoring, coaching, or other appropriate action. Neither party may appeal such a finding. If retaliatory behavior occurs after the issuance of this determination, either party may bring a new complaint.

3) A Finding of "Violation" of the Foundation's Non-Discrimination/Anti-Harassment Policy

If there is a determination that the behavior did violate Foundation policy, a written report will be submitted to the supervisor of the faculty member or staff involved at the CERGE-EI Foundation and the individual's home institution. Remedial steps, at the discretion of the Foundation, may include, but are not limited to, ongoing monitoring, counseling or training, separation of the parties, and/or discipline of the accused, including a written warning, financial penalty, suspension, demotion or termination. The Foundation's ability to discipline an individual who is not its direct employee may be limited. In such cases the Foundation will provide written documentation and a recommendation for appropriate remediation to senior officials of the institution (such as a university where a course is officially offered) with such ability. Failure of an institution to resolve any complaint to the satisfaction of the Foundation will be grounds for the Foundation to deny future support.