Department of Economics
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Examination

Economic Growth and Sustainable Development, NA0167.

Permitted aids: Pen, paper (lined or ruled), and pocket calculator.

Write on separate sheets. Do not staple them together.

Write your code on every sheet. Do not write your name anywhere.

In the event of questions, the examiner can be contacted on 072 555 4437.

Rules

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. Consider the following model, which is a variation of the DHSS model in which there is a resource in infinite supply but costly to extract, and competitive markets:

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

   (a) Analyse the model in the following respects:

      i. How Y, R, and w_R (the resource price) develop in the long run, assuming balanced growth;

      ii. How well these results match global aggregate observations of Y, R, and w_R for resources such as metals and fossil fuels.

   The model is not much use for predicting the future development of the global economy, partly because it does not include any of "Solow's three mechanisms", three ways outlined by Solow (1973) in which a resource-dependent economy can adapt to resource scarcity.

   (b) Explain briefly how the model can be extended to include each of Solow's mechanisms (separately).

   (c) Take one of Solow's mechanisms and explain how your extended model can be used to shed light on policy questions related to sustainability and natural resources or pollution.

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2. > [A]s the earth's supply of particular natural resources nears exhaustion, and as natural resources become more and more valuable, the motive to economize those natural resources should become as strong as the motive to economize labor. The productivity of resources should rise faster than now—it is hard to imagine otherwise.
   >
   > [Solow, *Is the end of the world at hand?*, Challenge, 1973, p47.]

   (a) Between 1800 and 1973 the price of primary energy fell greatly compared to the price of labour. Meanwhile, short-run evidence shows that labour and energy are poorly substitutable for one another, i.e. they are strongly complementary in the production function.

      i. Write down the profit-maximization problem of a final-good producer buying labour L and energy E on competitive markets, with a CES production function $Y = \left[(A_L L)^\epsilon + (A_E E)^\epsilon\right]^{1/\epsilon}$.

      ii. Take first-order conditions in the inputs to find an expression for the relative factor shares of the inputs in terms of their relative quantity, and show how this leads to the following result:

$$\frac{w_E E}{w_L L} = \left(\frac{A_E / w_E}{A_L / w_L}\right)^{\epsilon/(1-\epsilon)}.$$

      iii. Use this result to explain why the fall in the energy price might lead labour-augmenting knowledge A_L to grow faster than energy-augmenting knowledge A_E.

      iv. Explain why slow growth of A_E would drive up demand for primary energy (for given labour supply).

(b) Discuss evidence about energy-augmenting knowledge growth, using specific examples.

   i. Has A_E grown slowly relative to A_L?

   ii. How might we explain these observations?

   iii. What is the policy relevance of understanding DTC mechanisms?

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3. Over long time periods we have shifted towards energy-intensive goods such as passenger air travel.

   (a) How can such shifts help explain the data in Figure 1, if technological change is assumed to be *unbiased* (i.e. both labour productivity and energy productivity grow at equal rates)?

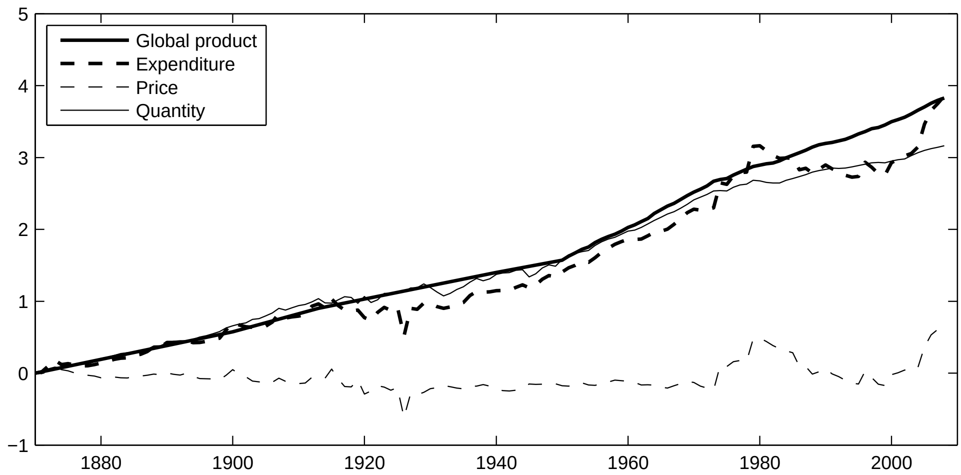

Figure 1: Long-run growth in global production and primary energy* expenditure, price, and quantity. Natural log scale. *Primary energy: Coal, oil, natural gas, and biofuel.

One possible explanation for such shifts is that rich people like energy-intensive stuff. Another is that energy-intensive stuff has got cheaper over time.

   (b) Discuss theory and evidence regarding these explanations.

Assume that a regulator wants to reduce energy consumption—and hence carbon emissions—in an energy-intensive sector such as passenger air travel, and is trying to choose between a flight tax and subsidies to energy efficiency research.

   (c) What is the relevance of your discussion above to this choice? Do you have other suggestions for the regulator?

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. 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. Explain why, as $A_L L$ grows from a very low initial level, the social planner will shift from X_1 to X_2.

(b) Discuss as deeply as you can the relevance of the model to ONE specific real world pollution problem. You should include some or all of the following in your answer:

- What extensions or adaptations we can make to the model so it better fits the specific case in question;
- How the model can help us to understand observations in the specific case;
- What predictions for the future we can make based on the model, in the specific case.