Econ674

Economics of Natural Resources and the Environment

Session 3

Sustainable Development: Concepts and Measures

Sustainability Concepts

Affluence and population growth

- The theory of demographic transition
- Most well-known theory used to explain the observed negative correlation between income level and population growth rate: four stages
- Its applicability to developing countries is unclear as the reasons for changes in birth rate and death rate and the period for each stage were generally different
- Two important determinants of population growths are:
  - The fertility rate
  - The life expectancy of each child

  Life expectancy has increased dramatically

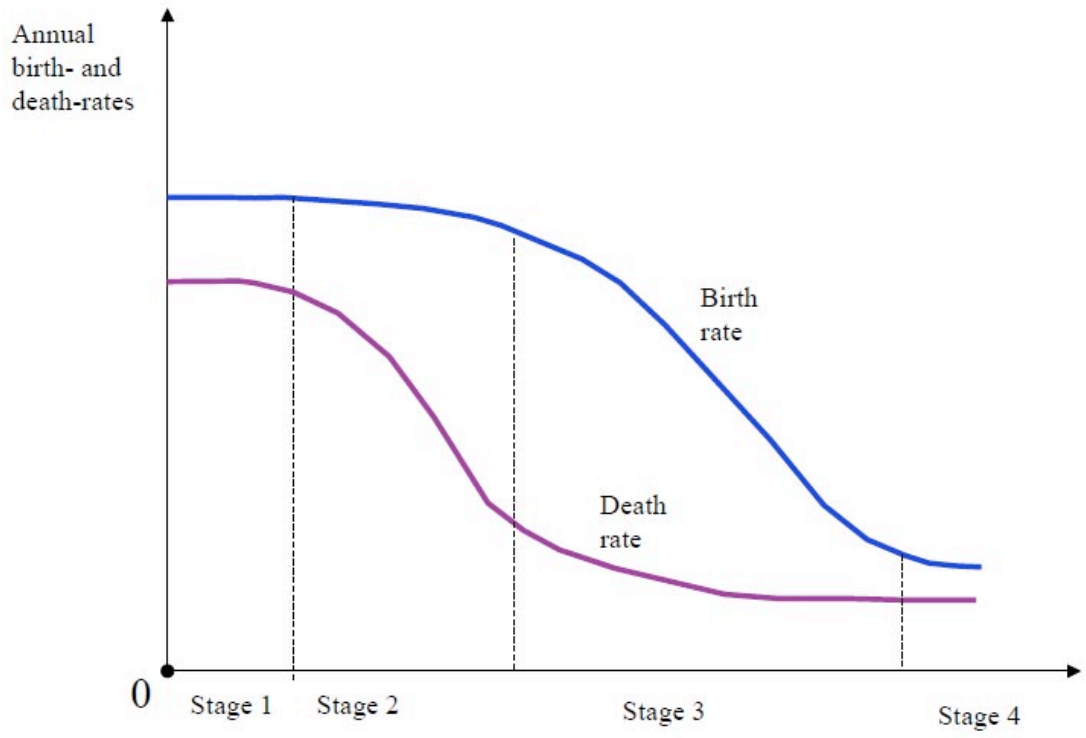
  Fertility rate is primarily the outcome of a choice made by (potential) parents

  Microeconomic theory suggests that family size is determined by:
  - Marginal benefits and
  - Marginal costs of children

  Thus measures that the government could take to reduce desired family size include: increase level of education, use of financial incentives to influence desired family size, provision of care for and financial support of the elderly, and economic development (which is the most powerful)

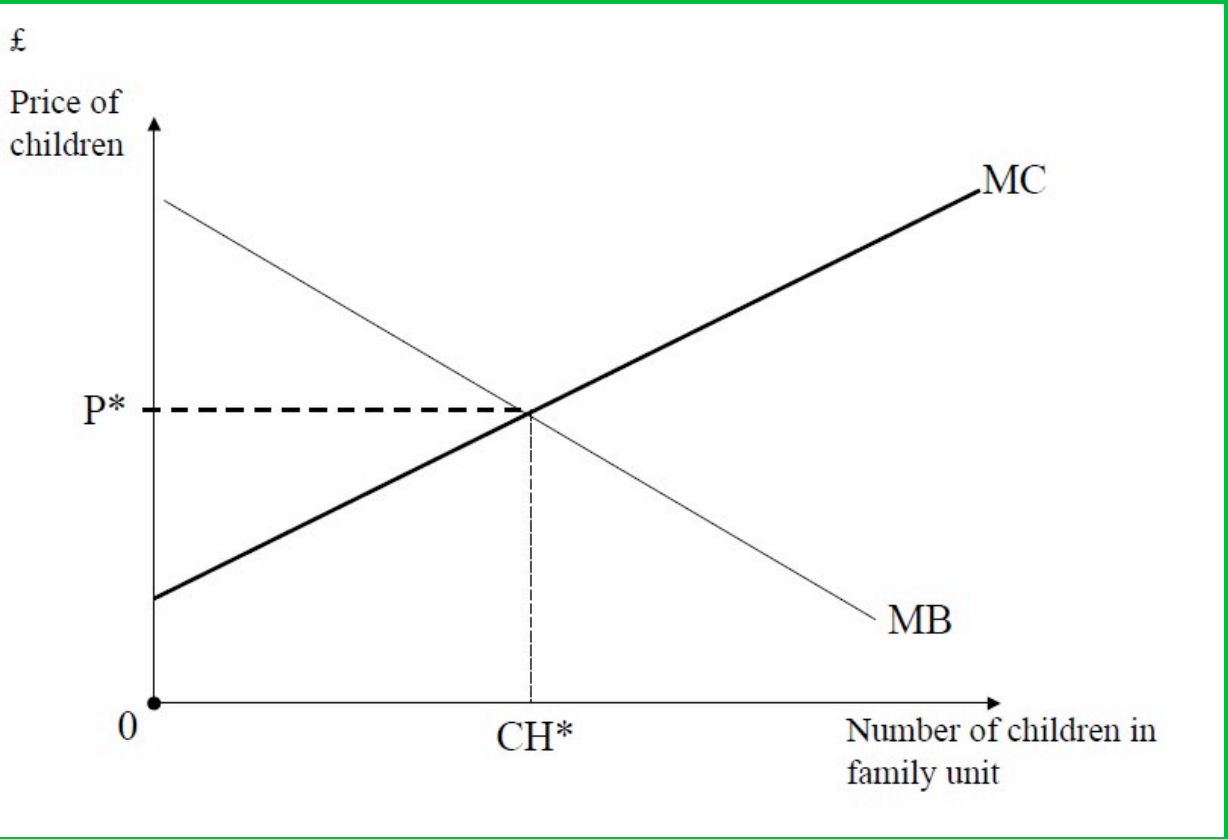
A Theory of Demographic Transitions

Demographic Transition under Development Dynamics



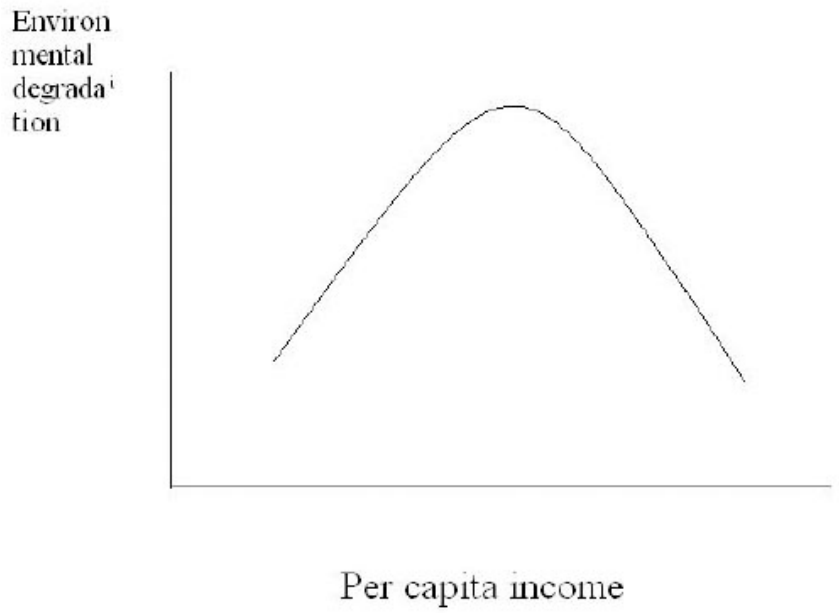
Sources: Boserup(1965); Hagen (1968)

The Microeconomics of Family Size and Growth



Family size and growth are a function of the price of children, along with a given level of risk aversion toward the future. In the absence of financial intermediation, the number of desired children corresponds to a form of family pension assets.

Technology and Pollution Dynamics



Environmental degradation proceeds quadratically with the level of per capita income. Beyond some level of per capita income, technology permits a reduction in environmental pollution. This relationship is often portrayed as the Kuznets Environmental Curve, following Kuznet's original formulation regarding the relationship of income inequality and per capita income.

Origins of Sustainability Theories

- The origins of what may be called the sustainability problem include:
  - The laws of thermodynamics
  - Ecology: issues of stability and resilience of ecosystems and biodiversity
  - Roles of population, affluence and technology and their interaction combined with intergenerational equity
  - Limits to growth (Meadows *et al.* 1992)

Steps Toward the Framework of Environmental Sustainability

- Since the 1970s that economic growth has an environmental dimension has been recognized
- Poverty, economic development and the natural environment became a common theme
- World Commission on Environment and Development (WCED) (established in 1983) and the Brundtland Report (Our common future 1987)
- UNCED—Rio de Janeiro 1992 (a result of a recommendation of WCED) (this led, among others, to the establishment of the UN Commission on Sustainable Development (UNCSD))
- World Summit on Sustainable Development: Johannesburg 2002 (organized by UNCSD)
- All these suggest the wide acceptance of the need to address the economic and environmental problems arising from economy-environment linkages

Dimensions of Change Bearing on Sustainability

Resource depletion and environmental degradation

- Various types of problems including:
  - Water pollution and scarcity
  - Air pollution (incl. indoor air pollution)
  - Soil/land degradation
  - Deforestation/forest degradation
  - Depletion of non-renewable resources
  - Misuse of renewable resources such as fish
  - Climate change, ozone layer depletion, acid rain, biodiversity loss

Resource Depletion and Environmental Degradation

Resource depletion and environmental degradation

- These problems could have local, regional or global dimensions
- The problems may have different effects including:
  - Health effects of water and air pollution
  - Reduction in (agricultural) productivity due to land degradation, air pollution, and water pollution and scarcity

These have immediate and long-term effects on development/welfare

Determinants of Environmental Degradation

Factors responsible for resource and environmental degradation

- Several factors depending on the problem. These include:
  - Market failure for various reasons including the nature of the goods
  - Policy failure such as use of subsidies that encourages use of a resource leading to pollution and depletion
  - Institutional failure such as inappropriate property rights, absence of appropriate laws and lack of enforcement

The Relationship between Environmental Quality, Poverty, and Income Inequality

Poverty/income and the environment

- Similarity with issues raised when discussing EKC
- However, this focuses on poverty and the environment
- Various hypotheses concerning poverty and the environment including:
  - The poor as victims of environmental degradation
  - The poor as causes of environmental degradation
  - The rich/the powerful as causes of environmental degradation
  - Two-way causation
- Need for empirical examination particularly at the micro level
- Links to millennium development goals
- Possible implications of outcomes for:
  - poverty reduction (and role of irreversibilities)
  - inter- and intra-generational equity

Propositions Regarding Sustainability

Sustainability

- Arguments in support of organising economic activity on a sustainable basis are ethical (equity) issues
- Arguments justifying sustainability may follow from two types of moral obligation:
  1. the present generation is morally obliged to those coming (such concerns should be incorporated into current decision making, e.g., due to use of non-renewable resources in production)
  2. people living at any time have a right to decent minimum standard of life
- Reasons for concern about sustainability include ecological and economic in addition to the moral reasons
- No claim that efficient behaviour is sustainable, nor that sustainable behaviour is more efficient than non-sustainable behaviour
- Efficiency arguments alone cannot support sustainability
- Even if we show that sustainable behaviour is necessary for maximizing intertemporal SW, the argument needs an ethical criterion (the SWF).
- Therefore, arguments for sustainability are ethical in nature (issues of equity)

Formal Arguments on Sustainability

- No universally agreed definition/meaning even within the economics literature
- Pezzey (1997) notes the presence of thousands of definitions
- Classification of the major forms helps to understand the relative merits of each
- Pezzey (1997) distinguishes between:
  - 'sustainable' development',
  - 'sustained' development and
  - 'survivable' development.
- Let

U_t = the utility level at time t

$\dot{U}_t$ = the rate of change of utility at time t

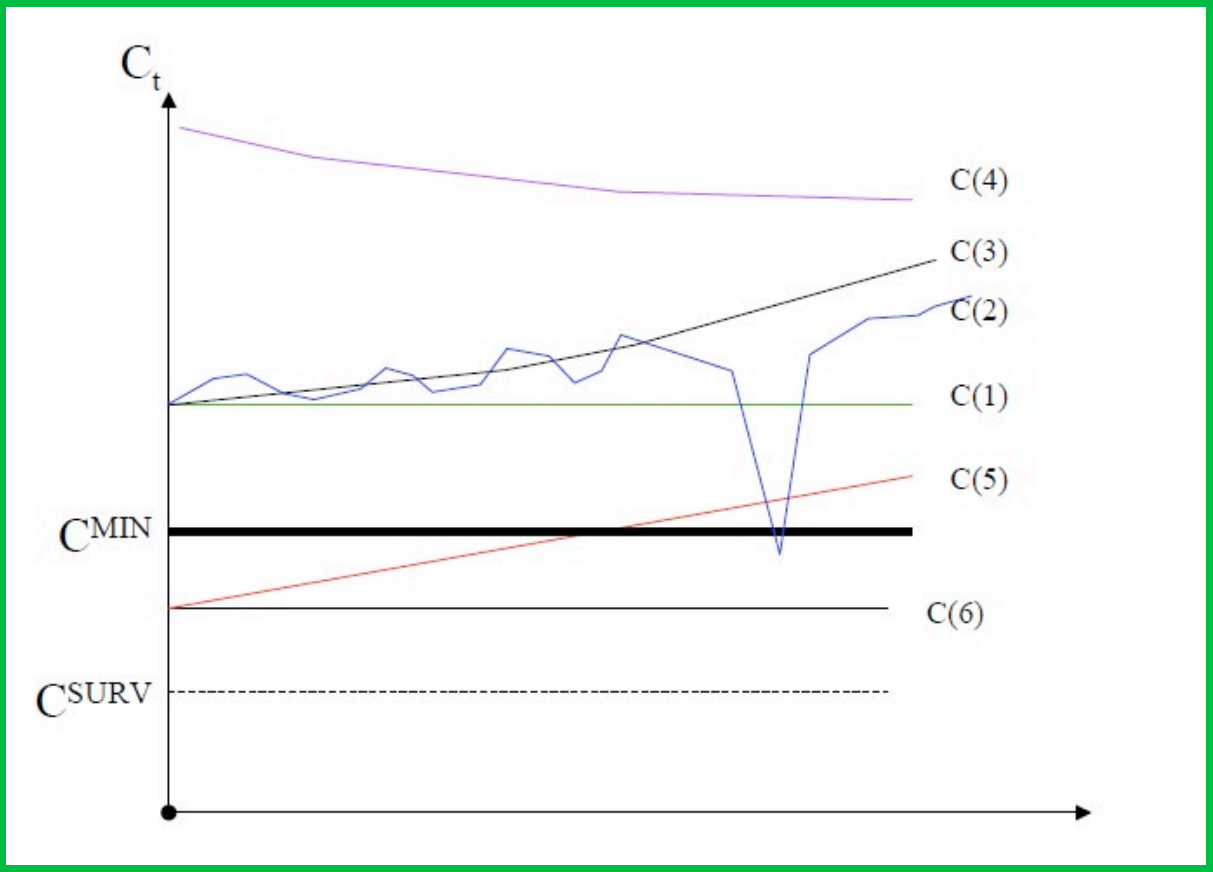
U_t^{MAX} = the maximum attainable U which can be held constant forever from time t onwards given production opportunities at time t

- U^{SURV} = the minimum utility level consistent with survival of the given population
- For Pezzy development is
  - sustainable if $U_t < U_t^{MAX}$ always
  - sustained if $\dot{U}_t > 0$ always
  - survivable if $U_t > U^{SURV}$ always
- If utility (U) is a function of consumption (C) alone, only replace 'U' by 'C' and the word utility by consumption in each of these criteria

- Levels of U or C for survivability are constant over time (C^{SURV} no time subscript).
- But the max. level of sustainable C an economy (C_t^{MAX}) obtains from any point of time onwards depends on when it starts

Formal Arguments on Sustainability - 2

Sustainable Consumption Paths



Formal Arguments on Sustainability - 2

Where:

- C_{MIN} = minimum C socially and morally acceptable by society
- C_{SURV} = minimum C for survival (biophysical minimum consumption)

- As a social planner aiming to do the best over many generations, how would you rank the alternative consumption paths over time?
  - If sustainability is taken as non-declining consumption as a constraint (a concept mostly used in economic analysis),
    - C(1), C(3), C(5) and C(6) satisfy this criterion
    - C(4) would be ruled out by the non-declining consumption constraint although it has higher consumption at every point in time
    - Adherence to the non-declining consumption property implies choosing C(6) instead of C(2) (an example of a case where an apparently sound ethical principle leads to outcomes not sensible)
    - A serious problem with the non-declining consumption criterion is that it has no requirement on the magnitude of the non-declining consumption (Very low living standards would be acceptable as long as they do not go down further; moreover, a development path where consumption could decline in the medium future is also ruled out by this criterion)

And where consumption time paths are affected by:

- Survivable development as a possible constraint in the maximization of intertemporal welfare function
  - This would avoid the problem with non-declining consumption constraint mentioned above; for example, C(2) and C(4) would not be ruled out
  - But it may not be 'fair' to future generations
  - In poverty analysis the poverty line is culturally rather than biologically determined
- Some culturally-determined minimum level of consumption as a constraint
  - It may be argued that C shouldn't fall below some minimum, decent, culturally-determined level over time, say C_{MIN}
  - We can refer to this as the minimum condition
  - Such a constraint would rule out C(2) but not C(4)

Different Choices for Sustainability Depend on the Underlying Welfare Criteria Chosen

Consumption time paths

- There may be conflicts between choices made using sustainability criteria and those made using conventional net benefit maximisation criteria
- C(1) and C(3) satisfy all the three criteria considered
- C(3) would be chosen over C(1) if we max. conventional utilitarian intertemporal SW function
- C(4) would be chosen with survivability or minimum condition criteria but ruled out with non-declining consumption

Consumption path	Criterion (constraint)		
	Non-declining	Survivability	Minimum condition
C(1)	S	S	S
C(2)	NS	S	NS
C(3)	S	S	S
C(4)	NS	S	S
C(5)	S	S	NS
C(6)	S	S	NS

Key: S = Satisfied, NS = Not satisfied

- Even restricting attention to consumption, a 'concern for future generations' does not translate into a single simple constraint on current planning
- Feasibility of a positive consumption level was assumed in the discussion earlier but some argue this may not be guaranteed given, for example, that non-renewable resources are used in production

Six Sustainability Concepts

These six concepts are the following: A sustainable state is one in which

1. utility or consumption is non-declining through time.
2. resources are managed to maintain future production opportunities.
3. natural capital stock is non-declining over time.
4. resources are managed to maintain a sustainable yield of resource services.
5. minimum conditions for ecosystem resilience through time are satisfied.
6. there is institutional development and consensus building.

- They are not necessarily mutually exclusive. For example:
  - The first largely entails the second
  - The fourth is a particular case of the second
  - The first seems to require the fifth
- None specifies duration of time over which it operates. Very long horizons needed for the idea of sustainability to have substance.
- However, it is not necessary to decide upon any particular span of time

Alternative Approaches to Sustainability: Economists, Ecologists, and the Role of Institutions

Economists on sustainability

- Concepts 1, 2 and 3 are basically economic in nature
- Note, however, that the third concept reflects a position on substitution possibilities that is more commonly found among ecologists (and ecological economists) than among economists
- Most economists would opt for what Pezzey calls 'sustained' as the definition of sustainability that focuses on the behaviour of utility/consumption over time
- Pezzey regards 'sustainable' rather than 'sustained' development as the appropriate criterion of sustainability
- Note that WCED's (1987) definition of sustainable development is a version of the opportunities-based view (concept 2)
- While the utility/consumption-based and opportunities-based concepts start from different places, where they end up in terms of formal analysis is very much the same place
- In the models discussed (e.g., Hartwick rule) constant consumption and equal opportunities are inextricably linked.

- Is substitution feasible?
- Use of a model with a non-renewable resource as an input in production clearly reflects the problem of sustainability and substitution issues
- In a criticism of environmentalists urging conservation of resources for future generations, Nobel laureate economist Solow (1986) notes: 'We have no obligation to our successors to bequeath a share of this or that resource. Our obligation refers to generalized productive capacity or, even wider, to certain standards of consumption/living possibilities over time'.
- The basic issues can be presented using a framework of simple optimal growth model where production uses a non-renewable resource as follows.

A Formal Representation of the Economic Approach to Environmental Sustainability

Economists on sustainability

- The inter-temporal social welfare function to be maximized is

$$W = \int_{t=0}^{t=\infty} U(C_t) e^{-pt} \mathrm{d}t$$

subject to the constraints

$$\dot{K} = Q(K_t, R_t) - C_t$$

$$\dot{S} = -R_t$$

$$\bar{S} = \int_{t=0}^{t=\infty} R_t \mathrm{d}t$$

where W is social welfare, U(C) is utility as a function of consumption (C), t is time, K is (human-made) capital, R is (a non-renewable) natural resource, Q is output, S is the stock of the natural resources, K dot and S dot represent changes in K and S overtime

- Feasibility of constant consumption depends on the nature of the production function
- If the production function exhibits perfect substitution between K and R, as shown by the following equation, then R is not essential and hence the problem is trivial

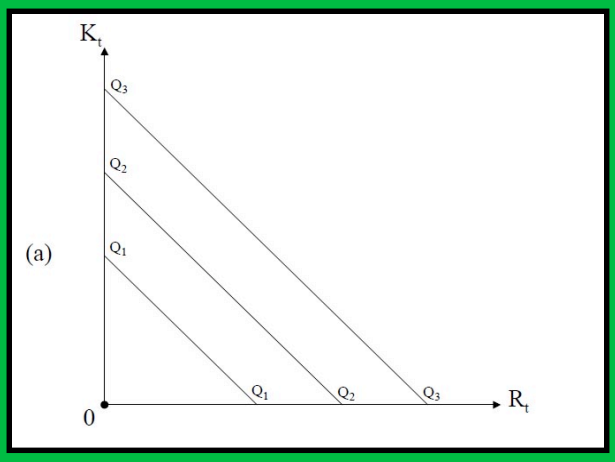
  $Qt = \alpha Kt + \beta Rt$
- If the production function exhibits perfect complementarity between K and R, as shown by the following equation, then constant consumption over time is not feasible

  $Qt = \min(\alpha Kt, \beta Rt)$
- Solow's remark mentioned above does not apply to either of these two cases; like most economists Solow assumes substitution possibilities are between these two cases which makes the problem non-trivial but soluble; the following is an example of such a production function

$$Q_t = K_t^{\alpha} R_t^{\beta} \text{ with } \alpha + \beta = 1$$

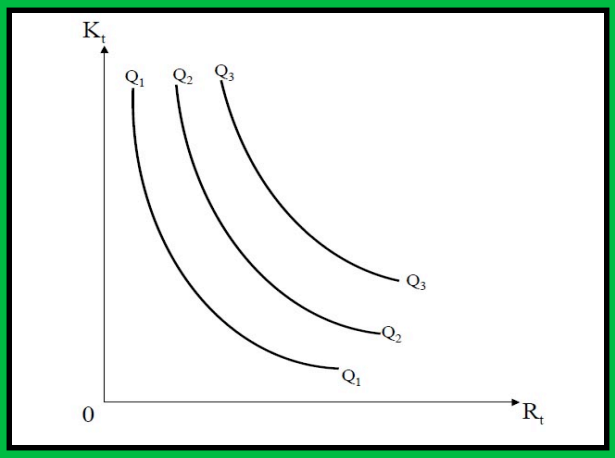
A Diagrammatic Representation of the Economic Approach to Environmental Sustainability: Production

The infinity elasticity of substitution case

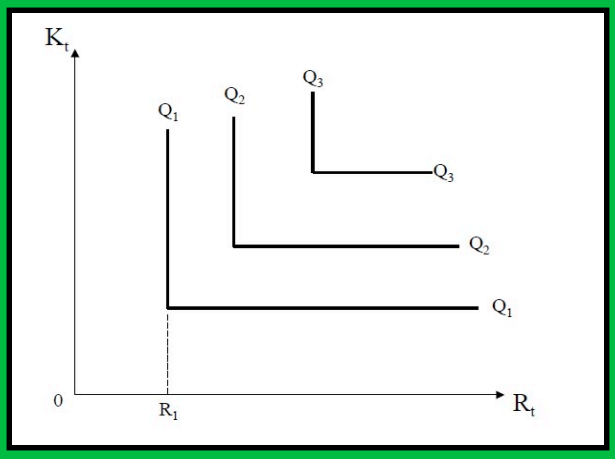


C-D=1,

CES $0 \leq \varepsilon \leq 1$



The zero elasticity of substitution case (Leontief)



Implications of the Elasticity of Substitution on the Economic Approach to Sustainability

- For this Cobb-Douglas production function, if $\alpha > \beta$ then constant consumption for ever is feasible; note that for this production function R is essential but K can substitute for R in production
- The Hartwick (1977, 1978) rule: is that at every point in time the total rent arising in the resource extraction industry be saved and invested in reproducible capital. (details discussed elsewhere)
- The Hartwick rule (which can be shown using the optimization problem stated above and a C-D production function) is necessary but not sufficient—following it will realize constant consumption only if intertemporal efficiency conditions are satisfied, and if sustainability as constant consumption is feasible, i.e., if substitution possibilities as between K and R are great enough.
- Following the Hartwick rule means the total value of the economy's stock of reproducible capital together with its stock of the non-renewable resource is held constant over time –as the value of the remaining stock of resource declines, so the value of the stock of reproducible capital increases in compensating amount.
- The constant consumption level that goes with following the Hartwick rule can be thought of as being like the interest on this constant stock of total wealth

Economic Theory on Weak versus Strong Sustainability

- Weak and strong sustainability: a distinction made in some of the economic contributions to the literature
- These are not different definitions/conceptions of sustainability (in both constant consumption or utility over time is what sustainability is)
- They reflect differences in the conditions to be met to realize sustainability as constant consumption or utility over time
- The difference is about substitution possibilities
  - For 'weak sustainabilists' a production function such as C-D with $\alpha > \beta$ captures the state of the world
  - For 'strong sustainabilists' a production function with fixed-proportions (perfect complementarity) is more relevant
- The weak versus strong sustainability debate makes use of the concept of natural capital
- Define K in a very broad sense: any economically useful stock, other than raw labour.
- In this broad sense K consists of:
  - Natural K (any naturally provided stock);
  - Physical K (stock of plant, equipment etc.)
  - Human K (learned skills embodied in particular individuals);
  - Intellectual K (disembodied skills and knowledge)
- Define human-made capital = physical + human + intellectual capital
- Then total capital consists of two parts: natural and human-made (reproducible) capital.
- We can write the economy's production function as $Q = Q(L, K_N, K_H)$
- Strong sustainabilists argue that sustainability requires non-declining K_N while for weak sustainabilists it is the sum of K_N and K_H that should be non-declining

Economic Theory on Weak versus Strong Sustainability, part 2

- Most, but not all, economists (including Solow and Hartwick) are weak sustainabilists
- In so far as their arguments can be cast within this framework, most, but not all, ecologists are strong sustainabilists (to be discussed below)
- Economists have focused on the issue of substitution in relation to use of resources in production; substitution between natural and human capital and also within natural resources
- Problematic is the substitutability between man-made capital and elements of natural capital other than non-renewable energy and mineral resources. E.g. functions performed by the ecosystem, life-support and amenity services provided by natural capital
- No answer to the question: How far is K_H substitutable for K_N?
- In some particulars, the answer is as much a matter of taste and/or ethics as it is a matter of science and technology
- Weak sustainabilists advice that the stock of capital be non-declining while strong sustainabilists advice that the stock of natural capital should be non-declining
- In both cases valuation of natural capital is an important issue
- Some *very* strong sustainabilists argue for maintaining individually subsets of $K_{N;}$

Economic Theory on Weak versus Strong Sustainability, part 3

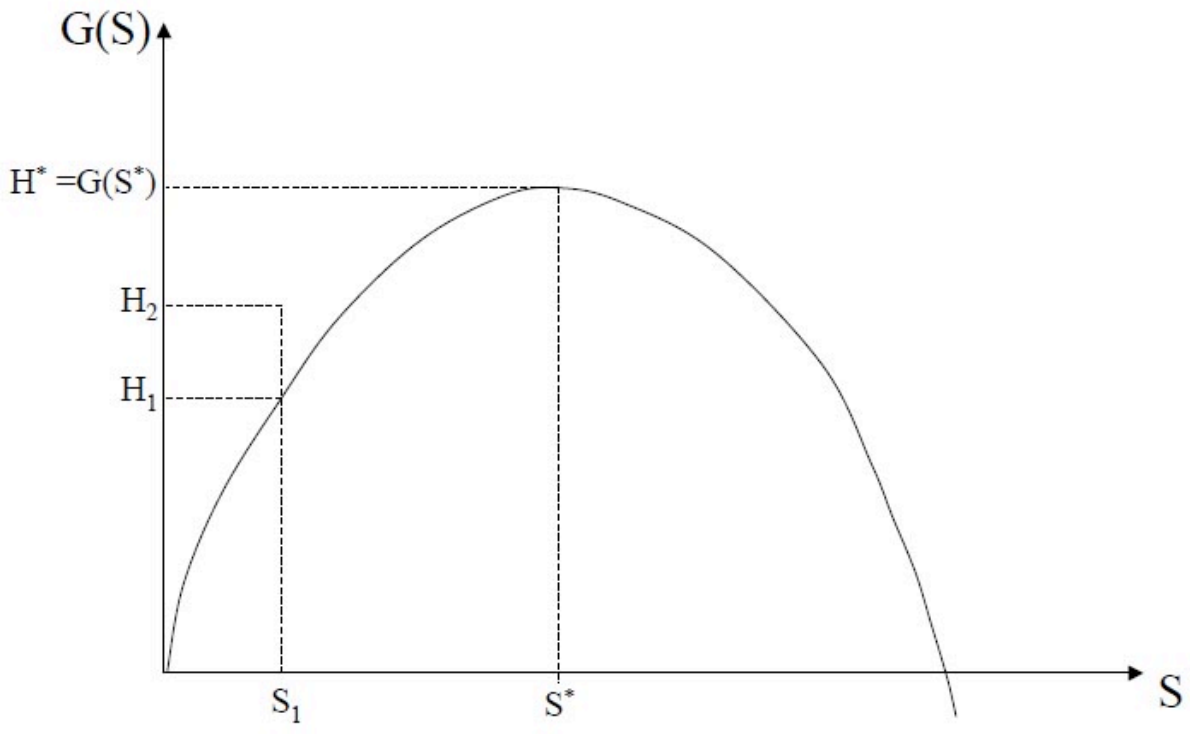
- For example, UNESCO notes:

  Every generation should leave water, air and soil resources as pure and unpolluted as when it came on earth. Each generation should leave undiminished all the species of animals it found on earth.
- But this appears to be infeasible; Almost every form of human activity will have some adverse impact on the environment
- Even if wider classes are considered it would imply that substitution between different forms of natural capital is acceptable
- But then it should also be ok to accept that the total natural capital be kept constant

Ecologists on Sustainability

- From the six concepts of sustainability, concepts 4 and 5 originate with ecologists
- Concept 4 is associated with the concept of sustainable yield (for renewable resources)
- For most ecologists the ideal rate of harvest for renewable resources is the maximum sustainable yield
- The same concept cannot be applied to non-renewable resources; a way out is to require that some of the proceeds from the sale of non-renewable resources be used in research and development to find a (more sustainable) substitute, for example, solar energy as a substitute for fossil fuels

Sustainable Harvests



Ecologists on Sustainability - 2

- Concept 5 is explained using the concept of resilience
- Sustainability is assessed in terms of the extent to which the prevailing structure and properties of the ecosystem can be maintained
- Human interests are not regarded as paramount; rather, they are identified with the continuing existence and functioning of the biosphere in a form more or less similar to that which exists at present
- Ecological views are often more human-centered, anthropocentric, than is made explicit in their advocacy
- Common and Perrings show that satisfying the conditions for intertemporal economic efficiency and following the Hartwick rule is neither necessary nor sufficient for sustainability as resilience
- *ex ante* we cannot know whether a system will be resilient in the face of future shocks that it will be subject to
- Some authors have suggested that some indicators are useful as monitoring devices: they can be used to make inferences about potential changes in the degree of resilience of ecosystems in which we are interested.

Ecologists on Sustainability - 3

- Schaeffer *et al*. (1988) propose a set of indicators, including:
  - changes in the number of native species
  - changes in standing crop biomass
  - changes in mineral micronutrient stocks
  - changes in the mechanisms of and capacity for damping oscillations.
- While these indicators are suggestive, none can ever be a completely reliable instrument in the sense that a satisfactory rating can be taken as a guarantee of resilience
- A note on Daly's steady-state economy(1973, 1974 prior to emergence of concepts of sustainability and sustainable development): influenced by Georgescu-Roegen (and uses terms like 'spaceship' as in Boulding (1966));
- All the three were trained as economists but can be considered as ecological economists who attach an important role for laws of nature
- Daly sees limited prospects for substitution of human for natural capital: hence can be considered a ('very early') 'strong sustainabilist'

Ecologists and the Precautionary Principle

- The ecological approach to sustainability is characterised by an insistence that our ability to predict the ecological consequences of our behaviour is highly imperfect.
- Our understanding of how natural systems function is very incomplete
- Thus resource management has to recognise that there is great uncertainty
- Given this, ecologists generally argue for a cautious approach to environmental policy
- Ecologists have tended to give uncertainty a more central role than have most economists
- Thus, ecologists advocate the precautionary principle and the idea of safe minimum standards

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The Institutional Approach to Sustainability

- The final concept of sustainability, concept 6, is a group of concepts which sees sustainability as being essentially a problem of governance in the broadest sense
- This is mainly found in the writings of political scientists and sociologists (though recognized by economists and ecologists)

- This focuses on processes not outcomes/ constraints.
- It views the issue primarily in terms of institutions and processes.
- De Graaf et al. (1996) define sustainable development in two ways

  First, as development of a socio-environmental system with a high potential for continuity because it is kept within economic, social, cultural, ecological and physical constraints.

  and second, as development on which the people involved have reached consensus
- They note the first is 'formal but not operational, the 2nd is 'procedural, but does not guarantee stability'.
- They argue separating environmental objectives from other social and political objectives (elimination of poverty) is impossible.
- Conventional approaches to sustainable development are flawed by
  - information problems and
  - their failure to address issues of political will and feasibility.
- Conventional approaches are classify as:
  - Human societies are parts of ecosystems=> determine its carrying capacity=> legislate prevention activity exceeding carrying capacities.

The Institutional Approach to Sustainability - 2

2. Environmental decline is external costs=> evaluate these costs and use them to internalise these costs.

- Strategy 1: insufficient as its success depends on persuading citizens; flawed as carrying capacities are unknown/unknowable.
- Strategy 2: is also of limited usefulness for similar reasons: prices unknown.
- Attaining sustainability not a technical problem. There are limits to our ability to know the consequences of human behaviour thus it is futile to look for necessary or sufficient conditions for sustainability.
- De Graaf *et al.* propose consensus building through negotiations.
- Essentially an institutional process of social choice with wide participation, and involves a process of trade-offs in which all benefit from the avoidance of environmental disturbances.
- Not yet clear exactly what this negotiation process will consist of.
- The different concepts discussed are not mutually exclusive; they should be considered complementary
- The issue is complex and involves the natural and social sciences
- A note on economic models and policy prescription: The economic models used to analyse sustainability issues are generally abstract analytical constructs.
- Here lie both the strength and the weakness of much of the conventional economics contribution to sustainability.
- Analytical models can sharpen our insights, and force us to think about what is crucial in any problem.

Deriving A Consensus on Sustainability

Sustainability and policy

- Beginning with a set of assumptions, we can often deduce very powerful general conclusions.
- But these rarely take a form that is immediately applicable to detailed policy prescription; Hartwick rule as example.
- The Hartwick rule also illustrates that deductions from a model are dependent on the particular assumptions built into it
- Our particular observations on policy can be conveniently classified as relating to:
- 1. Incentives: role of market failure and policy instruments; individual (selfish) behaviour, the future generation and the role of government;
- 2. Information:
  - role of information in influencing behaviour and sustainability;
  - education affecting information and also socialization
  - research who output is a public good producing information and solutions to problems
  - role of environmental accounting: national accounts; environmental indicators; green design principle for firms

Deriving A Consensus on Sustainability - 2

- 3. irreversibility
  - Reversibility implies that nothing would have been irretrievably lost
  - When irreversibility is combined with imperfect knowledge of the future then optimal decision rules can change significantly
  - then there are good reasons for keeping options open and behaving in a relatively cautious manner (with a presumption against development built into each choice).
  - This has important implications for policy appraisal methods and rules
- 4. Policy coordination at regional/international and local levels