Introduction to Resource Economics

Finite resources, growth and optimal management.

Anton Bondarev

Department of Economics,
University of Basel

20.09.2018

Some general ideas

- Why we need Resource Economics?
- Resources are special in:
  - They are typically **finite**;
  - Efficiency of their usage increases in the technology state;
  - This requires **dynamic** management.
- Optimal usage of finite resources with growing efficiency.

Resource Economics

- Many environmental problems have the **intertemporal** aspect: *The usage today has consequences for the future usage and/or utility*
- These future effects have to be included in today's planning of usage
- Resource Economics tackles with optimization problems which:
  1. Include intertemporal dependencies
  2. Assume usage of the natural resource which is essential for production/well-being

Some resource management problems

- Climate change
- Fossil fuels
- Water management
- Soil usage
- Mineral resources

Resource: Definition

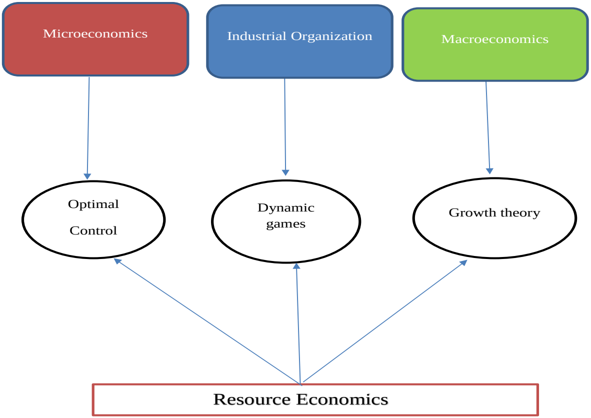
- Finite: is defined by natural stock
- No production: we can only use what is out there
- Intertemporal: the usage today influences usage possibilities tomorrow

Different kinds of resources

- Dynamic aspects:
  1. Renewable resources: can regenerate over time. *Water, air, soil, climate*
  2. Non-renewable resources: cannot regenerate over time. *Fossil fuels, minerals*
- Economic aspects:
  1. Essential resources: no economic activity is possible without them. *Oil, gas, water, soil*
  2. Non-essential resources: can be fully substituted by technology. *Diamonds, fossil energy, metals*

  Remark: State of technology defines which resources are essential and which are not.

Position of the discipline



Birth of Resource Economics

- Keynesian thought: aggregate behaviour different from individual;
- Ramsey (1927): it is important to take care of future generations:

$$\sum_{t=0}^{\infty} \mathrm{e}^{-\rho t} U(C) \to \max;$$

- Hotelling (1931): how to exploit finite and essential natural resource optimally:

$$\max_{C,R} \int_0^{\infty} \mathrm{e}^{-\rho t} U(C) dt$$

$$s.t.$$

$$\dot{S} = -R.$$

Limits to Growth

- The Book appeared in 1972;
- Contains predictions on the time of depletion of main natural resources;
- Idea: exponential growth requires exponentially growing usage of resources;
- Considers different scenarios:
  1. Standard run (Business as Usual);
  2. Standard run with natural resources doubled;
  3. Resources doubled plus technological change;
  4. Technological change, resources doubled, reduced pollution;
  5. As above plus birth control and increased food yield.
- All scenarios except the last one yield collapse of the world economy in XXIst century.

Nonrenewable resources

- There is a number of resources, essential for industrial production;
- The availability of these resources is measured by static reserves index;
- However the rate of resources usage is growing exponentially;
- This yields completely different estimates on the availability of resources.

Non-renewable natural resources		
Resource	Static index	Exponential index
Aluminium	100	31
Chromium	420	95
Coal	2300	111
Cobalt	110	60
Copper	36	21
Iron	240	93
Nickel	150	53
Molybdenum	79	34
Natural Gas	38	22
Petroleum	31	20

Role of prices

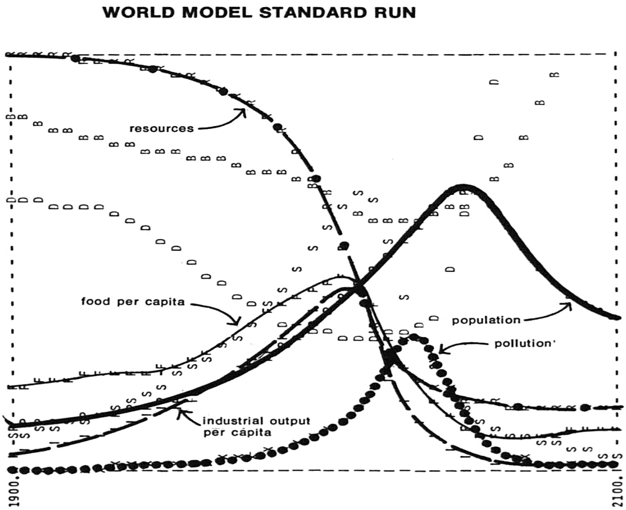
- As resource becomes scarce, its price increases;
- This slows down the rates of extraction and usage of the resource;
- Thus the rate of usage has a bell-shaped form;
- Still lifetimes are shorter, than under static reserves index;
- Doubling or tripling of known reserves do not help at all;
- In such a situation prices will increase at a lower rate and resource usage is higher.

Main conclusion on resources

Given present resource consumption rates and the projected increase in these rates, the great majority of currently important nonrenewable resources will be extremely costly in 100 years from now.

- This conclusion is independent of whether known reserves will increase and whether resources will be used in a more efficient way.

Typical simulation results



Dynamic optimization

- Maximization of utility or social welfare;
- This maximization is carried out over many periods (time);
- Problem consists in finding **optimal policy** for each period;
- This choice is constrained by the stock variable.

Resource usage is such an optimal policy subject to resource stock.

Resource economics: Microperspective

- An agent (community, firm, farm, etc.) owns/uses a fixed/growing resource stock;
- Problem is to maximize welfare from resource usage
- Subject to the constraint on resource.

Outcome: Optimal rate of resource usage throughout time;

Examples: Water management, fossils extraction

Resource economics: Mesoperspective

- Several agents (firms, communities, fisheries..)
- Common usage of some reosource (lake; forest; oil field..)
- Optimal usage vs. competitive usage: tragedy of commons
- Strategic interactions lead to suboptimal behavior (overexploitation)

Outcome: Game-theoretic profile of resource-extraction strategies

Examples: Shallow lakes, fisheries, forestry

Resource economics: Macroperspective

- Maximization of growth rate over resource constraint;
- Resource may enter utility as a good or just be used in production as a factor;
- Environmental quality is also a resource!
- Resource may be traded to boost capital investments: Hartwick's rule

Outcome: Set of optimal policies, including resource usage;

Examples: Economic growth with resources, International trade..

Lectures' Plan

27.09	Easter Island: Dynamical systems.
04.10	Hotelling model: Optimal control methods.
11.10	Water management: Optimal control application.
18.10	Shallow lakes: Strategic interactions.
25.10	Shallow lakes II: Differential games application.
01.11	No lecture
08.11	Resources in neoclassical growth theory.
15.11	Intergenerational fairness and limited resources.
22.11	International trade: Hartwick's Rule.
29.11	Resources in modern growth theory.
06.12	Resources in modern trade theory.
13.12	EXAM

Methods

- Dynamical systems (Lecture 2):
  - What is the dynamical system
  - How to find steady states/equilibria
  - Stability of those equilibria
- Optimal control (Lecture 3):
  - Optimal management in time
  - Opportunity costs and shadow costs
  - Hamiltonian formalism: how to solve an optimal control problem
- Differential games (Lecture 6):
  - Strategic interactions and game theory
  - Differential game: dynamic strategic interactions
  - Open-loop and closed-loop solution concepts

Models

- Optimal resource management:
  - Hotelling's model (Lecture 3)
  - Groundwater mining and management (Lecture 4)
- Common resource usage and strategic interactions:
  - Shallow lakes problem (Lectures 5,6)
- Macroperspective:
  - Resources in growth theory (Lecture 7)
  - Intergenerational fairness (Lecture 8)
  - Hartwick's rule (Lecture 9)
  - Modern treatment of resources (Lectures 10,11)

Next lecture: Easter Island

- Paper: J. Brander and S. Taylor (1998) The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use. *The American Economic Review, 88(1)*, pp.119-138
- Role of limited resources: how to reconcile them with population growth
- Introduction to dynamical systems and their equilibria (steady states concept)
- The role of initial conditions and stability.