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. 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:

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\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 three 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) Show briefly how the model can be extended to include each of Solow's mechanisms (separately). ((Bonus: Outline also very briefly how a more realistic model of resource stocks can be constructed.))

   (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. Explain briefly why, in theory, the fall in the energy price might lead labour-augmenting knowledge A_L to grow faster than energy-augmenting knowledge A_E.
      ii. Explain briefly why slow growth of A_E would drive up demand for primary energy (for given labour supply).
      iii. Discuss evidence briefly. Has A_L grown faster than A_E? What has happened to primary energy demand? How might we explain these observations?

   (b) Over the next 50 years there is likely to be a global switch from fossil to renewable sources of energy. Will this switch lead to rapid increases in the efficiency of renewable energy technologies, and hence declines in the price of (for instance) electricity generated from renewable sources? Will electricity from renewable sources become cheaper than electricity from fossil, without the need for carbon taxes? Discuss theory and evidence.

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3. Assume an economy with competitive markets in which total aggregate production is a function of labour-intensive and energy-intensive production, as follows:

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

The labour-intensive good is produced according to the following production function:

$$Y_1 = A_L L,$$

where A_L is labour-augmenting knowledge and L is labour, which is fixed. The energy-intensive good is produced according to the following production function

$$Y_2 = A_R R,$$

where A_R is energy-augmenting knowledge, and R is the energy flow. Energy is extracted using the final product as an input, and one unit of final product yields one unit of energy. Hence if we normalize the price of the final product to 1, the energy price is also 1.

(a) i. Find the relative shares in total product of Y_1 and Y_2. (That is, find $p_1 Y_1/(p_2 Y_2)$, where p_1 and p_2 are the prices of the two goods Y_1 and Y_2.)

ii. Find total energy use R for a given state of the economy. (This is, when L, A_L, and A_R are all fixed and known.)

iii. Assume that a regulator wants to reduce R, and that she can either boost w_r through a tax, or A_R through a research subsidy. Explain which option she should choose in this economy.

(b) Discuss to what extent the above model is relevant to real economies in which the energy share of the most energy-intensive products is typically only about 20 percent, rather than 100 percent as in the model.

4. Assume an economy in which total aggregate production is a Cobb–Douglas function of augmented labour and a resource-intensive intermediate good, as follows:

$$Y = (A_L L)^{1-\alpha} R^{\alpha}.$$

Labour productivity A_L grows exogenously at a constant rate, whereas L is constant:

$$\dot{A}_L / A_L = g_A.$$

The resource-intensive intermediate good is produced according to the following production function, where C is a clean input and D is a dirty input:

$$R = C + D.$$

The inputs C and D are available at fixed exogenous prices w_c and w_d, and $w_c > w_d$. All markets are competitive.

(a) i. Find expressions for $w_l L$ and $w_r R$ as functions of Y. What can we say about the shares of R and L?

ii. Describe how R will be produced in equilibrium, and find its price. (Note: You should find that the price is constant.)

iii. Use your answers to (i) and (ii) above to find the growth rate of R as a function of the growth rate of Y.

iv. Use the aggregate production function and your previous results to find the growth rates of Y, R, and D in terms of g_A.

(b) Now assume that the aggregate production function is actually

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

where ψ is a positive parameter and D represents both the use of input D as an input, and the consequent flow of pollution generated. It follows that the social cost of using input D is $w_d + \psi Y$.

i. Describe the development path of the economy if firms are forced to pay the full social costs of using the inputs C and D, assuming that $w_d + \psi Y$ is initially less than w_c.

ii. Discuss the extent to which this model can help us to explain and predict patterns in the paths of polluting emissions over time, focusing on one or more specific examples.