Zoom rules for NA0167 exam

Exam times and submission instructions:

- The exam takes place between 9.00 and 12.00 with 20 extra minutes to upload the exam in Canvas. Note! The extra 20 minutes are available for the student to upload the exam in Canvas and not to continue writing the exam.
- Submission closes 12.20 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 two models.

- Model 1 (a variation on the 'limits to growth' model).

$$Y_t = \min\{A_{Lt}L_t, A_{Rt}R_t\};$$
$$\dot{A}_L/A_L = g;$$
$$\int_0^\infty R_t \mathrm{d}t \le S_0.$$

  Labour L is fixed, and hired on perfect markets. The resource R is costless to extract and is of 'open access' character, i.e. no individual or group has property rights over the resource (and it is not storable after extraction). A_R is constant.

- Model 2 (a variation of the DHSS model with a resource in infinite supply but costly to extract, and competitive markets).

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

  Again, A_R is constant.

(a) i. Consider Model 1, and explain carefully (mathematical reasoning may help) how Y, R, and w_R develop over time, in the long run. Assume that the resource remains 'open access' throughout.

ii. In Model 2 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.

iii. Staying with Model 2, assume balanced growth and find expressions for $\dot{Y}/Y$ and $\dot{R}/R$.

(b) Compare the models in their ability 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.

(c) One of these models ignores resource scarcity altogether, whereas in the other the global economy 'falls off a cliff' due to scarcity.

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. Will it 'fall off a cliff'? Why, or why not?

2. Assume an economy on an island with a single product, widgets. Widgets are made using labour and energy, in a Leontief production function:

$$Y = (A_Y L_Y)^{1-\alpha} E^{\alpha}.$$

Of production Y, X is used to make energy inputs and the rest is consumed. The flow of energy inputs E is as follows:

$$E = A_F L_F + A_R L_R,$$

where F denotes fossil fuels and R renewables. So energy may be produced using one or both of fossil and renewable sources, where the two are perfect substitutes. A_Y, A_F, and A_R are productivities, and L_Y, L_F and L_R are quantities of workers in each sector. All markets are perfect, and there is no scarcity. Normalize the price of a widget to 1 SEK.

Now assume that in addition to labour L there are researchers. A fixed number of researchers work on raising A_Y, and as a consequence $A_Y(t+1)/A_Y(t) = 1.2$ (one time period is 10 years). Furthermore, there is a fixed number of researchers Z in the energy sector, divided between Z_F and Z_R. And

$$A_F(t+1) = 0.95 A_F(t) + \phi Z_F(t)[\sigma A_Y(t) + A_F(t)]$$

and

$$A_R(t+1) = 0.95 A_R(t) + \phi Z_R(t)[\sigma A_Y(t) + A_R(t)].$$

Assume that $A_{Y0} = 100$, $A_{F0} = 10$, and $A_{R0} = 1$, while $Z = 5$, $\phi = 0.01$, and $\sigma = 0.4$. Finally, assume that researchers are allocated 'myopically' according to current factor shares.

(a) i. Find an expression for the price of energy w_E when it is generated from fossil fuels. Your expression should be in terms of A_F and w_L (the wage, which is the same for all workers). Find an equivalent expression when renewables are used.
   ii. Explain why fossil fuels will be used exclusively, and why all researchers will be allocated to fossil research.
   iii. Show that A_Y and A_F will grow at equal rates.

Note that when A_Y and A_F grow at equal rates we have balanced growth, and E, Y, and w_L also grow at the same rate, while w_E is constant.

The government discovers that fossil fuel burning is having severe negative effects on the quality of the environment, whereas renewables would have no such effects. Assume that a Pigovian tax (equal to marginal damages) would add $0.1 w_L$ to the price of energy generated from fossil fuels.

(b) Find the market allocation if the Pigovian tax is applied at $t = 0$. In broad terms, how will the economy evolve? (Think about how the Pigovian tax changes over time.)

(c) Assuming that the society is patient (low social discount rate), this allocation will not be socially optimal. Explain why not, and discuss alternative (or additional) policies.

   Discuss briefly what we can learn from the model regarding optimal regulation of CO_2 emissions from the burning of fossil fuels.

3. You are given the production and instantaneous utility functions in two models which provide alternative explanations of why consumers may shift towards more energy-intensive goods over time.

   - Model 1.
     There are two products Y_1 and Y_2 produced by labour and energy respectively.

$$Y_1 = A_L L;$$
$$Y_2 = A_E E.$$

     Labour L is fixed, and energy is extracted at fixed unit cost. All markets are perfect. Instantaneous utility is a Cobb–Douglas function of the two:

$$u = Y_1^{1-\alpha} Y_2^{\alpha}.$$

   - Model 2.
     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.

   In both models the 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.

   (a) Consider Model 1. Show that the factor share of energy is constant, and explain what this implies about the growth rate of energy use given that the energy price is constant. What happens if energy efficiency A_E increases faster than A_L?

   (b) Consider Model 2. Explain why, as A_L and A_E grow, consumers shift to more energy-intensive goods. What are the implications for the growth rate of energy use? What happens 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.

   (c) Explain how each of the models above might be able to shed light on these observations, using the terms 'substitution effect' and 'income effect'. Which model do you think comes closest to the truth?

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4. Consider the CES production function

$$X = [(A_1 X_1)^\epsilon + (A_2 X_2)^\epsilon]^{1/\epsilon},$$

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 $w_1 X_1/(w_2 X_2)$ 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 a natural resource input, while Y is final product. Suggest an appropriate value for ϵ, and discuss—using theory and evidence—how changes in natural-resource supply may affect the factor share of resources in the short and 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 $Y = (A_L L)^{1-\alpha} X^\alpha$. 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.