Brief suggested answers

EGSD Examination, January 2017.

Note that longer answers may be required for full marks. For instance, it is important to show your working in calculation questions. And for discussion or essay questions my answers are intended as an outline.

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1. (a) The gist of the historical data is that nonrenewable natural resource prices have been remarkably constant while extraction rates have risen rapidly, broadly tracking GDP growth. Draw a figure . . .

   Model 1 predicts that prices should rise at the interest rate, i.e. rapidly. This follows from the Hotelling rule, and the fact that extraction costs are zero. You should explain this a bit more . . .

   On a b.g.p. in this model we know that if the resource price is rising at rate ρ while the growth rate is g^*, then resource use must rise at rate $g^* - \rho$. This follows because then the factor returns to the resource rise at g^*, which they must do to keep the factor share constant (Cobb–Douglas). Since the interest rate is greater than the growth rate this implies that resource extraction should decline over time, whereas in fact we see a rapid rise.

   Model 2 predicts that prices should be constant, because we have $R = \phi X$ so the flow of resource extraction is in proportion to the flow of final goods into extraction. And since the real price of final goods must be constant (normally we normalize it to 1), the unit cost of extraction must be constant.

   Since the resource price is constant, it is straightforward to show (in an ideal answer you could do this) that we will get balanced growth and resource use R will track GDP (keeping the resource share constant). This is quite closely in line with observations.

   The problem, however, is that this extraction path is obviously unsustainable, since it implies that the extraction rate approaches infinity. So we need a new (or extended) model to explain how and why the extraction rate will stop growing, and even decline.

   (b) The key point here is that initially (when A_L is low) the extraction rate will be very low, depth will be essentially constant, and the model economy behaves just as in Model 2 above: the resource price is constant and extraction tracks GDP. But as the extraction rate increases, depth starts to increase. This causes the resource price to trend upwards, braking the growth in the extraction rate. In the very long run, as exhaustion approaches, the resource price grows at close to the interest rate (Hotelling), and the extraction rate approaches zero.

   The model is a step forward in that it can both explain observations and make sensible predictions about the future. However, to make predictions about actual resources we need detailed information about the nature of stocks, and also stocks of substitute resources. If a resource has a close substitute then if its price rises above that of the substitute then demand will fall steeply as the substitute is used instead. This will of course affect the price and extraction path of the resource. Many other factors are also relevant: it's not easy to predict the future!

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2. (a) i. Here you should explain why, because labour and energy are complementary, the fall in the price of energy might be expected to lead to a fall in the factor share of energy. Such a fall will lead to a fall in investment in energy-augmenting knowledge. This may cause energy-augmenting knowledge to fall relative to labour-augmenting knowledge, which would tend to push the factor share of energy back up since it effectively makes energy scarcer. So this could explain why the factor share of energy has stayed rather constant even though the price of energy has fallen relative to labour.

   ii. The evidence suggests that energy-augmenting knowledge has grown at least as fast as labour-augmenting knowledge. Evidence we discussed in the course concerns lighting and motive power from combustion of fossil fuels. More generally, there are myriad uses to which we can put energy today compared to 300 years ago. Each of these uses implies a completely new stock of (product-specific) 'energy-augmenting knowledge'.

   (b) Here theoretical models of DTC can give very strong results. If fossil and renewable inputs are good substitutes then—simplifying slightly—whichever is cheaper will dominate the market, and thus will attract all the investment in new knowledge (making it even cheaper). If productivity of a given input (fossil or renewable) is very simply related to investment in that productivity then the cheapest input (whether fossil or renewable) will get cheaper and cheaper over time. So all a regulator needs to do is to ensure that renewable knowledge reaches a point such that renewables are cheaper than fossil, and after that fossil fuels will be uncompetitive and there will be no demand for them.

   Unfortunately in reality the productivities of the alternatives (fossil and renewable) are not as sensitive to investment in knowledge as in these extreme models: without subsidies to renewables or taxes on fossil, I personally suspect that fossil energy is always likely to be cheaper than (for instance) solar PV. With fossil, the planet has already done the hard work—concentrating the sun's energy—for us.

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3. (a) i. $X_c = (\phi_c \gamma_H / A_c)U$.

   ii. $X_g = (\phi_g \gamma_T / A_g)U$.

   iii. $Q_c = (\gamma_H / A_c)U$, $Q_g = (\gamma_T / A_g)U$.

(b) $U = (1 + \phi_c \gamma_H / A_c + \phi_g \gamma_T / A_g)^{-1} A_L L$.

(c) i. $U = 10/11$, $X_c = 0.05U$, $X_g = 0.05U$.
Coal share $= X_c/U = 0.05$, i.e. 5 percent.
Gasoline share $= X_g/U$, also 5 percent.

ii. Energy consumption is Q_c and Q_g, and $Q_c = 40/11$, $Q_g = 10/11$. So $Q_c = 3.64$ MJ, and $Q_g = 0.91$ MJ.

(d) i. Gasoline consumption should halve, so a saving of 0.45 MJ.

ii. U rises to $1/1.075$, hence $Q_c = 40/10.75$ and $Q_g = 5/10.75$. So $Q_c = 3.721$ and $Q_g = 0.465$, and total energy use declines from $50/11$ to $45/10.75$, a decline of 0.36 MJ.

Note that we have 20 percent rebound, but of a type we did not analyse in the course.

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4. (a) The marginal costs are input costs plus damages:

$$MC_1 = w_1 + \psi(A_L L)^{1-\alpha} R^\alpha;$$
$$MC_2 = w_1(1 + \gamma).$$

The marginal benefits are identical for the two inputs:

$$MB_1 = MB_2 = \alpha Y / R.$$

They are perfect substitutes.

(b) i. The condition is

$$w_1 \gamma / \psi = (A_L L)^{1-\alpha} R^\alpha,$$

and it implies that as A_L and L grow (also causing X_1 and hence R to grow) there comes a point when it is better to use input X_2 instead of X_1.

ii. If the economy is optimally regulated then R will initially be produced using X_1, and X_1 (and also pollution flows) will grow at a high rate (close to the overall growth rate). As GDP increases, pollution damages become significant, and brake the growth in X_1 somewhat (this could be through the use of a Pigovian tax, for instance). Then, when the condition above is fulfilled, the tax becomes so high that the economy switches totally to input X_2. (Alternatively, input X_1 is banned.)

(c) The model is relevant to the EKC, i.e. the environmental Kuznets curve hypothesis. The basic observation behind the EKC is that —for many pollutants, in many countries—pollution flows tend to first rise, and then fall. This is exactly what is predicted by the model.

Having stated this, you could develop your answer in 1000 different ways. For instance, you could discuss a particular case which supports the model (lead, asbestos, etc.), or you could discuss whether the model sheds light on the problem of carbon dioxide emissions, even though these are still rising in most countries, and the global aggregate is still rising steeply.
