THE DRIVERS OF ENVIRONMENTAL CHANGE
THE IPAT

Introduction to Environmental Science and Natural Resources

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Origins of the idea

- Does population growth, economic affluence (or poverty) or technology drive environmental change?
- Needed some framework to highlight the main drivers

The IPAT concept

The Identity

$$I = P \times A \times T$$

I: Environmental impact
P: Population (individuals)
A: Affluence (output/person, consumption/person)
T: Technology (Pollution/output)

Example

- What are the contributing factors of fuel use by cars in the United States?

- *I = PAT*
- Fuel use = population (individuals) x
  affluence (number of cars per capita) x
  Technology (average fuel use per car)

Must be very careful with UNITS

Why use the IPAT to assess environmental problems?

1. Shows how contributing factors compound to produce a total effect.
2. Allows assignment of blame, or praise, to important factors
3. Can guide policy and action. What factors to focus on when trying to reduce environmental impact – and can be used to answer "what if questions".
   - What if population size will double by 2050, and affluence double as well, how much does average fuel use per car need to decline to keep total fuel use constant at current levels?

Properties

- Framework assumes causal relationships
- Assumes independence of the factors
- Is multiplicative, NOT additive, unless log scale is used.

Fundamental recurring issues

1. The IPAT equation can have many more terms than simply the PAT. E.g. CO_2 emissions from energy use:

CO_2 (tons) = population (individuals) x
GDP/capita ($/individual) x
Energy/GDP (BTU/$) x
CO_2/Energy (tons/BTU)

Fundamental recurring issues

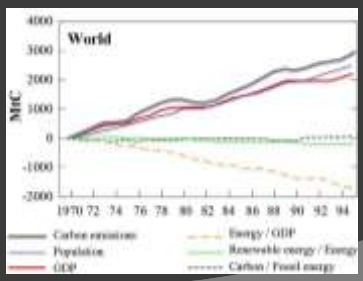
2. IPAT excludes "finer" issues such as culture, property rights, social structure etc.
3. MUST keep track of units.
4. Factors may in reality NOT be independent!
   - E.g. *P*, *A* and *T* frequently are dependent. Larger *A* could mean lower *T*, larger *P* could mean lower *A*.

Units: Kaya identity

Equation relating factors that determine the level of human impact on climate, in the form of emissions of the greenhouse gas carbon dioxide

- CO_2 emissions = Population * affluence * energy intensity * carbon intensity
- Tons = Individuals * ($/individual) * (Joule/$) * (tons/Joule)

Historical trends in energy-related CO_2 emissions



Fun with IPAT

- Assess components of growth in carbon emissions between 1960 and 1970

$I_{1970}/I_{1960} = P_{1970}/P_{1960} \times A_{1970}/A_{1960} \times T_{1970}/T_{1960}$

1,58 = 1,22 x 1,36 x 0,95

The IPAT concept

- Often expressed in percentages

Example:
P increases 30%, Crop production per capita increases 5%, and pesticide use per crop increases 168%.

=> I = 1.30 x 1.05 x 2.68 = 366, or 266%

Fun with IPAT

- Assessing fractional importance of each component:
- Take logarithm of each:

$$\log\left(\frac{I_{1970}}{I_{1960}}\right)=\log\left(\frac{P_{1970}}{P_{1960}}\right)+\log\left(\frac{A_{1970}}{A_{1960}}\right)+\log\left(\frac{T_{1970}}{T_{1960}}\right)$$

  - BUT: can only apply this directly when all factors increase

Fun with IPAT

- What if questions.
- Sustainable development goals:
  - How much does technology need to improve if we are to?
    - Double size of human population
    - Quadruple Consumption per capita
    - Half the environmental impact (diminish by a factor of 2).

2. Towards the IPAT concept

Paul Ehrlich

$I = P \times F$

I: Impact

P: Population; Individuals

F: Impact per capita; e.g. carbon emissions per capita

Supposed to justify Paul's ideas expressed in the Population Bomb

warned of the mass starvation of humans in 1970s and 1980s due to overpopulation and advocated immediate action to limit population growth.

Towards the IPAT concept

- Non-linear representation

$I = P(I,F) \times F$

F dependent on *P*

P dependent on *I* and *F*

Towards the IPAT concept

Technological pessimism

Barry Commoner:

Closing the Circle; Pollution is the result of economic growth and technology!

I = P x (Economic good/Population) x (Pollutant/Economic good)

⇒ Added technology into the equation

Towards the IPAT concept

Technological Optimism

- **Ester Boserup (1910 - 1999):** Population growth and economic growth create an increase in demand for resources. The resulting scarcity drives technological progress and with it the search for subsitutes and increased efficiency. Thus the net effect is neutral or even positive.
- **Julian Simon:** More people means increased human capital - more minds to find solutions to our problems

Towards the IPAT concept

Ehrlich/Holdren early 1970'ss

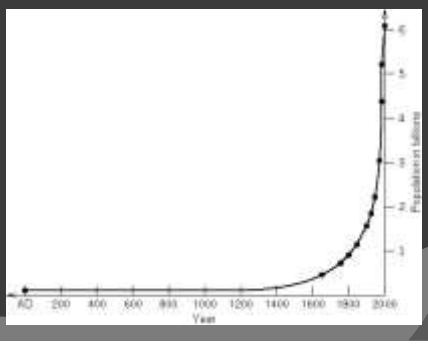
Various versions:

I = Population x Consumption/person x damage/unit of production

I = Population x GNP/Population x Pollution/GNP

I = Population x Consumption/person x Pollution/unit of production

The P in IPAT



Population

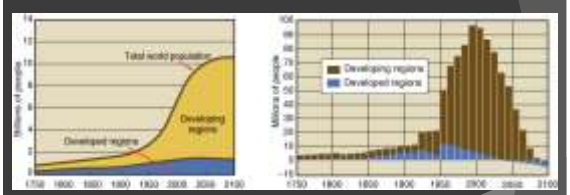
- Usually expressed as number of individuals – per time-period
- Forecasted using growth models
  - Linear
  - Logistic
  - Cohort component method

Questions with regard to P

Is population growth the culprit?

If yes….
Can we/should we do something about it?
Ethics!

Changes in developed vs. developing regions



The *A* in IPAT

- Affluence is defined as a per capita measure of wealth - but in this context often linked to consumption, and thus presented as GDP/capita, cars/capita, energy/capita etc…..
- "Consumption is the human transformation of materials and energy…" (Kates 1999)

The *A* in IPAT

To consider:

- Is it affluence or is it poverty?
- Positive feedback between poverty and environmental degradation (Fuller 2007)

The *A* in IPAT

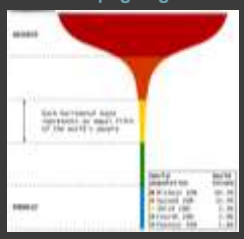
- The **20%** who live in high-income regions, including Western Europe, Japan, North America and Australia, account for **86%** of total private consumption.
- The poorest 20% account for only 1.3%.
- A child born today in an industrialized country will add more to consumption and pollution over his or her lifetime than 30 to 50 children born in developing nations.

Smashing myths

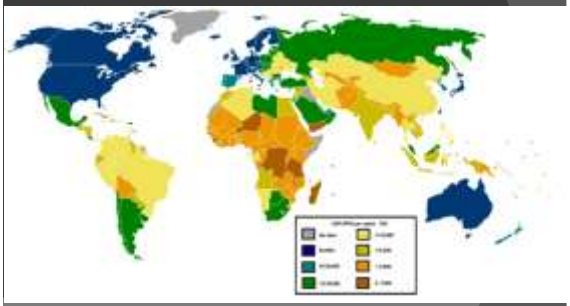
- Most environmental degradation is done by the poor?
- Poverty reduction leads to environmental degradation?
- Population growth necessarily leads to env. degradation?
- The poor are too poor to invest in env?
- Poor people lack technical knowledge for resource management?

Myths

The champagne glass



GDP per capita



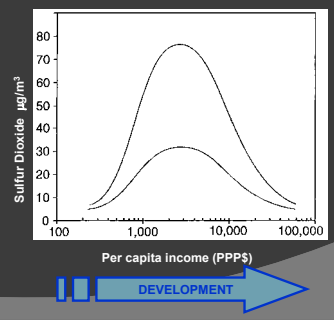
Issues

- Common measures very aggregate
  - Disaggregate by:
    - Economic sector
      - Industry
      - Commercial
      - Households
      - Transportation
    - Region
  - Is Income distribution important?

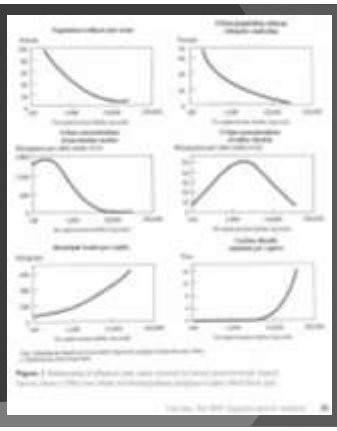
Does *I* increase with increasing *A*?

- Environmental Kuznets Curve (EKC)
  - Grossman and Krueger
- Measures empirical relationship between *I* and affluence *A*.
- Been measured for most pollutants
- In many cases shows an inverted U-shaped relationship between affluence *A* and *I*

Environmental Kuznets Curve



I and A



The *T* in *IPAT*

Recall; $I = P * A * T$

- Very difficult to measure and thus becomes a residual term
- How defined?
  - Pollutant/output
  - Damage/output

Culprit or savior?

- Culprit or savior?
  - Many argue that *T* is the only way to reduce the impact of *A* and *P*
- Robert Solow (Harvard Economist):
  - Illustrated that labor and capital account for 10% of productivity growth in USA
  - "residual" accounts for rest!
  - Other research shows that 30-40% can be contributed to technology

T, Culprit or savior

- The factor 10 Club illustrates that *T* must increase productivity by a factor of 10 to outweigh increase in populations and resources
- Can use the equation to ask such "what if" questions:
  - Given a certain increase in *P* and *A*, how much does *T* need to reduce the impact?

T, Culprit or savior

- Enter Industrial Ecology
  - Looks at industries as agents of change
  - Aims to reduce the environmental impact of industry/society often via technological fixes, but in a cost effective way
    - LCA – *Life Cycle Analysis*
    - LCC – *Life Cycle Cost*
    - DFE – *Design for Environment*

Extensions

- Stochastic version

$$I = a \cdot P^b \times A^c \times T^d$$

- Where: each parameter is linear or contains a more complex function
- Estimated using regression analysis:

$$\ln(I) = \ln(a) + b\ln(P) + c\ln(A) + d\ln(T)$$

Critiques of IPAT

- Very simplistic
- Correlation does not necessarily imply causality
- Interaction among the terms
  - Hard to isolate impact from one factor
- Local vs. global impact

Missing factors

- Culture
- Political economy
- Social structure
- Economic behavior
- Property rights
- Trade impacts
- FDI *(Foreign Direct Investment)* impact

- Can we ever capture those in IPAT?

Decomposition analysis

- Price indexes:
  - Laspeyres index
  - Divisia index
  - Fisher index

Price index:
http://en.wikipedia.org/wiki/Price_index