Written Exam Economics Winter 2017-2018

Econometrics II

December 15 to 22

This exam question consists of 14 pages in total

Please note that the language used in your exam paper must correspond to the language of the title for which you registered during exam registration. I.e. if you registered for the English title of the course, you must write your exam paper in English. Likewise, if you registered for the Danish title of the course or if you registered for the English title which was followed by "eksamen på dansk" in brackets, you must write your exam paper in Danish.

If you are in doubt about which title you registered for, please see the print of your exam registration from the students' self-service system.

The paper must be uploaded as <u>one PDF document</u>. The PDF document must be named with exam number only (e.g. '1234.pdf') and uploaded to Digital Exam.

Focus on Exam Cheating

In case of presumed exam cheating, which is observed by either the examination registration of the respective study programmes, the invigilation or the course lecturer, the Head of Studies will make a preliminary inquiry into the matter, requesting a statement from the course lecturer and possibly the invigilation, too. Furthermore, the Head of Studies will interview the student. If the Head of Studies finds that there are reasonable grounds to suspect exam cheating, the issue will be reported to the Rector. In the course of the study and during examinations, the student is expected to conform to the rules and regulations governing academic integrity. Academic dishonesty includes falsification, plagiarism, failure to disclose information, and any other kind of misrepresentation of the student's own performance and results or assisting another student herewith. For example failure to indicate sources in written assignments is regarded as failure to disclose information. Attempts to cheat at examinations are dealt with in the same manner as exam cheating which has been carried through. In case of exam cheating, the following sanctions may be imposed by the Rector:

- 1. A warning
- 2. Expulsion from the examination
- 3. Suspension from the University for at limited period or permanent expulsion.

The Faculty of Social Sciences
The Study and Examination Office
October 2006

Econometrics II, Fall 2017
Department of Economics, University of Copenhagen

Introduction and Formal Requirements

The exam is a portfolio exam consisting of four separate parts. The first three parts are based on the assignments you have worked with during the semester. The last part is a theoretical part.

Each of the four parts is weighted by approximately 25 percent in the overall assessment.

Formal Requirements:

(1) You are allowed to work in groups of up to three students. The formal requirements and the assessment criteria are the same for individuals, groups of two, and groups of three students.

(2) You are only assessed based on what you hand in for the final exam, so the assignments you have handed in during the semester are not included in the assessment.

(3) Your answer to Part 1 must be maximum of 14,400 characters including spaces, math, and formulas (corresponding to 6 normal pages), plus a maximum of two pages with figures and tables.

(4) Your answers to each of Parts 2 and 3 must be maximum of 12,000 characters including spaces, math, and formulas (corresponding to 5 normal pages), plus a maximum of two pages with figures and tables.

(5) For Part 4, there is no limit on the maximum number of characters.

(6) You must hand in the exam in one pdf-document, which includes a frontpage and your answer to each of the four parts of the exam.

(7) On the frontpage, you must provide a count of the characters (including spaces, math, and formulas, but excluding tables and figures) for each of Part 1, 2, and 3.

(8) If you hand in as a group, you must specify on the frontpage who is responsible for the individual parts of the exam.

(9) The exam must be handed in at the Digital Exam platform (`http://eksamen.ku.dk`).

(10) **The deadline is at 10:00 (in the morning) on Friday, December 22.**

Part 1
House Prices

The Case: What determines house prices? Is there a house price bubble? Such questions regarding the housing market gain a lot of public attention as they have broad economic consequences. In recent years, Danmarks Nationalbank has published several empirical analyses of the determinants of Danish house prices, and the estimated relationship determining house prices is an important component in their model for the Danish economy, MONA.

Danmarks Nationalbank assumes that the theoretical long-run demand for owner-occupied housing, K_t^D, is a function of the real house price, P_t, the real household disposable income relative to the housing stock, Y_t, the user cost, u_t, the lowest possible first-year payments on a fully leveraged house purchase, f_t, and the expected future change in the (log) house price, π_t:[1]

$$K_t^D = F(P_t, Y_t, u_t, f_t, \pi_t). \tag{1}$$

The real house price, P_t, is assumed to adjust to match the demand and supply of housing. As the supply of housing is assumed fixed (at least in the short-run), a long-run relation for the real house price can be found from (1) assuming a linear function $F(\cdot)$ (partly in logs):

$$\log P_t = b_0 + b_1 \log Y_t + b_2 u_t + b_3 f_t + b_4 \pi_t, \tag{2}$$

where it is expected that $b_1 > 0$, $b_2 < 0$, $b_3 < 0$, and $b_4 > 0$.

Using quarterly data covering the period 1971(1)–2016(3), the aim of this assignment is to estimate the long-run relation for house prices in (2).

The Data: The file Assignment3.in7 contains the variables from Danmarks Nationalbank's MONA database listed below. The names in parentheses indicate the variable names in MONA, which are also used in Dam *et al.* (2011).

[1] For more details and the exact specification of the individual variables, see Section 3 and Appendix B in Dam *et al.* (2011), "Developments in the Market for Owner-Occupied Housing in Recent Years – Can House Prices be Explained?", Chapter 1 in Monetary Review, 1st Quarter 2011. You can download the publication here: `https://www.nationalbanken.dk/en/publications/Documents/2011/05/mon1_2011_part2_web.pdf`.

HOUSEPRICE	Real house price index deflated by the consumer price index (KP/PCP).
USERCOST	The user cost of housing measured as the 30-year bond rate corrected for taxes and expected inflation (RENTE30 + SSATS - DPCPE).
FIRSTYEAR	The lowest possible first-year payment measured as a weigthed average of 1 and 2-year bond rates corrected for taxes and repayments (RENTEMIN + SSATS + AFDRAG).
INCOME	Households' real disposable income relative to the housing stock (YD / PCP / AIH).
EXPPRICE	Measure of the expected short-term change in the (log) house price (DRKPE), see Hint (1) below.

Consider the following transformations:

$$p_t = \log(\text{HOUSEPRICE}_t) \qquad \Delta p_t = p_t - p_{t-1}$$
$$u_t = \text{USERCOST}_t \qquad \Delta u_t = u_t - u_{t-1}$$
$$f_t = \text{FIRSTYEAR}_t \qquad \Delta f_t = f_t - f_{t-1}$$
$$y_t = \log(\text{INCOME}_t) \qquad \Delta y_t = y_t - y_{t-1}$$
$$\pi_t = \text{EXPPRICE}_t.$$

The Assignment: Conduct an empirical analysis to determine if a long-run relationship exists between house prices and the households' real disposable income relative to the housing stock, the user cost, the lowest possible first-year payments, and the expected future change in the house price. If you find such a relationship, investigate how the corresponding equilibrium is sustained and explain if the estimated long-run coefficients have the expected signs.

Hints:

(1) As data on households' expected future changes in house prices are not available, the variable $\pi_t = \text{EXPPRICE}_t$ is used as an approximation of these expectations. Assuming adaptive expectations, the variable is constructed as a first-order autoregressive process based on the four-quarter change in the actual house prices, see Dam *et al.* pages 72-73. Consequently, you should not test for a unit root in the process for π_t and simply treat this variable as stationary. Moreover, in the model in the second step of an Engle-Granger analysis or in an ADL-model, you should exclusively include the level of this variable with one lag, i.e. only include π_{t-1} in the model and no other lags or first-differences of this variable (otherwise you will get problems with multicolliniarity due to the construction of the variable).

(2) Conduct a graphical analysis to determine the stationarity of time series variables and to check if they seem to cointegrate.

(3) Carry out unit root tests to formally confirm or reject the conclusions from your graphical inspection.

(4) Perform a cointegration analysis based on either the Engle-Granger two-step procedure and/or a dynamic model (ADL/ECM). Comment on the signs and sizes of the estimated cointegration parameters.

(5) Use an error-correction model to investigate the forces driving the system back to the equilibrium after a deviation from the long-run relationship.

Formal Requirements:

(1) You must hand in a report that (*i*) presents your graphical analysis, (*ii*) describes the econometric model, (*iii*) outlines the modeling progress (e.g., the approach you have taken, the alternative models you have estimated, etc.), (*iv*) presents your preferred model including interpretation and statements on economic and statistical significance, and (*v*) discusses the potential weaknesses of the model.

Part 2
Volatility Spillovers in International Stock Returns

The Case: Today, international stock markets are closely integrated. When the stock market in London opens, investors and the financial press look to what has just happened in major foreign stock markets that have been open while the London stock market was closed. Consequently, news might influence the stock prices in Japan while the stock market in London is closed, but then the news spill over from Tokyo to London when the stock market in London opens later in the day.

In this assignment, we consider the daily returns on the major stock indexes for the Tokyo, London, and New York markets. We focus on the London stock exchange, as measured by the FTSE 100 stock index, and consider spillovers from the Japanese Nikkei 225 index and the US SP 500 index.

Using daily observations covering the period from January 4, 2000, to October 31, 2017, the aim of this assignment is to test for return volatility spillovers from the Nikkei 225 and the SP 500 indexes to the FTSE 100 stock index.[2]

The Data: The file Assignment4.in7 contains daily observations for the stock indexes at the end of each trading day were all three markets were open:

NKY	Nikkei 225 stock index, closing prices.
UKX	FTSE 100 stock index, closing prices.
SPX	SP 500 stock index, closing prices.
EPS_NKY	Estimated residuals from a GARCH(1,1) model for the log-returns on NKY, see Hint (1).
EPS_SPX	Estimated residuals from a GARCH(1,1) model for the log-returns on SPX, see Hint (1).

The data is from the Bloomberg database.

Consider the following transformations:

$$r_t = 100 \cdot \Delta \log(\mathsf{UKX}_t), \qquad s_t^{NKY} = (\mathsf{EPS\_NKY}_t)^2, \qquad s_t^{SPX} = (\mathsf{EPS\_SPX}_t)^2.$$

[2] An example of an empirical analysis of volatility spillovers is Hamao *et al.* (1990), Correlations in Price Changes and Volatility across International Stock Markets, *The Review of Financial Studies*, Vol. 3, number 2, p. 281-307. They estimate a GARCH(1,1) model for open-to-close returns with the estimated squared innovations from the foreign markets included as explanatory variables in the equation for the conditional variance. They find evidence of international volatility spillovers, and they also consider various interesting extensions of the basic model, see Hint (6).

The Assignment: Conduct an empirical analysis to determine if there are volatility spillovers from the Nikkei 225 and the SP 500 indexes to the FTSE 100 index. Specifically, estimate a GARCH model for the log-returns (close-to-close) on the FTSE 100 index and augment the model with the latest estimated squared innovations to the log-returns on the Japanese and US markets (provided in the data set).

Hints:

(1) The variables EPS_NKY and EPS_SPX are the estimated residuals, $\widehat{\epsilon}_t$, from the GARCH(1,1) models,

$$r_t = \delta + \theta r_{t-1} + \epsilon_t, \tag{2.1}$$

$$\epsilon_t = \sigma_t z_t, \qquad z_t \sim N(0,1), \tag{2.2}$$

$$\sigma_t^2 = \varpi + \alpha \epsilon_{t-1}^2 + \beta \sigma_{t-1}^2, \tag{2.3}$$

where r_t is the log-returns on NKY and SPX, respectively, multiplied by 100. The model has been estimated individually for the returns on the Nikkei 225 and the S&P 500 indexes for the effective sample from January 6, 2004, to October 31, 2017. In the former case, the restriction $\theta = 0$ is imposed.

(2) To improve the numerical accuracy it is typically a good idea to scale the log-returns by a factor of 100, as in the suggested transformation above.

(3) Conduct a graphical analysis to detect if there is volatility clustering in the log-returns.

(4) Test formally for the presence of ARCH effects using a relevant test, and construct an econometric model accordingly to measure the volatility.

(5) You can estimate ARCH and GARCH models using the PcGive module in OxMetrics. Select the category Models for financial data and the model class GARCH Models using PcGive. Note that a GARCH(p,q) model in PcGive corresponds to a GARCH(q, p) model in the lecture notes. For example, a GARCH model with $p = 0$ and $q = 1$ in PcGive is an ARCH(1) model.
To include explanatory variables in the equation for the conditional variance, you should select them as H: X in h_t in the Formulate window. Think about the relevant timing when including the squared estimated residuals s_t^{NKY} and s_t^{SPX}.

(6) You can choose to extend the empirical analysis by considering various extensions of the classic GARCH(1,1) model with exogeneous variables in the equation for the conditional variance. For example, you can allow for threshold asymmetric impacts of the squared innovations, you can allow for international spillovers in the conditional mean (in addition to the conditional variance), or you can consider a GARCH model with t-distributed innovations.

Formal Requirements:

(1) You must hand in a report that (*i*) presents your graphical analysis, (*ii*) describes the econometric model, (*iii*) outlines the modeling progress (e.g., the approach you have taken, the alternative models you have estimated, etc.), (*iv*) presents your preferred model including interpretation and statements on economic and statistical significance, and (*v*) discusses the potential weaknesses of the model.

(2) The dataset Assignment4.in7 contains daily observations from January 4, 2000. You can use the entire sample period or you can focus exclusively on the sample starting from January 4, 2004. You do not need to motivate your choice of sample period.

Part 3
The New Keynesian Phillips Curve

The Case: Inflation tends to be pro-cycical with high inflation during times of high economic activity. When economic activity is measured by the unemployment rate, the inverse relation between inflation and unemployment is known as the Phillips curve. The empirical validitiy of the Phillips curve is a hot topic among economists right now as the US economy is experiencing low unemployment and low inflation. While this has led some economists to reject the Phillips curve, others offer potential explanations or extensions that explain the current situation maintaining the Phillips curve.[3]

In the 1960s, a *stylized Phillips curve* linking current inflation to lagged inflation and the unemployment rate became central in US macroeconomic policy in pursuit of low unemployment. The stylized Phillips curve was not derived from an explicit theory, but its parameters were seen as structural in the sense that they were invariant to policy interventions. Phelps (1967) proposed an *expectations-augmented Phillips curve* linking current inflation to expected future inflation and the unemployment rate. With inflation expectations modeled as adaptive, so they are a function of the past inflation rates, inflation expectations would converge to the actual inflation in the long run and the unemployment rate would settle at its natural rate consistent with stable inflation. Consequently, there is no trade-off between inflation and unemployment in the long run. With the high inflation and unemployment in the 1970s, Phelps' theory became widely accepted and from 1979 the Federal Reserve with Paul Volcker as chairman focused on reducing inflation.

From the research program on general equilibrium models with rational expectations emerged the *new Keynesian Phillips curve (NKPC)*. The NKPC is derived from a microfounded general equilibrium model with mononopolistic firms having forward-looking rational expectations and facing staggered prices, so that only a fraction of the firms can adjust their prices each period. The model yields the equilibrium relation for inflation:

$$\pi_t = \delta + \phi \cdot \tilde{y}_t + \gamma_f \cdot E[\pi_{t+1}|\mathcal{I}_t], \tag{1}$$

where $\tilde{y}_t$ is the output gap as a measure of overall economic activity and $E[\pi_{t+1}|\mathcal{I}_t]$ is the rational expectation of inflation next period. The parameters $\phi > 0$ and $\gamma_f > 0$ are derived from the structural parameters of the model, while in equilibrium $\delta = 0$. Empirically, the NKPC in (1) have had limited succes in explaining inflation with $\widehat{\phi}$ often being negative and/or insignificant.

[3]For example, see Phelps (2017) for a comment on the current situation with low unemployment and low inflation in the US. The brief outline of the Phillips curve presented here is partly based on the introduction to the New Keynesian Phillips curve in Hornstein (2008).

Galí and Gertler (1999) showed that the general equilibrium model underpinning the NKPC in (1) actually implied that inflation is driven by marginal costs rather than the output gap:

$$\pi_t = \delta + \lambda \cdot mc_t + \gamma_f \cdot E[\pi_{t+1}|\mathcal{I}_t], \tag{2}$$

where mc_t are the marginal costs faced by firms and $\lambda > 0$. Under certain assumptions, they show that marginal costs are proportional to the output gap, $mc_t = \kappa \cdot \tilde{y}_t$ with $\kappa > 0$, so the NKPC in (1) is a special case of (2).

Moreover, as the NKPC in (2) has difficulty explaining the persistence in inflation, Galí and Gertler (1999) extended the model underpinning (2) to allow a subset of firms to set prices according to a backward looking rule of thumb. That yields the *hybrid new Keynesian Phillips curve* relation,

$$\pi_t = \delta + \lambda \cdot mc_t + \gamma_f \cdot E[\pi_{t+1}|\mathcal{I}_t] + \gamma_b \cdot \pi_{t-1}, \tag{3}$$

where $\gamma_f > 0$ and $\gamma_b > 0$ are interpreted as the fractions of firms exhibiting forward and backward looking price setting behavior, respectively.

Galí and Gertler (1999) estimate the models in (1), (2), and (3) by *generalized method of moments* for the US economy over the sample 1960(1) to 1997(4). They use the implicit GDP deflator to measure the inflation rate, π_t, the de-meaned labor income share as a measure for marginal costs, mc_t, and the quadratically de-trended real GDP as a measure of the output gap, $\tilde{y}_t$. They find $\widehat{\gamma}_f \approx 0.95$ and clearly significant in both (1) and (2). However, they find a positive and (borderline) significant effect of marginal costs in (2) and (3), but, surprisingly, a negative and significant effect of the output gap in (1). Moreover, they find that $\widehat{\gamma}_f \approx 0.7$ and $\widehat{\gamma}_b \approx 0.3$ in (3) with both coefficients clearly significant and for various instruments, restrictions, and measures of the data. They conclude that marginal costs determines inflation, as suggested by their theory, and that while backward-looking price-setting is significant it is "not quantitatively important."[4]

Using quarterly data covering the period 1960(1)-1997(4), the aim of this assignment is to re-assess the empirical results of Galí and Gertler (1999) explained above by analyzing if there is empirical evidence of the three proposed Phillips curves in (1), (2), and (3).

[4]Galí, Gertler, and Lopéz-Salido (2001) find similar results for the Euro-area. However, several other papers have found the effects of marginal costs in (2) and (3) to be insignificant, while others have questioned the empirical strategies by Galí and Gertler (1999) and Galí, Gertler, and Lopéz-Salido (2001).

The Data: The file Assignment5.in7 contains quarterly data for the following variables:

INFL	Inflation rate measured as the first-difference of the log of the implicit GDP deflator.
GAP	Output gap measured as the quadratically de-trended real GDP per capita.
MC	Marginal cost measured as the log of the labor income share in the non-farm business sector.
SPREAD	Interest rate spread measured as the 5-year Treasury constant-maturity rate interest rate minus the 90-day Treasury bill rate, quarterly average.
WAGEINFL	Wage inflation measured as the first-difference of the log of the hourly wages per unit of output.
COMMINFL	Commodity price inflation measured as the first-difference of the log of the Producer Price Index for all commodities.

The data is from the FRED Database of the Federal Reserve Bank of St. Louis.

The time series correspond to the model variables and instruments considered by Galí and Gertler (1999).[5] All time series are de-meaned by their sample averages and should be interpreted as the deviations from their steady state values. No transformations of the data are necessary.

The Assignment: Conduct an empirical analysis based on *generalized method of moments* estimation to analyze if there is empirical evidence of the three proposed Phillips curves in (1), (2), and (3).

Hints:

(1) Your assignment should contain a short description of the economic theory for the Phillips curves in (1), (2), (3) as outlined in the text above. You must explain how the *generalized method of moments* (GMM) estimator can be derived from the economic model. In particular, explain how the moment conditions can be derived, and under what assumptions, and how you choose your instruments for GMM estimation. You can combine the economic and econometric theory in one section.

(2) You should report some robustness analysis for your empirical results. Hints (3) to (5) below gives some suggestions for robustness analyses along different dimensions.

(3) You can try different choices of instruments. Are your results robust for your choice of instruments? Argue for your preferred choice of instruments and report the Hansen test for overidentification.

(4) You can estimate your models with different weight matrices. What seems like a reasonable assumption about the moments, and what does it imply for the choice of the weight matrix? Are your results robust for different weight matrices?

[5]However, the data description in Galí and Gertler (1999) is very limited, so the data is not identical to their data. Consequently, you might get different empirical results than theirs.

(5) You can estimate your model for different subsamples and compare to the full sample estimates. Are your results robust over time?

(6) Conduct a graphical analysis to detect if there is evidence of a Phillips. You can plot the actual inflation rate together with the rate predicted by the estimated models.

Formal Requirements:

(1) You must hand in a report that (*i*) presents your graphical analysis, (*ii*) describes the econometric model, (*iii*) outlines the modeling progress (e.g., the approach you have taken, the alternative models you have estimated, etc.), (*iv*) presents your preferred model including interpretation and statements on economic and statistical significance, and (*v*) discusses the potential weaknesses of the model.

References:

Galí, J. and M. Gertler (1999), "Inflation dynamics: A structural econometric analysis." *Journal of Monetary Economics*, 44, p. 195-222.

Galí, M. Gertler, and J. D. Lopéz-Salido (2001), "European inflation dynamics." *European Economic Review*, 45, p. 1237-1270.

Hornstein, A. (2008), "Introduction to the New Keynesian Phillips Curve." *Economic Quarterly*, Vol. 94, Number 4, Fall, p. 301-309.

Phelps, E. S. (1967), "Phillips Curve, Expectations of Inflation, and Optimal Inflation over Time." *Economica*, 34, p. 254-281.

Phelps, E. S. (2017), "Nothing Natural About the Natural Rate of Unemployment." *Project Syndicate*, www.projectsyndicate.org.

Part 4
Theoretical Problems

#4.1 Maximum Likelihood Estimation in an AR(1) Model with a Level-Shift

Consider the AR(1) model

$$y_t = \rho \cdot y_{t-1} + \mu \cdot D_t + \epsilon_t, \qquad t = 1, 2, ..., T, \tag{4.1}$$

where $\epsilon_t \sim IIDN(0, \sigma^2)$ and given some initial value y_0. Assume that $|\rho| < 1$. The variable D_t is given by

$$D_t = \mathbf{1}\left(t > \frac{T}{2}\right), \tag{4.2}$$

where $\mathbf{1}(t > \frac{T}{2})$ is an indicator function which takes on the value 1 for $t > \frac{T}{2}$, and 0 otherwise. Assume that T is an even integer.

(1) Derive the maximum likelihood estimator of μ as a function of ρ.
Hint: Derive $\widehat{\mu}(\rho)$ as the solution to $\frac{\partial \ell(\rho,\mu,\sigma^2)}{\partial \mu} = 0$ for a fixed coefficient ρ, where $\ell(\rho, \mu, \sigma^2)$ is the log-likelihood function.

(2) State the concentrated log-likelihood function $\ell(\rho, \sigma^2) = \ell(\rho, \widehat{\mu}(\rho), \sigma^2)$ by replacing μ in $\ell(\rho, \mu, \sigma^2)$ by the maximum likelihood estimator $\widehat{\mu}(\rho)$ derived in Question 1.

Use the concentrated log-likelihood function to derive the maximum likelihood estimator of ρ.

#4.2 Stationarity and Forecasting in an ADL Model

Consider the ADL(2,1) model

$$y_t = \delta + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \gamma x_t + \epsilon_t, \qquad t = 1, 2, ..., T, \tag{4.3}$$

where $\epsilon_t \sim IID(0, \sigma_y^2)$ and given some initial values y_0 and x_0. Moreover, assume that the process for x_t is given by

$$x_t = \rho x_{t-1} + \eta_t, \tag{4.4}$$

where $|\rho| < 1$ and $\eta_t \sim IID(0, \sigma_x^2)$.

(1) Assume that $\phi_2 = 0.5$ and that $-1 < \phi_1 < 1$. Given these restrictions, for which values of ϕ_1 and γ is the process y_t stationary?

(2) Derive the forecasts of y_{T+1} and y_{T+2} conditional on the information set $\mathcal{I}_T = \{y_{-\infty}, ..., y_{T-1}, y_T, x_{-\infty}, ..., x_{T-1}, x_T\}$.

(3) Conditional on the information set $\mathcal{I}_T$, find the forecast of y_{T+k} for $k \to \infty$.