Econ674

Economics of Natural Resources and the Environment

Session 2

Markets and States in Environmental Choices

Static Optimization and Market Failure

- 1. Firms that pursue economic efficiency through profit maximization pursue technical and allocative efficiency in a simultaneous fashion
- 2. Technical efficiency is the least costly way of producing a given output, I.e., setting to equality the respective ratios of marginal products to their corresponding input prices
- 3. Allocative efficiency follows the classic marginal rule - MC=MC
- 4. Once economic efficiency of the firm has been achieved, one can then derive four corresponding financial ratios.
- 5. These ratios are the rate of return on sales, the rate of return on equity, the rate of return on invested capital, and the rate of return on assets. These ratios serve as proxy measures to determine whether firms should enter or leave a market.

Static Optimization and Market Failure - 1

- 1. Once a firm has achieved economic efficiency, this may not constitute an industry steady-state solution
- 2. Achieving a steady-state economic solution requires that the number of firms in an industry each earn no economic profits, i.e. they earn only normal profits equal to the opportunity cost of capital.
- 3. However, even if an industry generates a steady-state economic solution, it may not conform to an environmentally sustainable solution.
- 1. Environmental sustainability requires that the stock of natural capital be maintained for future generations.

Static Optimization and Market Failure - 2

- 1. As natural resources in general, and energy resources in particular, are part of any production process, firms that may achieve technical efficiency are likely to do so in the presence of external costs.
- 2. The basis for external costs in any production process is determined by the laws of thermodynamics, in particular, the second law, which stipulates that any production process is governed by differences in ambient and combustion temperature.
- 3. Natural science points to the role of carrying capacity in the determination of any any environmentally sustainable process. This may permit the emission of some byproducts of energy transformation into the atmosphere, but for which the environment has some degree of recovery capacity

Static Optimization and Market Failure - 3

- 1. Environmental sustainability is defined by biophysical processes and may be a nonlinear function of the level of economic activity.
- 2. Given that market prices do not alone incorporate the external costs on the environment, the challenge is to find a way to set prices that balances economic efficiency with environmental sustainability.
- 3. Market pollution permits, and cap-and-trade systems, represent one approach to achieving a balance between economic efficiency and environmental sustainability. Setting the price of tradeable pollution permits derives from an underlying environmental carrying capacity function that embodies the biophysical capacity of a given habitat to absorb the byproducts of any given energy transformation.

Static Optimization and Market Failure - 4

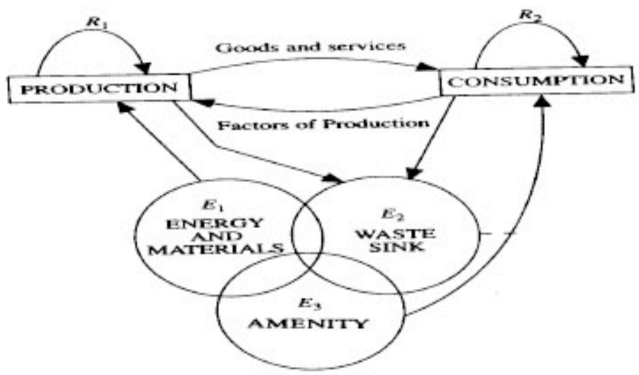
- **Sources of Market Failure**
  - **1. <u>Incomplete markets</u>**
  - **(Pareto conditionality):**
    - **a. complete markets with well defined property rights**
    - **b. competitive markets under utility/profit maximization and cost minimization conditions**
    - **c. perfect information on prices at all levels**
    - **d. zero transactions costs**
  - **2. <u>Externalities</u> (Arrow 1969, Mishan, Coase 1960)**
    - » **a. positive**
    - » **b. negative**

Static Optimization and Market Failure - 5

- **Sources of Market Failure, contd.**
  - **3. <u>Non-exclusion</u> (Hardin, 1968)**
    - **a. common property**
    - **b. open access**
  - **4. <u>Non-rival consumption</u> (MSC=0)**
  - **Pure public goods (Samuelson, 1954)**
  - **5. <u>Non-convexities</u>**
  - **Polynomial ambiguity**
  - **6. <u>Asymmetric information</u>**
    - **a. moral hazard**
    - **b. adverse selection**

Linkages Between the Economy and Environment

Interlinkages between economy and environment



E4. GLOBAL LIFE-SUPPORT SERVICES

- **The economy**: two sectors (production and consumption). Exchange takes place in these sectors.
- **The environment** is shown in two different ways:
  - one of them having three different linkages with production and consumption (E1, E2, and E3)
  - and one with a general element (E4).

Economy and the environment

- E1: Here the role of the environment is supplying resources;
  - production extracts energy and materials from the environment, transforms them into outputs (useful goods traded with consumers and harmful-emissions such as SO_2).
  - some recycling in production and consumption (loops R1 and R2)

- E2: Here the environment serves as a sink/receptor
  - Limited assimilative capacity for waste
  - But we mostly have increasing damage and the rate of increase may exhibit abrupt changes due to 'threshold' effects

The effects of waste on the environment depend on the type/nature of the pollutant

- **A note on classification of pollutants:**

1. 'Cumulative'/''conservative'/non-biodegradable pollutants: With no natural processes to transform some inputs to the environment into harmless/less harmful, substances; e.g. Lead, cadmium, and man made substances such as PCBs (polychlorinated biphenyls) and DDT (dichloro-diphenyl-trichloro-ethane).

Linkages Between the Economy and Environment - 2

Economy and the environment

- Unbroken by chemical/biological processes, and build up by 'bioaccumulation'.
- For such pollutants a positive flow in a year (F_t) adds to the stock, and the stock S_t^c at any time t^* is given as

$$S_{t^*}^c = \sum_{t_i}^{t=t^*} F_t$$

where t_i is the historical date when emissions began

- Note that for a given location this may not accurately predict the stock of pollutants because
  - pollutants may move to other locations
  - sediments may build up over the stock pollutant and put it 'out of harm's reach'

2. Assimilative/degradable pollutants: The stock in any time period is current flows less the amount removed by biodegradation/chemical reactions.

- In this case the stock at time period t is

$$S_t^a = F_t - A_t$$

where A = amount assimilated in any period.

A_t may depend on the level of previous period emissions of either
  - the pollutant whose stock is being modeled or
  - another pollutant.

- E3: The environment acts as a supplier of amenity, educational and spiritual values to society.
  - Non natives may derive pleasure *from* the existence of wilderness areas or rainforests.
  - Natives may attach spiritual and cultural values to them, and the flora and fauna therein.
- Economists 'count' these values
- For now, the question is 'what constitutes economic value within neoclassical economics?
- Economic value is dependent on social well-being, measured in a particular way.
- Social well-being is seen as depending on the (possibly weighted) sum of individuals levels of well-being.
- Individual well-being is measured by utility, thus social welfare is the sum of individual utilities.

Linkages Between the Economy and Environment - 3

- A representative individual will have preferences which could be represented in the following generalized way:

$$U_A = U(X_1, X_2, \ldots X_n; Q_1, Q_2, \ldots, Q_m)$$

- Where
  - U_A is utility,
  - $(X_1 \ldots X_n)$ are produced goods and services, and
  - $(Q_1 \ldots Q_m)$ are environmental assets.

  The environment supplies utility to individual A
    - directly via the vector of assets, and
    - indirectly via its roles in the production of the vector of goods and services $(X_1 \ldots X_n)$.
  - An 8 in X_i vector6 9Q_j vector.
- E.g. X_1 is consumption of services of a car, but the use of car decreases air quality, Q_1. An increase in the consumption of 'car services' increases utility

$$\frac{\partial U_A}{\partial X_1} > 0$$

- but this increase in car use decreases air quality

$$\frac{\partial Q_1}{\partial X_1} < 0$$

- This fall in air quality reduces utility in an amount

$$\frac{\partial U_A}{\partial Q_1}\frac{\partial Q_1}{\partial X_1}$$

- Net effect-ambiguous: depends on the relative strength of these positive and negative changes.

Linkages Between the Economy and Environment - 4

- Thus, using the environment for one purpose can reduce its ability to supply us with other services. The reason for E_1, E_2 and E_3 to be shown as overlapping: there are conflicts in resource use.

- Thus, the environment is a scarce resource, has conflicting demand placed on it. Scarcity in this cases is called **relative scarcity.** In principle a correct set of (shadow) prices could solve it.
- This differs from **absolute scarcity**, whereby all demand on environmental services are together increasing.
- The major cause of absolute scarcity is economic growth: this implies an
  - ↑ in demand for materials and energy,
  - ↑ in waste outputs, and
  - ↑ in demand for environmental quality.
- Yet if the amounts of environmental resources are fixed then absolute scarcity will increase as world economic growth occurs.
- Therefore, economics has a role to play since it is concerned with allocating scarce resources to conflicting demands.
- But it is also clear that the economic system, primarily the market system, works very poorly in allocating environmental resources mainly because of:
  - imperfect specification of property rights
  - individual benefits of preservation understate the collective benefits
- *E4* represents the global life-support services provided by the environment. These include
  - maintenance of an atmospheric composition suitable for life; a composition whose limits of variability are small from the point of view of continued existence;

Linkages Between the Economy and Environment - 5

  - maintenance of temperature and climate:
    changes in composition of the upper atmosphere change climate
  - recycling of water and nutrients.
    Examples are the hydrological, carbon and oxygen cycles.
- Clearly, economic activity operates within this environment.

- A note on substitution for environmental services: Examples

  1. Recycling (two ways of substitution possible);

  2. Reproducible (man-made) capital services substituting natural capital services such as waste sink: e.g., a sewage treatment plant substituting for waste sink function of the environment

  3. Energy conservation: e.g., through use of energy saving equipment substituting for resource base functions

  4. Amenity services: e.g., use of manufactured swimming pool and services of the entertainment industry from which people derive pleasure from the natural environment (could be better with advances in IT) as close substitutes

  5. Substitution possibilities with life support services considered by many scientists as most limited (from a purely technical point of view this may not be the case, e.g., possibilities of life outside the biosphere though the quality of life supported and the quantity of service is limited)

Elements of Environmental Science

Most important elements of environmental science to an understanding of the implications of economy-environment interdependence include:

- thermodynamics (the science of energy)
- ecology

A. Thermodynamics

- Two important physical laws known as the first two laws of thermo-dynamics that govern the interdependence
- Both laws hold true in strictly closed systems, systems with no external inputs
- A closed system is one which does not exchange matter/energy with its environment.
- **The first law of thermodynamics**: matter, like energy, can neither be created nor be destroyed (materials balance principle).
- This implies that we can convert matter into energy, convert one form of energy into another form of energy and, in principle, convert energy into matter (although in nature this only happens inside nascent stars).
- However, a closed system cannot add to its stock of matter-energy.
- The earth is not a completely closed system, since we import energy from the sun, and occasionally matter, as meteorites.
- But we make use of only a tiny fraction of the energy falling on the earth from the sun - about 1 % through photosynthesis
- The majority of world energy demand is met from the results of past solar energy: gradually transformed into the fossil fuels

Elements of Environmental Science - 2

- The first law of thermodynamics has two important implications in addition to limits on matter–energy supply (Kneese *et al.*).
  - With the extraction of more matter for production, we generate more waste which must be returned to the environment, as the matter/energy content of the extracted material cannot be destroyed. Economic growth which results in increased extraction of material/energy must produce an equivalent increase in residuals output. In this sense, 'consumption' is a rather inadequate description of what consumers do.
  - It places limits on the degree to which resources can be substituted for each other in production.

Implications for production function specification: A synthesis of resource and environmental economics production functions recognises that material inputs enter the production function (R) and material outputs (in the form of waste, M, as well as output) emanate from production. This yields a production function such as

$Q=f(L, K, R, M[R], A[\Sigma M]$ where A denotes the ambient concentration level of some pollutant (which can affect production possibilities)

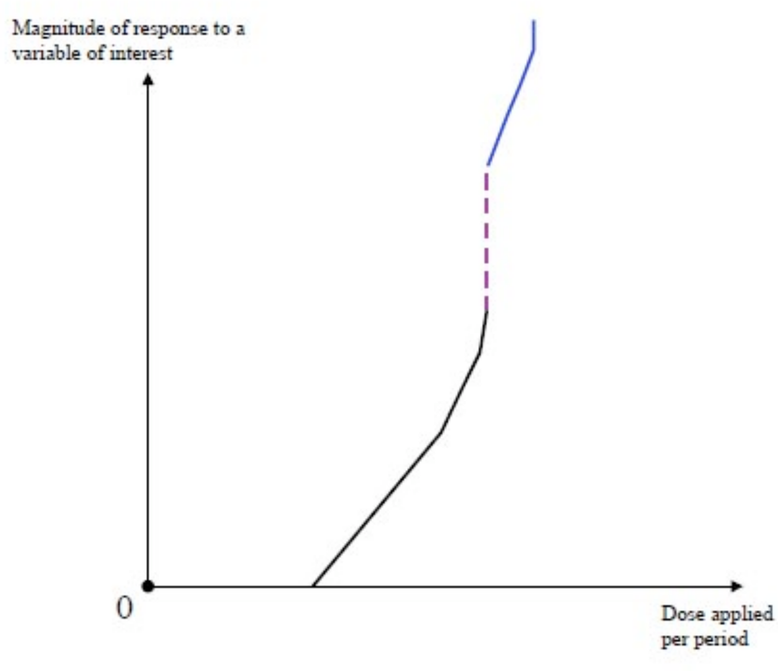
- **The second law of thermodynamics** (entropy law). In a closed system, the use of matter-energy causes a one-way flow from low entropy resources to high entropy resources; (from order to disorder; from a hotter to a colder body) and that heat cannot be transformed into work with 100% efficiency.
- As an energy resource, for example, is used, the amount of work that energy can do is diminished.
- The major implication of the second law is that energy cannot be recycled in such a way that we get back *all* the capacity of the original energy source to do useful work
- If the earth is a closed system, with a limited stock of low entropy energy resources (fossil fuels), then that system is unsustainable, since economic activity inevitably degrades the energy resource so that, eventually, no capacity for useful work could remain.
- Economist Georgescu-Roegen referred to the second law as the 'taproot of economic scarcity'
- The entropy law implies that there can't be complete recycling of matter
- a number of economists argue that substitution is generally not limited

Elements of Environmental Science - 3

B. Ecology

- Ecology is the study of the distribution and abundance of plants and animals
- Ecosystem: interacting set of plant and animal populations together with their abiotic, non-living, environment.
- An ecosystem can be defined at various scales: from the small and local-a pond or field- through to the large and global-the biosphere as a whole.
- Stability and resilience are two concepts of fundamental importance in ecology
- Stability is the propensity of a population to return to some kind of equilibrium following a disturbance
- Resilience is the propensity of an ecosystem to retain its functional and organizational structure following a disturbance
- Some economic activities appear to reduce resilience; under such conditions dose-response relationships may involve thresholds and some changes may involve dose-response relationships with significant non-linearities and discontinuities

Non-linearities and discontinuities in dose-response relationships



Environmental Biodiversity

- Biodiversity captures two dimensions:
  - the number of biological organisms and
  - their variability

  Three levels at which biodiversity can be considered are: population, species and ecosystems.

  Biodiversity is important in the provision of environmental services to economic activity in a number of ways: life support services, amenity services, inputs to production

  Ecologists see the greatest long-term importance of biodiversity in terms of ecosystem resilience and evolutionary potential. Diverse gene pools represent a form of insurance against ecological collapse

  Note, however, that we have very poor information about the current extent of biodiversity. A current best guess of the actual number of species is 12.5 million but even the currently know number of species is subject to some dispute, with a representative figure being 1.7 million species; about 13,000 new species are described each year.

Environmental Biodiversity - 2

Measuring Biodiversity

Rates of natural growth vary across species and as a function of spatial density. We can derive an index of relative biodiversity through use of logistic equations for individual species and from which we can then construct an index of relative biodiversity (IRB), as shown below:

Index of Relative Biodiversity

P. LeBel, 2002

$IRB = (1/(S/ha))(1 - \bar{g}/\bar{x})$, where:

S/ha = the number of species per hectare

$\bar{g}$ = the geometric mean of biomass across species

$\bar{x}$ = the arithmetic mean of biomass across species

Table 1

Multi-Species Logistic Growth Example

	S-1	S-2	S-3	S-4	S-5
r=	0.100	0.070	0.060	0.055	0.048
h=	200,000	230,000	100,000	140,000	120,000
a=	399.00	459.00	199.00	279.00	239.00
t(msy)=	11.56	16.90	17.02	19.76	22.02
P(t,msy))	1621.92	1668.30	1408.79	1508.87	1462.26
MSY(t)	160.88	115.93	83.34	82.09	69.33

Figure 3

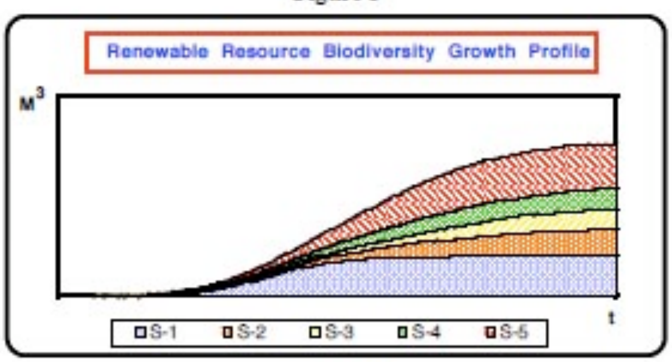


Figure 4