ECN 275/375 Environmental and natural resource economics 11: Efficient & optimal use of natural resources (Perman *et al.* Ch 14)

Introduction to natural resources

Topics that will be dealt with in this part of the course include:

- substitution between natural capital (resources), and financial capital (essential in the sustainability debate: weak or strong sustainability)
- excavation profiles over time for non-renewables and renewables
- management of renewables
- social welfare associated with resource use
- stock pollutants (viewing emissions as an accumulation of pollutants where the accumulated amount of pollutants are what causes the damage – example: climate gas emissions)

Reading guide

Read all of chapter 14 to get an overview, but focus most sections 14.1-4, which deals specifically with the substitution issue (first bullet above). See also section 3.5.3 (which we skipped in the beginning of the course).

- understand the basic substitution model and the implications of varying degrees of substitutability (figure 14.1 key)
    - weak and strong sustainability (follows from fig. 14.1)
    - choice of functional form for the production side (the book discusses two functions in particular, Cobb-Douglas (CD), and Constant elasticity of substitution (CES)
- the Hartwick rule (section 14.4.2) – see also Chapter 3 on the Hartwick savings rule that we postponed in the start of the course

A simple model of natural and production capital – functional form

Starting point: two kinds of resources, (financial) capital K and natural resources R: $Q=Q(K,R)$

Price of capital K: δ = the interest (= opportunity cost of capital)

Resource R price: v = the costs to make the resource available (ex. oil price at production site)

Profit function: $\pi = pQ(K,R) - \delta K - vR$

FOC for profit-max:

$$\frac{\partial \pi}{\partial K} = pQ_R(K,R) - \delta = 0 \quad \text{and} \quad \frac{\partial \pi}{\partial R} = pQ_R(K,R) - v = 0$$

Implications: (i) as the price of a resource, v, increases, less of the resource will be used, (ii) an increase in the interest rate, δ, has the same effect on capital.

The degree of substitutability between R and K: $\sigma = \dfrac{\frac{d(K/R)}{K/R}}{\frac{d(Q_R/Q_K)}{Q_R/Q_K}}$

The Cobb-Douglas (CD) function: $Q = AK^{\alpha}R^{\beta}$ (A, α, β > 0) – elasticity of substitution σ = 1. You tube video showing the steps: https://www.youtube.com/watch?v=0BJ4GUpvKHQ (not exam question, but nice to know)

Constant elasticity of substitution (CES) function: $Q = A(\alpha K^{-\theta} + \beta R^{-\theta})^{\frac{\varepsilon}{\theta}}$ (A, α, β, ε > 0, α + β = 1, 0 ≠ θ > -1) – elasticity of substitution: $\sigma = \frac{1}{1+\theta}$. Derivation of CES elasticity of substitution: https://economics.stackexchange.com/questions/11412/ces-production-function-elasticity-of-substitution-sigma-1-1-rho (not exam question, but nice to know)

CES is very flexible (see Fig 14.1 for some typical values for θ).
Remarks: (i) θ = 0 → CD. (ii) Nested CES used a lot in general equilibrium models.

Weak and strong sustainability

Sustainability: Non-declining total consumption over time.

Remark: In an economy with increasing population numbers, an alternative definition is non-declining consumption per capita over time. That makes sustainability even more difficult to achieve.

Weak sustainability: Human capital (K) **can** replace natural resources (R) , but this may entail some extra costs. Implication: Natural resources not essential. In CES: $\sigma = \frac{1}{1+\theta} > 0$.

Strong sustainability: Human capital (K) **cannot** replace natural resources (R). Implication: Natural resources essential. In CES: $\sigma = \frac{1}{1+\theta} = 0 \leftarrow \theta >> 0$. Explanation: the CES collapses to a Cobb-Douglas where isoquants never cross neither the horizontal nor or the vertical axes.

Hartwick's rule (HR)

Hartwick's rule defines the amount of investment in produced capital (buildings, roads, knowledge stocks, etc.) that is needed to exactly *offset declining stocks of non-renewable resources without experiencing declining consumption (sustainability) through time*.

HR is often referred to as a savings rule. Example: The Norwegian sovereign fund (petroleum fund) which is meant to make Norwegian future consumption not decline as we transfer wealth from the "natural resource bank" to financial wealth.

Remarks:

1. If an economy is not already on a sustainable path, HR is not sufficient get the economy back on a sustainable track.
2. Even if an economy were on a sustainable path, HR requires that rents are generated from an *efficient* resource extraction program in a competitive economy (or an economy that produces the same results as would a competitive economy).
3. Even under (2), HR does not guarantee sustainability under the *strong sustainability* condition (assumption).

Exercises

… for this gathering focus on the impact of the shape of isoquants (11.1), and the difference between unconstrained and constrained optimization (11.2), with a start on formal mathematical for our “beloved” Cobb-Douglas production function, and 11.2.f focuses on the interpretation of the shadow price (= marginal cost/value) of the constraint.

Discussion topics

Impacts on sustainability from various degrees of substitutability

1. Why are concerns of running out of a resource less the larger the degree of substitutalbility?
2. Is there such a thing as an *essential resource* in the long run? Why or why not?

Identify some cases where *strong sustainability* would better describe the world than *weak sustainability.*