1. Introduction: Origins of environmental and Resource Economics and the Sustainability Problem

Three important themes in resource economics:

i) Efficiency
- Technical inefficiency
- Allocative inefficiency

ii) Optimality
a. Who is 'society'?
b. Overall objective of that society
c. Efficiency is necessary but not sufficient for optimality

iii) Sustainability

1.1 Emergence of resource and environmental economics

1.1.1 Classical economics: Smith, Malthus, Ricardo and Mill

-classical economists of the 18th and 19th centuries
- belief in the efficiency of the market mechanism
- natural resources seen as important determinants of national wealth and growth
- limited land availability and geometrically growing population implied poor prospects for economic well being
- Thomas Malthus (1766-1834) believed living standards would be driven to subsistence level
- Mills (1806-1873) – less emphasis on diminishing returns and more on effect of opening up new tracts of land and technical progress

1.1.2 Neoclassical economics: marginal value and theory

-value is determined in exchange – preferences and cost of production are key
- early neoclassical models of growth included neither land nor natural resources
- 1970s neoclassical economics first investigated optimal use of natural resources

1.1.3 Welfare economics

- a framework for normative judgements
- when can one say one allocation of resources is superior to another
- requires an ethical criterion
- utilitarian philosophy of Hume, Bentham, and Mill
- to avoid the use of a social welfare function, economist typically use economic efficiency (allocative efficiency, Pareto optimality)

1.1.4 Ecological Economics

- interdisciplinary field developed in the 1980s
- emphasizes that the economy is part of the larger system that is earth
- studies joint economy-environmental system
- Boulding metaphor of 'Spaceship Earth'

1.2 Economy-environment independence

-1950's and 1960's – growth seen as the solution to poverty

- without growth more redistribution is required

- are we straining the earth's resource base and natural systems – can we continue to grow?

1.2.1 Services provided by the environment

i) Source of natural resources used in production

Types of Natural Resources			
Flow	**Stock**		
	Renewable	**Non-renewable**	
		Fossil fuels	**Minerals**
Today's uses does not affect tomorrow	Can grow through natural reproduction - sustainable yield = harvest rate equal to natural growth rate	Use is an irreversible process – fuel cannot be recovered after combustion. Source of waste emissions.	Can be recycled – can delay the rate of exhaustion of initial stock

ii) Waste sink

iii) Source of amenity services – recreational opportunities and other sources of pleasure

- may not directly involve consumptive material flow

iv) Basic life support functions for humans

- temperature regulation

- ozone in the stratosphere absorbs UV-B radiation – depletion of ozone layer threatens human existence

1.2.2 Substitution for environmental services

i) Recycling reduces demand for waste sink and reduces demands on resource base

ii) Capital – To what extent can human made capital substitute for:

a. Waste sink
b. Resource base
c. Amenity services
d. Life support

1.2.3 Thermodynamics – science of energy

'open system': exchanges energy and matter with the environment
'close system': exchanges energy but not matter
'isolated system': exchanges neither energy nor matter with the environment

Earth is:

First law of thermodynamics: energy and matter cannot be created nor destroyed. The mass of materials flowing into the economic system from the environment has to either accumulate in the economic system or return to the environment as waste.

Second law of thermodynamics: Heat cannot be transformed into work with 100% efficiency. In an isolated system entropy increases. (Entropy is a measure of unavailable energy.) Energy changes form, degrading into components that have different characteristics from the original matter. – eg as we burn gasoline, the petroleum is used up.

Consequence: given a fixed rate of receipt of solar energy, there is an upper limit to the amount of work that can be done on the basis of the energy available on earth.

Nicholas Georgescu-Roegen - second law of thermodynamics is the 'taproot of economic scarcity'

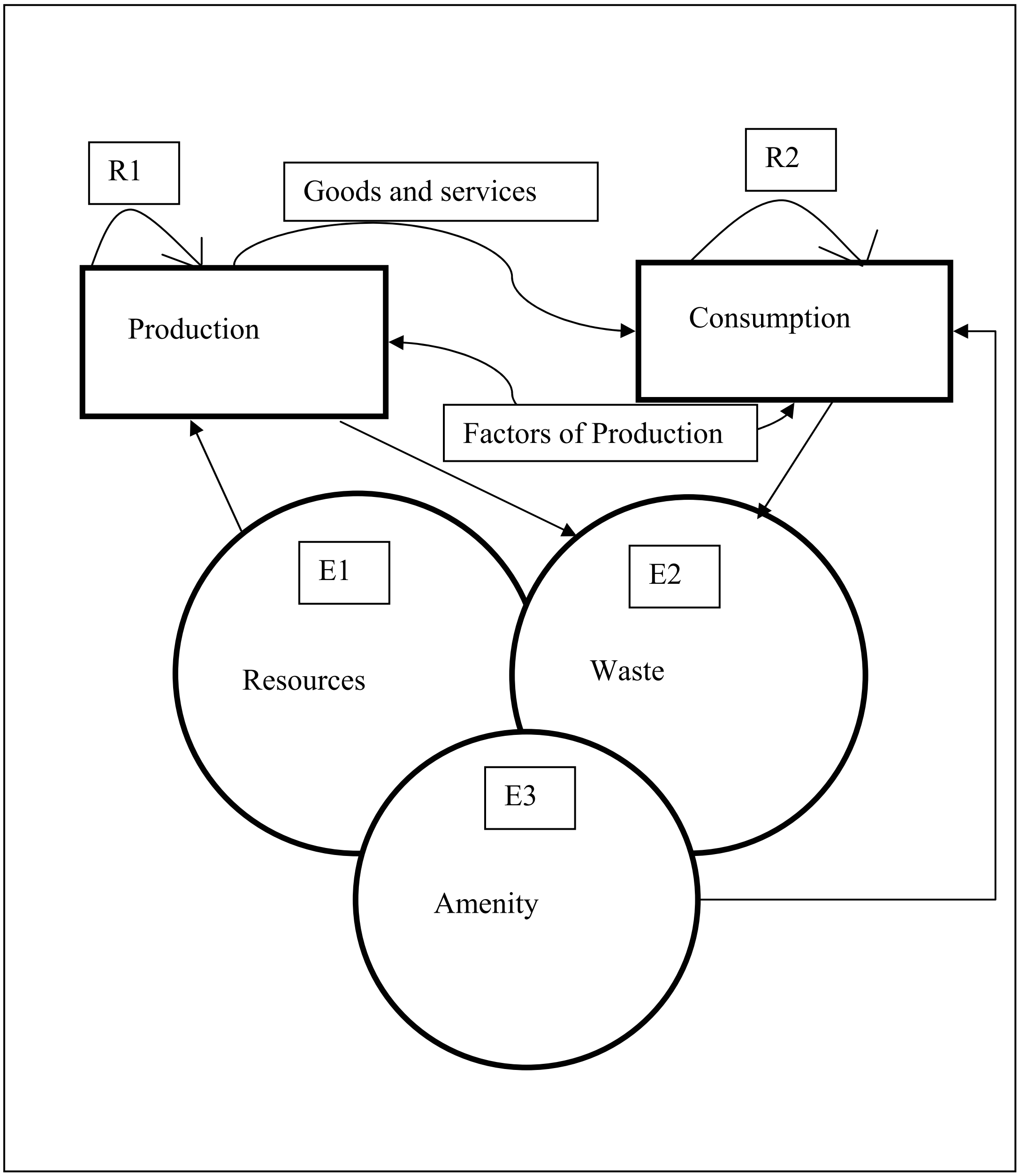
Given enough energy complete recycling of material is possible – shortage of minerals is not a constraint on the economy

But in practice complete recycling is not possible.
"The problem is that such expenditure of energy would involve a tremendous increase in entropy in the environment which would not be sustainable for the biosphere" (Biancardi *et al*, 1993)

1.2.4 Materials balance

- economic activity cannot create matter
- involves transforming matter extracted from the environment into items that are more valuable to humans
- All matter extracted must eventually be returned to it – in a transformed state

Materials Balance Diagram



E4 Global Life Support

ECONOMY-ENVIRONMENT INTERACTIONS
Adapted from Hanley, Shogen, and White, 1997, p. 3

1.2.5 **Production function**

Traditional for firm *i*:

$Q_i=f_i(L_i,K_i)$

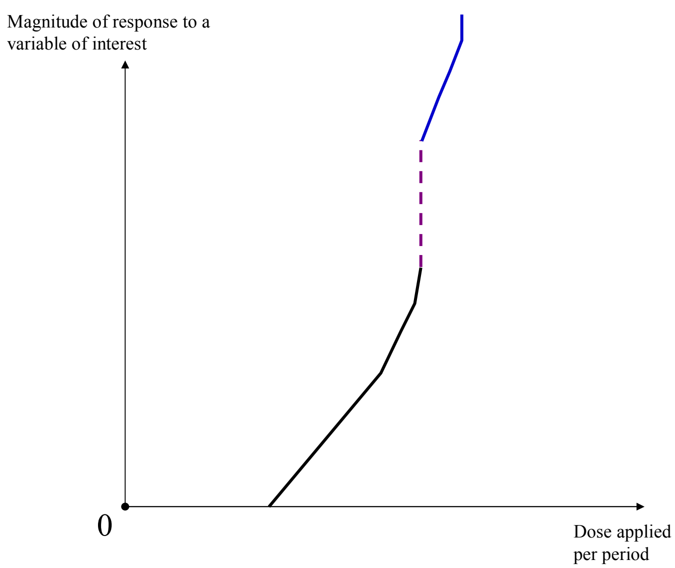
Production function consistent with principles of materials balance:

$$Q_i = f\left(L_i, K_i, R_i, M_i[R_i], A\left[\sum_i M_i\right]\right)$$

1.2.5 Ecology

- Study of the distribution and abundance of plants and animals
- Ecosystem: set of plant and animal populations, together with their abiotic environment – can be defined at various scales
- Stability – ability of a population to return to some equilibrium level following a disturbance
- Resilience: propensity of an ecosystem to retain its functional and organisational structure following a disturbance
- Some economic activities reduce ecosystem resilience – lower key thresholds

Figure 2.3 Non-linearities and discontinuities in dose-response relationships



- Biodiversity – number of biological organisms and their variability

- Biodiversity is a property of populations (genetic), species (# of species), ecosystems.
- Importance of biodiversity is not well understood – resilience and evolutionary potential?
- Number of species is not known: 3-10 million; 50-100 million

1.3 Environmental Impact

1.3.1 The IPAT identity

- environmental impact of humans depends on population and per capita impact
- per capita impact depends on production technology and individual consumption (affluence)

- In 1971, biologist Paul Erlich devised the IPAT equation estimating environmental stress:

Environmental **I**mpact = **P**opulation * **A**ffluence * **T**echnology.

Example: an estimate of the global auto CO_2 emissions (contributing to global warming) is:

CO_2 emissions	= P	* A	* T
Per year	6 billion people	* .1 cars per person	5.4 tons CO_2 per car per year

If population grows, to 10 billion by 2150, then to keep emissions constant, technology would have to advance to reduce emissions per car to _____________.

1.3.2 What determines A, P, and T?

Affluence and population growth

- theory of demographic transition (Todaro, 1989) – one attempt to explain the negative correlation between income and population growth rates
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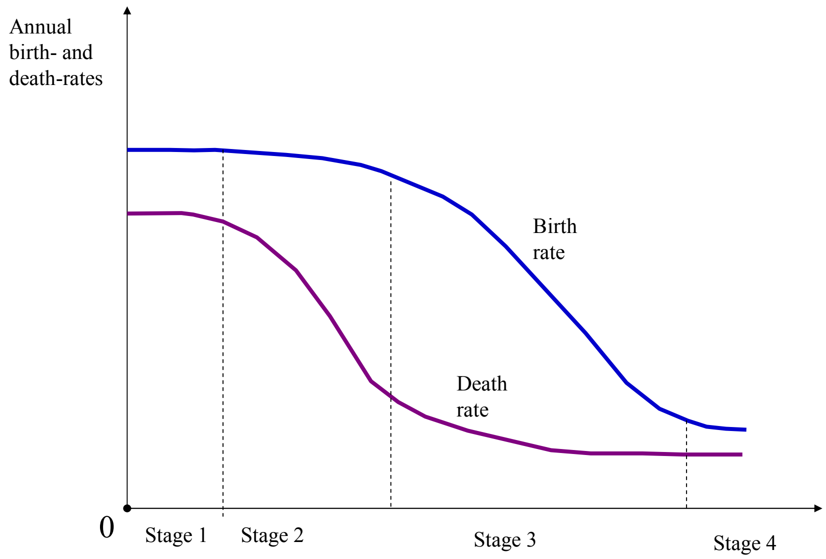
Figure 2.6 The theory of demographic transition



- questionable whether this theory will apply to currently developing countries
- drop in birth rates lagging drop in mortality rates

Environmental impact and income: the Environmental Kuznets Curve

Does economic growth necessarily harm the environment?

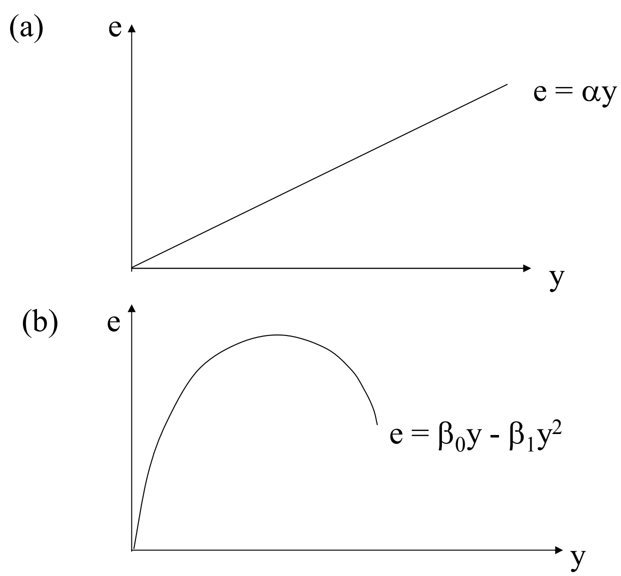
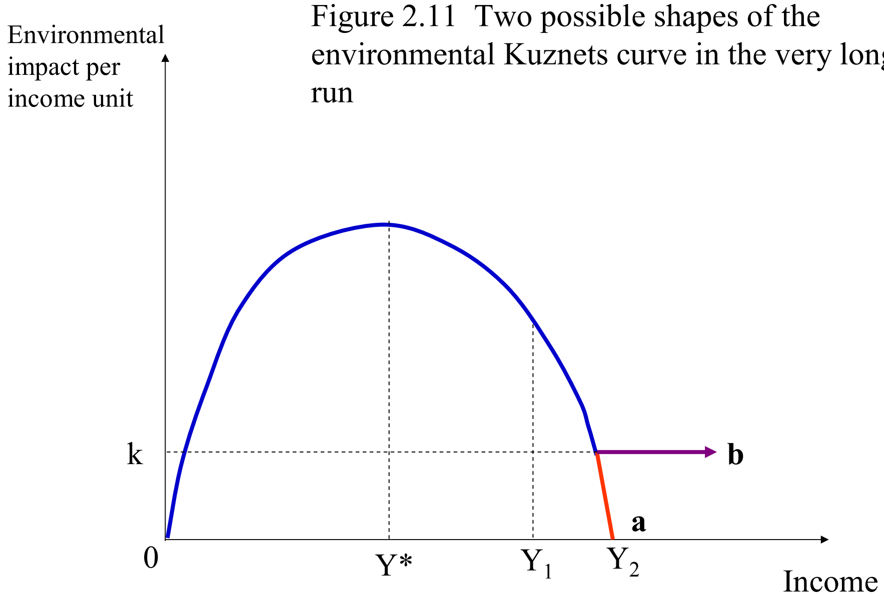


Figure 2.8 Environmental impact and income

Environmental Kuznets Curve – named after Kuznets (1955) who hypothesized an inverted U-shaped relation between income inequality and income distribution

- Empirical results are mixed – seems to hold for some pollutants in some countries but not for others – SO_2, nitrous oxides, particulate matter, - not for CO_2
- EKC in the very long run – Common (1995)
- Two types of EKC's, a and b.

Figure 2.11 Two possible shapes of the environmental Kuznets curve in the very long-run



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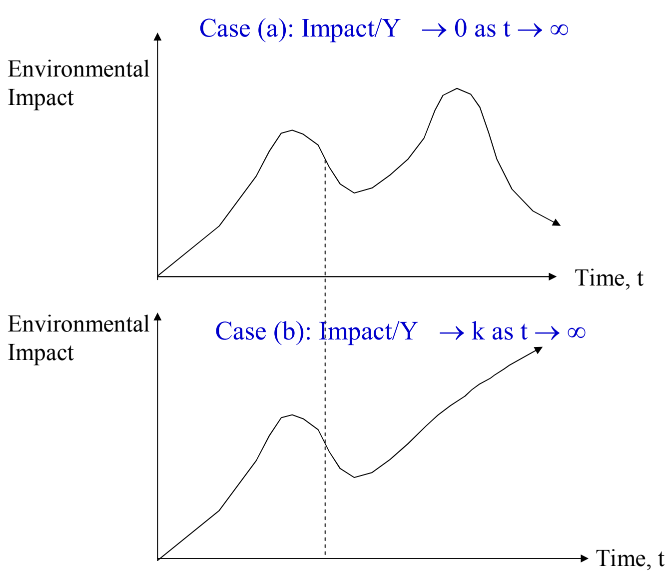

Figure 2.12 Two scenarios for the time profile of environmental impacts

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Suppose the world consists of 2 types of nations: developed and developing
Long run path of environmental impact if EKC is Case 'a' would be the upper diagram showing environmental impact versus time, or lower diagram is EKC is Case b.

There are many current references that examine the EKC. A review article is: S. Dasgupta *et al*, Confronting the Environmental Kuznets Curve, Journal of Economic Perspectives, vol. 16, no. 1, Winter 2002, pp. 147-68

1.4 Limits to Growth

Study published in 1972 had a large impact on the environmental movement

Meadows, D.H. *et al* (1972) *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. (Also known as the Club or Rome Report)

Updated in 1992: Meadows, D.H. *et al, Beyond the Limits: Global Collapse or a Sustainable Future*.

Computer model of the world economy and ecosystem used to simulate the future.

Key features:
- Limited land available for agriculture
- Limit to the amount of agricultural output producible per unit of land in use
- Limit to the amounts of non-renewable resources available for extraction
- Limit to the ability of environment to assimilate waste

Modelled past trends, influenced by positive and negative feedbacks on variables such as population, consumption, industrial output, pollution etc.

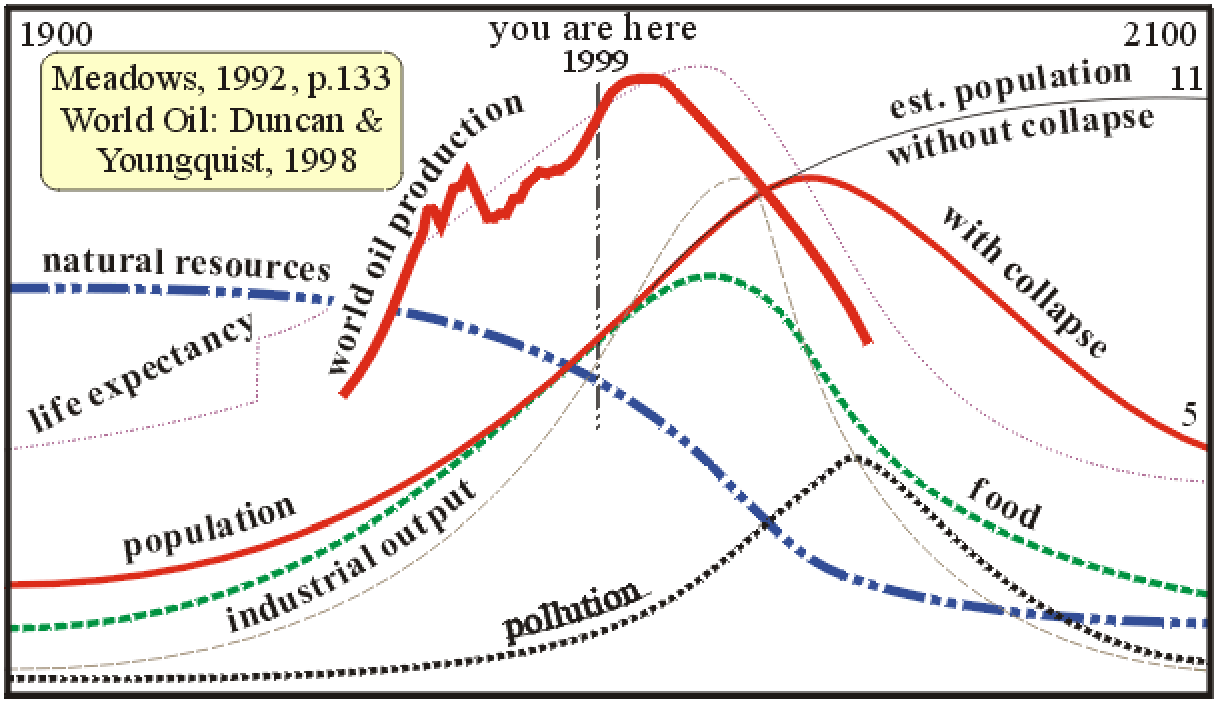

Diagram copied from: http://dieoff.org/page5.htm

Conclusions of Meadow *et al*

1. If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next 100 years. The most probable result will be a sudden and uncontrollable decline in both population and industrial capacity.

2. It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable far into the future. The state of global equilibrium could be designed so that the basic material needs of each person on earth are satisfied and each person has an equal opportunity to realize his or her individual human potential.

3. If the world's people decide to strive for this second outcome rather than the first, the sooner they begin working to attain it, the greater will be their chances of success. (Meadows et al., 1972)

- Reaction of many economists was very negative. Basis for critique:

The updated report received much less attention.

A groundbreaking report in terms of its political impact: World Commission of Environment and Development, 1983, established by the U.N.
Produced a report in 1987, now called the Brundtland report – puts environment on the world political stage.