Zoom rules for NA0167 exam

Exam times and submission instructions:

- The exam takes place between 13.00 and 16.00 with 30 extra minutes to upload the exam in Canvas. Note! The extra 30 minutes are available for the student to upload the exam in Canvas and not to continue writing the exam.
- Submission closes 16.30 on the dot so please start submitting well in advance.
- Submission files are restricted to doc, docx and PDF.
- Exams submitted late, after exam ends, will not be graded.

Rules that must be followed:

- Write your anonymity code on ALL pages in the upper right corner. You can find your anonymity code in Ladok. If you are unsure, contact ekon-adm@slu.se
- Name your file with your anonymity code to ensure complete anonymity. **Your file name is visible to the grader.**
- Collaboration between students or other individuals is NOT allowed.
- Images and scanned documents must be pasted, in order, in ONE Word file.
- Your exam will be reviewed in URKUND for plagiarism.
- If you log in to Zoom after the exam starts or if you log out from Zoom meeting during the exam you are not be allowed to continue the exam.

For issues or technical difficulties:

- For technical questions about Canvas during the exam, contact ekon-adm@slu.se before the exam ends.
- If you have a problem submitting your exam – e-mail your exam to ekonadm.slu@analys.urkund.se. Doc, Docx and PDF are allowed. E-mail only ONE file.

Rules specific to this exam

You must have access to a camera (webcam, phone), microphone and a stable Internet connection. The camera must be aimed at your desk where you and your hands are visible.

Since you will write on paper, it should be clear to the invigilator that you are NOT using a computer during the exam, except possibly to view the questions on screen if you are unable to print them out. If you seem to be writing on a keyboard (or using a phone in any way) during the exam then the invigilator should warn you and make a note of this. Your exam may not be graded in this case, or you may be asked to do a supplementary oral examination. The same applies if you seem to be consulting books or papers.

Department of Economics
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Examination

Economic Growth and Sustainable Development, NA0167.

Rules

Permitted aids: Pen, paper, and pocket calculator.

You have 3 hours to write your answers.

Answer 3 questions in total, out of 4 available. Each question is worth 20 points, and where a question is divided into parts, each part gives equal points. (If you answer 4, I will add up all your points and then multiply by 3/4.) As a broad guideline, there is one question related to each of the following topics.

1. Neoclassical growth theory, and the DHSS model.
2. Directed technological change and sustainability.
3. Consumption, rebound, and sustainability.
4. Any or all of the above.

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1. You are given the following model, a variation of the DHSS model with a resource in infinite supply but costly to extract, and competitive markets.

$$\begin{aligned} Y &= (A_L L)^{1-\alpha-\beta} K^{\alpha} (A_R R)^{\beta}; \\ \dot{A}_L / A_L &= g; \\ \dot{K} &= s(Y - X) - \delta K; \\ C &= (1 - s)(Y - X) \\ R &= \phi X. \end{aligned}$$

A_R is constant.

(a) i. The resource price w_R is equal to its extraction cost. Explain why in a few words, and use this fact to find a simple expression for w_R.

ii. Assume balanced growth and find expressions for $\dot{Y}/Y$ and $\dot{R}/R$.

iii. Now assume $\dot{A}_R/A_R = h$, where $h > 0$. Find new expressions for $\dot{Y}/Y$ and $\dot{R}/R$. Discuss briefly.

iv. Discuss the ability of the model to (i) match and (ii) explain global aggregate observations of GDP growth, and growth rates of resource use and prices for resources such as metals and fossil fuels.

(b) Discuss how we can build more realistic models of how the global economy may be affected by (and adapt to) resource scarcity or the need to reduce polluting emissions associated with resource use. Set out at least three different ways in which we can adapt, and how each of these ways can be modelled. Explain briefly how these models can help us to better understand and predict how the economy develops, and to design effective policy.

2. Consider the CES production function

$$X = [(A_1X_1)^\epsilon + (A_2X_2)^\epsilon]^{1/\epsilon},$$

where X_1 and X_2 are inputs and X is an output, while A_1 and A_2 are productivities. Markets are perfect.

(a) Derive an expression for $w_1X_1/(w_2X_2)$ in terms of the quantities X_1 and X_2, the productivities A_1 and A_2, and ϵ.

(b) Assume X_1 is labour and X_2 is energy, while Y is final product. Suggest an appropriate value for ϵ, and discuss—using theory and evidence from global trends in the last 100 years—how changes in energy supply may affect the factor share of energy in the short and the long run. Focus particularly on how the changing factor share may affect investments in energy-augmenting knowledge A_2, and how these investments may affect the relative knowledge stocks in the long run.

(c) Assume X_1 and X_2 are alternative primary energy inputs (e.g. oil and renewables) and X is an intermediate input into the final good production function $Y = (A_LL)^{1-\alpha}X^\alpha$. Suggest an appropriate value for ϵ, and discuss—using theory and evidence—how changes in supply of one of the resources may affect its factor share in the short and the long run. Focus particularly on how the changing factor share may affect investments in renewable-augmenting knowledge A_2, and how these investments may affect the relative knowledge stocks in the long run.

3. Consider the following model, which provides an explanation of why consumers may shift towards more energy-intensive goods over time.

   There is an infinite series of products Y_i, and the production function for product i is as follows:

   $$Y_i = (1/2^{i-1}) \min\{A_L L_{Yi}, A_E E_i/2^{i-1}\},$$

   where A is productivity, L_Y is labour in final-good production, E is the energy input, and A_E is fixed. Consumers have lexicographic preferences such that they always prefer to consume the good with the highest i that they can afford, given that they demand a minimum quantity.

   Productivities A_L and A_E each grow at the constant exogenous rate g, and the initial factor share of energy is approximately 5 percent. All markets are competitive.

   (a) i. Find an expression for E_i/L_{Yi}, i.e. the ratio of energy to labour inputs in producing product i. Note that this is a measure of energy intensity.

   ii. Compare the energy intensity of final goods i and $i+1$.

   iii. Explain why, as A_L and A_E grow, consumers shift to more energy-intensive goods.

   iv. Explain the implications for the growth rate of energy use if the growth rates of A_L and A_E are equal.

   v. What difference does it make if energy efficiency A_E increases faster than A_L?

   Swedes' spending on international flights rose rapidly between 1980 and 2018 (much more rapidly than GDP). The result was that energy use and carbon emissions from the sector grew rapidly, despite increasing efficiency of airplanes.

   (b) Explain how the model above might be able to shed light on these observations, using the terms 'substitution effect' and 'income effect'. Discuss also alternative explanations and how they can be modelled and tested.

4. Assume an economy controlled by a social planner with a single final good produced in quantity Y using inputs of labour L and electricity E. The production function is as follows:

$$Y = (A_L L)^{1-\alpha} E^{\alpha} (1 - \psi D),$$

where A_L is labour productivity and D is the flow of pollution (which does not accumulate), ψ is positive and α is close to zero (so the resource has a small factor share). A_L and L grow exogenously at constant rates. Electricity E is produced using coal X_1, and we choose units such that

$$E = X_1,$$

i.e. the flow of energy is equal to the flow of coal. The extraction cost of coal, w_1, is constant. Furthermore, burning a unit of coal leads to ϕ units of polluting emissions,

$$D = \phi X_1.$$

Utility U is production Y minus total extraction costs, $w_1 X_1$, so

$$U = (A_L L)^{1-\alpha} E^{\alpha} (1 - \psi D) - w_1 X_1.$$

(a) i. Write down an expression for utility in terms of X_1, and find an expression for $\partial U / \partial X_1$.

ii. Find an approximate expression for the planner's optimal choice of X_1 assuming that $A_L L$ is very small. (Hint: What does this imply about pollution damages per unit of X_1, compared to extraction costs?)

iii. Find an approximate expression for the planner's optimal choice of X_1 assuming that $A_L L$ is very large.

iv. Describe the development of the economy over time assuming that at $t = 0$, $A_L L$ is very small.

(b) Assume that there is an alternative method of producing electricity using an input X_2 that is more expensive ($w_2 > w_1$) but emissions-free. Find an expression for $\partial U / \partial X_2$ assuming that only X_2 is used, and (by comparing this expression to the one you derived earlier for $\partial U / \partial X_1$) explain why, as $A_L L$ grows, the social planner will shift from X_1 to X_2.

(c) Consider two cases: (i) one observed real-world shift from dirty to clean technology (such as from leaded to lead-free petrol, or from CFCs to HFC-134a in refrigerators, or any other shift of your choice); and (ii) the coming (or not coming!) shift out of carbon-emitting technologies. How relevant is the model as it stands to understanding your two cases, and what could be added to make it more relevant?