

# Population and Climate Change: How Depletion of Nature and Human Inequality Impact Sustainability

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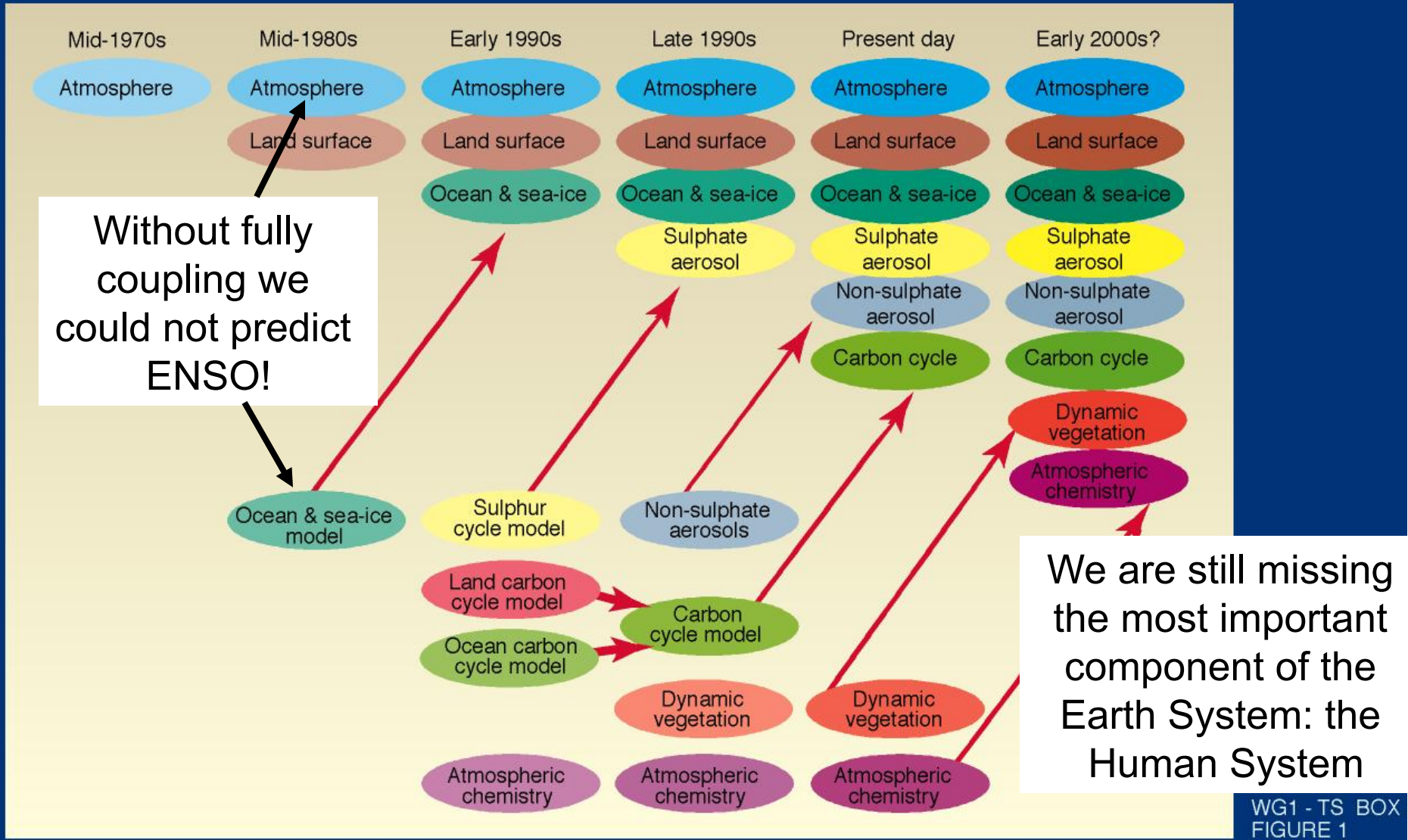
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Fang Zhao, Courtney Gustafson,

**UN SAB, 31 January 2014**

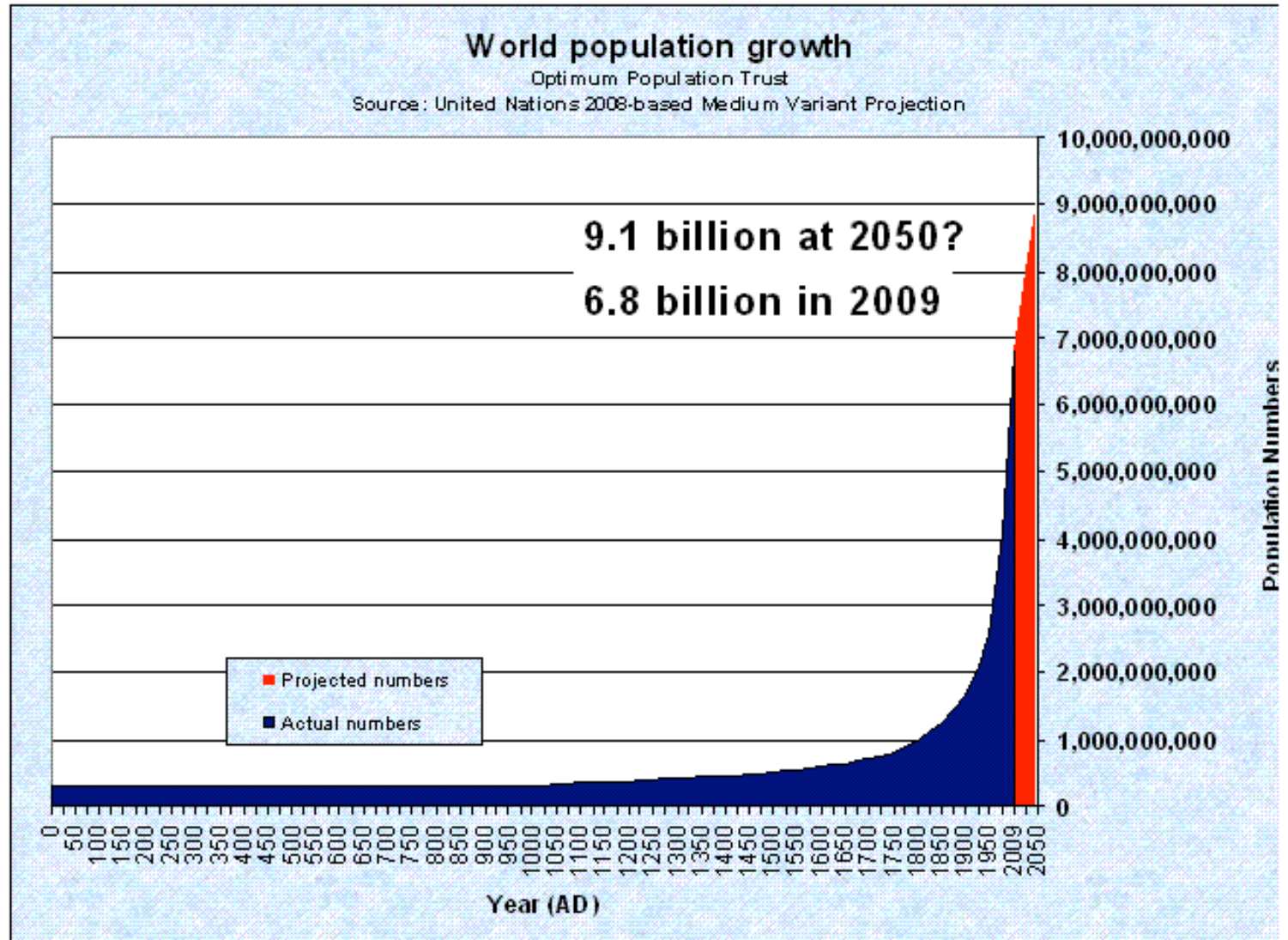
# The development of climate models, past, present and future



WG1 - TS BOX  
FIGURE 1

# Population growth

<b>1AD</b>	<b>0.3b</b>
<b>1650</b>	<b>0.5b</b>
<b>1800</b>	<b>1.0b</b>
<b>1927</b>	<b>2.0b</b>
<b>1960</b>	<b>3.0b</b>
<b>1975</b>	<b>4.0b</b>
<b>1987</b>	<b>5.0b</b>
<b>1998</b>	<b>6.0b</b>
<b>2011</b>	<b>7.0b</b>



# Why was the population able to grow so fast since the 1950' s?

Two reasons:

- 1) Sanitation and antibiotics (living longer)
- 2) Use of fossil fuels in agriculture starting in the 1950' s:
  - fertilizers, pesticides, irrigation, mechanization (Green Revolution).

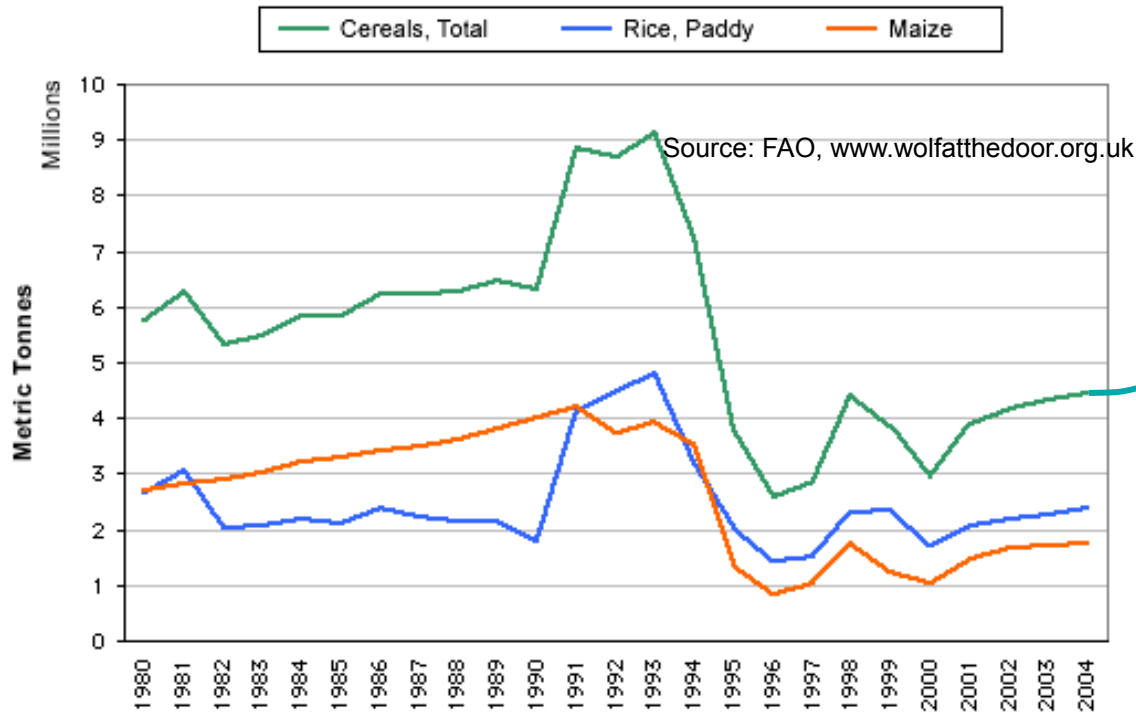
1950 to 1984: production of grains increased by 250% and the population doubled

**Without fossil fuels population would be much smaller!**

- Growth in grain production is now flattening out
- Industrial farming is destroying forests, soil
- Urban and suburban sprawl is overrunning best farmland

**This is not sustainable: “We are drawing down the stock of natural capital as if it was infinite” (Herman Daly)**

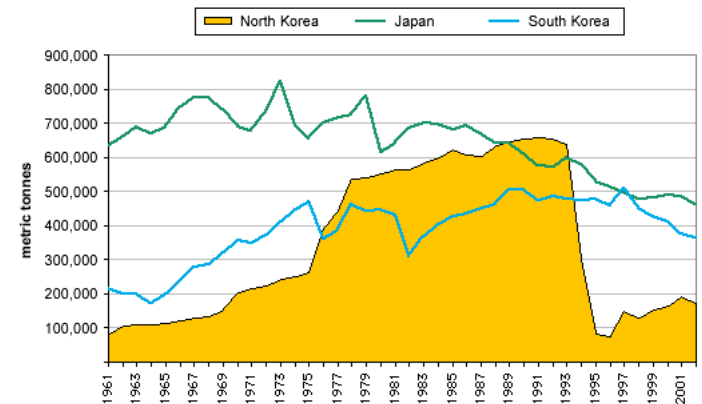
# Example: North Korea, got cheap oil from the former Soviet Union until early 1990s



Production of grain in North Korea, updated to 2008

The famines in North Korea are the result of the sudden loss of access to abundant fossil fuel

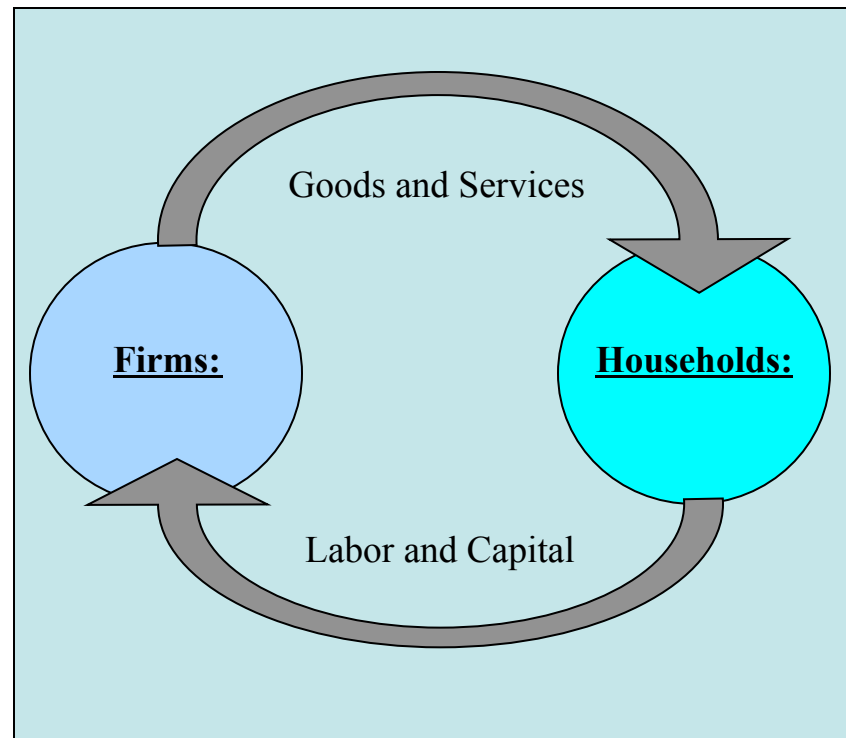
## G2. Fertiliser Use (Nitrogenous) - Far East





# Standard Neoclassical Economic Model

As Herman Daly, Robert Costanza, and other scholars in the field of Ecological Economics describe,



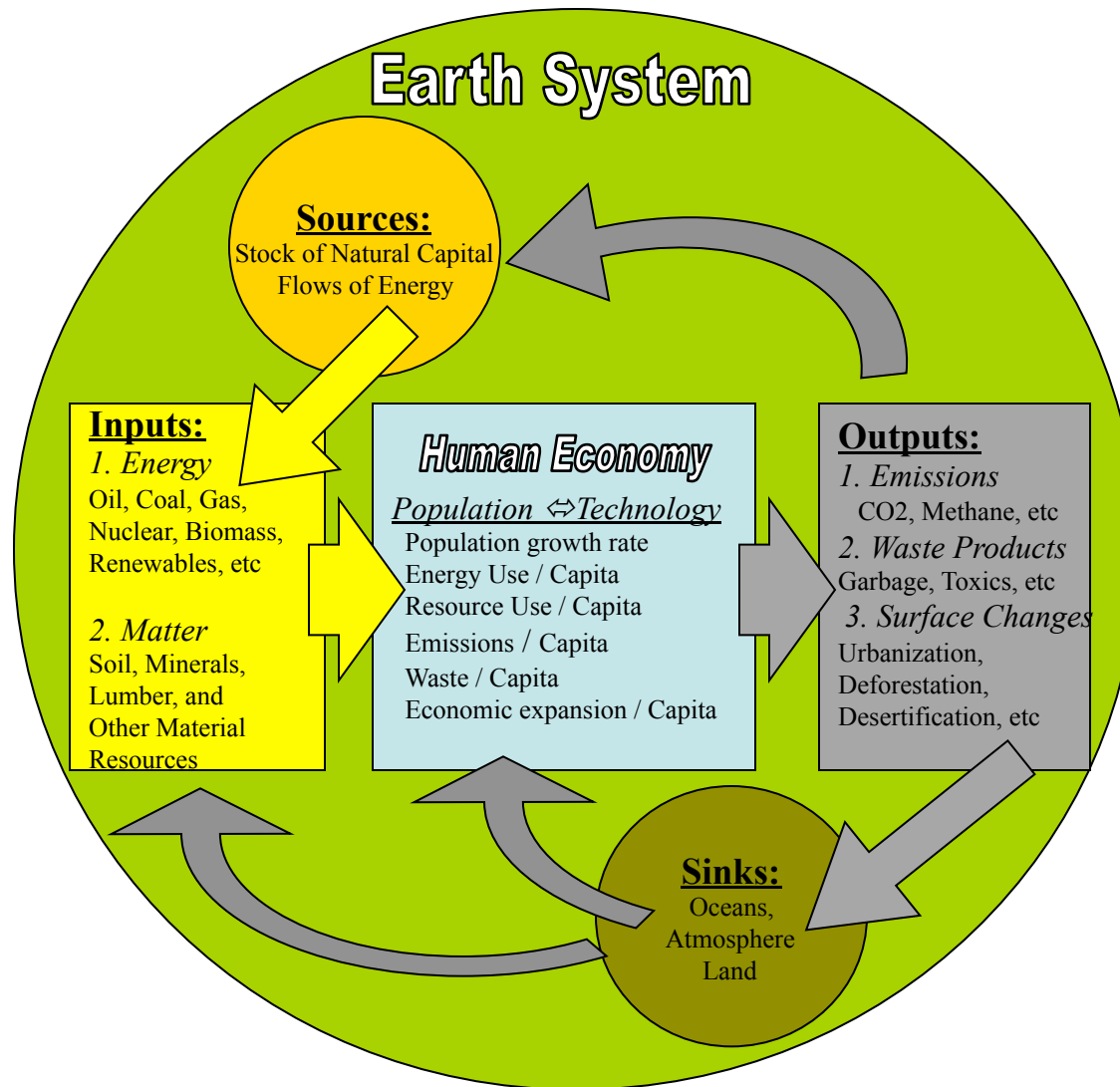
The standard Neoclassical Economic Model does not account for:

- Inputs (resources)
- Outputs (pollution)
- Stocks of Natural Capital
- Dissipation of Energy (i.e., a Perpetual Motion Machine)
- Depletion, Destruction or Transformation of Matter

Therefore, no *effects on the Earth System*, and *No Limits to Growth*.

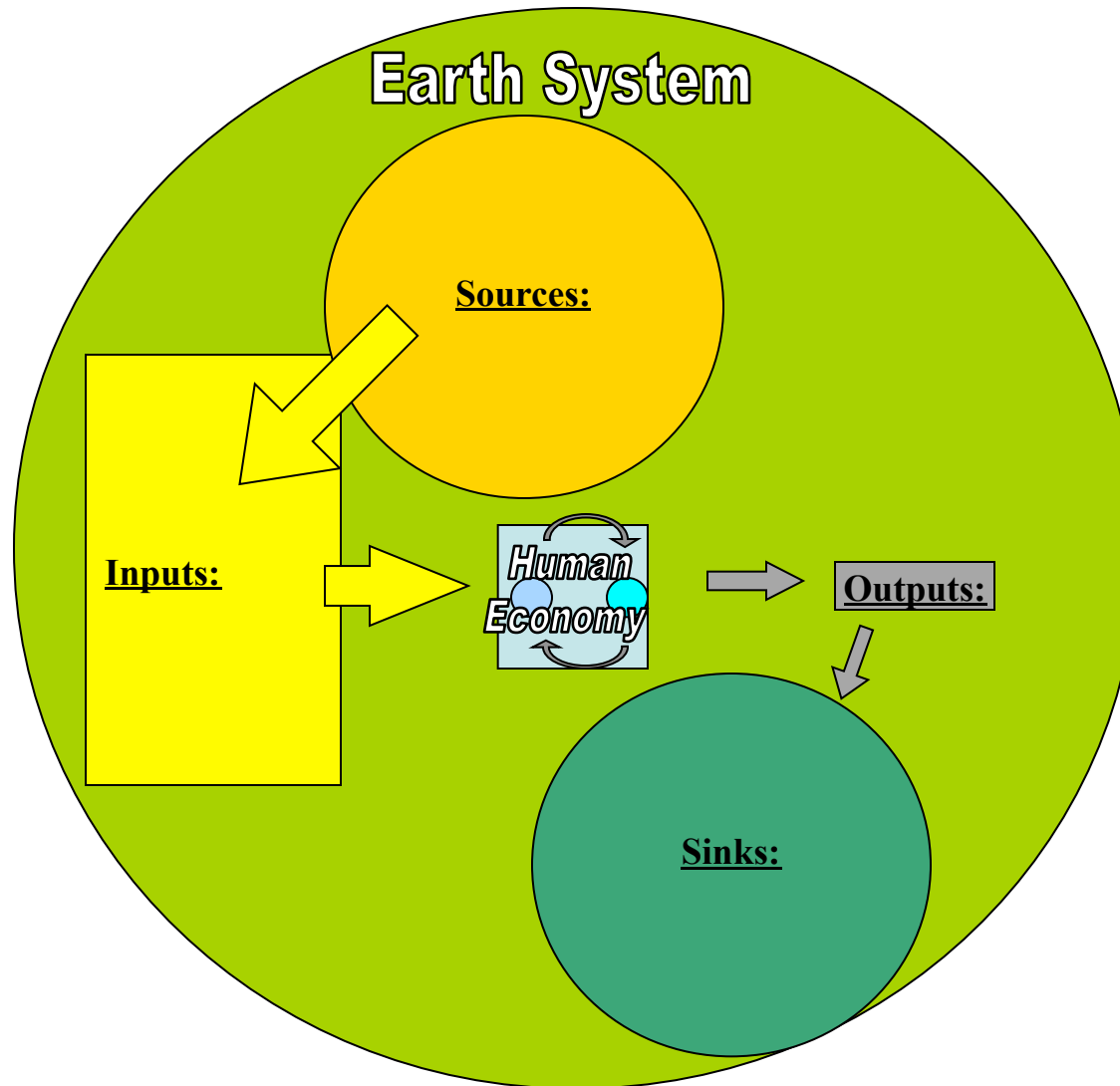
# Realistic **Ecological** Economic Model (Herman Daly)

- Incorporates INPUTS, including **DEPLETION** of **SOURCES**
- Incorporates OUTPUTS, including **POLLUTION** of **SINKS**



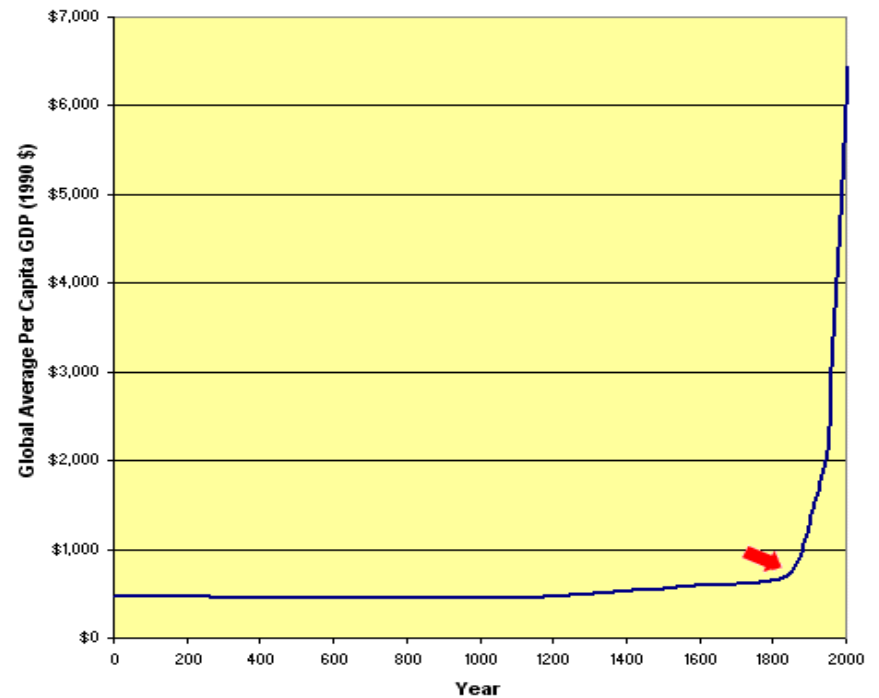
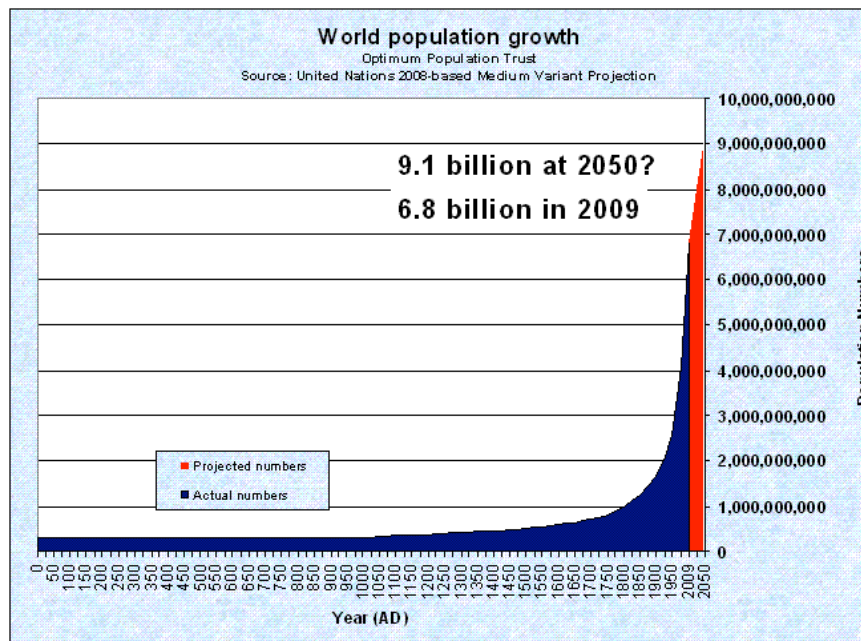
# “Empty World” Model

- Throughout most of human history, the **Human Economy** was so **small** relative to the **Earth System**, that it had little impact on the **Sources** and **Sinks**.
- In this scenario, the standard isolated economic model might have made sense.





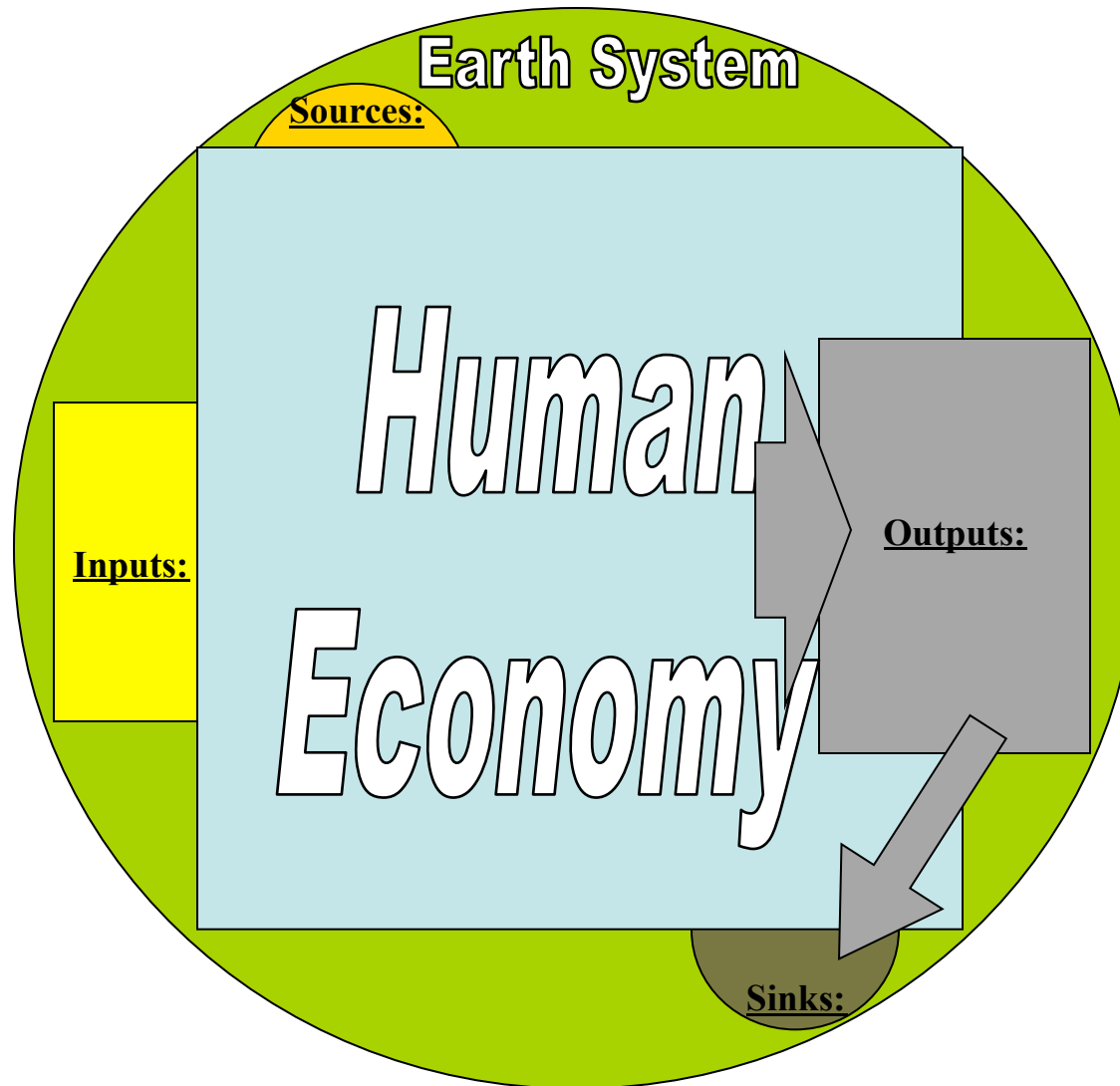
But Population and Economic Output *per Capita* have grown, and the net impact is their product!



Technology allows more efficient production,  
but also much faster consumption!

# “Full World” Ecological Economic Model

- Today, the **Human Economy** has grown so large, it has very large **Effects** on the **Earth System**, **Depleting** the **Sources** and **Filling** the **Sinks**. It is clear that **growth cannot continue forever**.



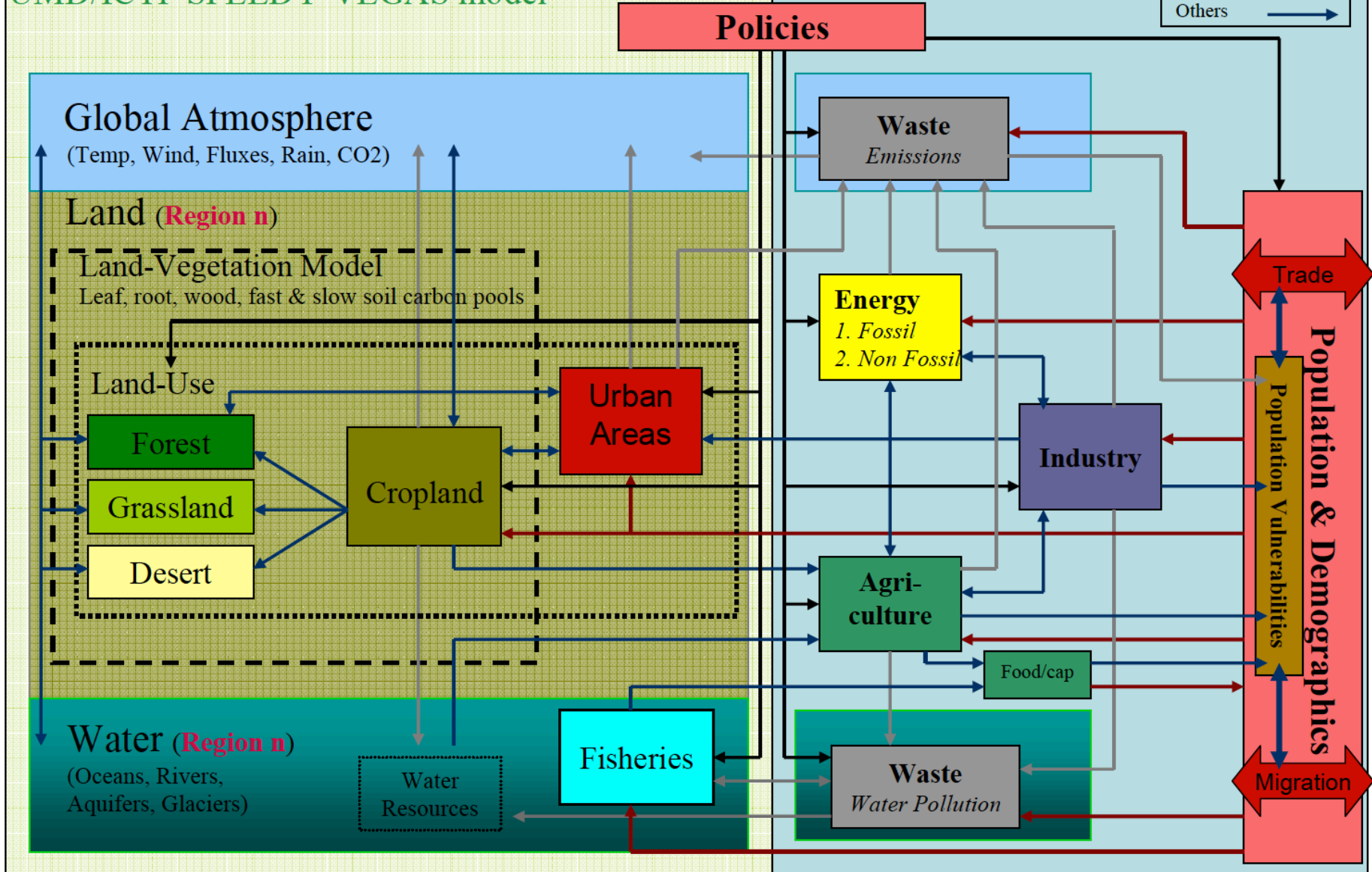
# Prototype Earth System - Human System Feedbacks

## Earth System

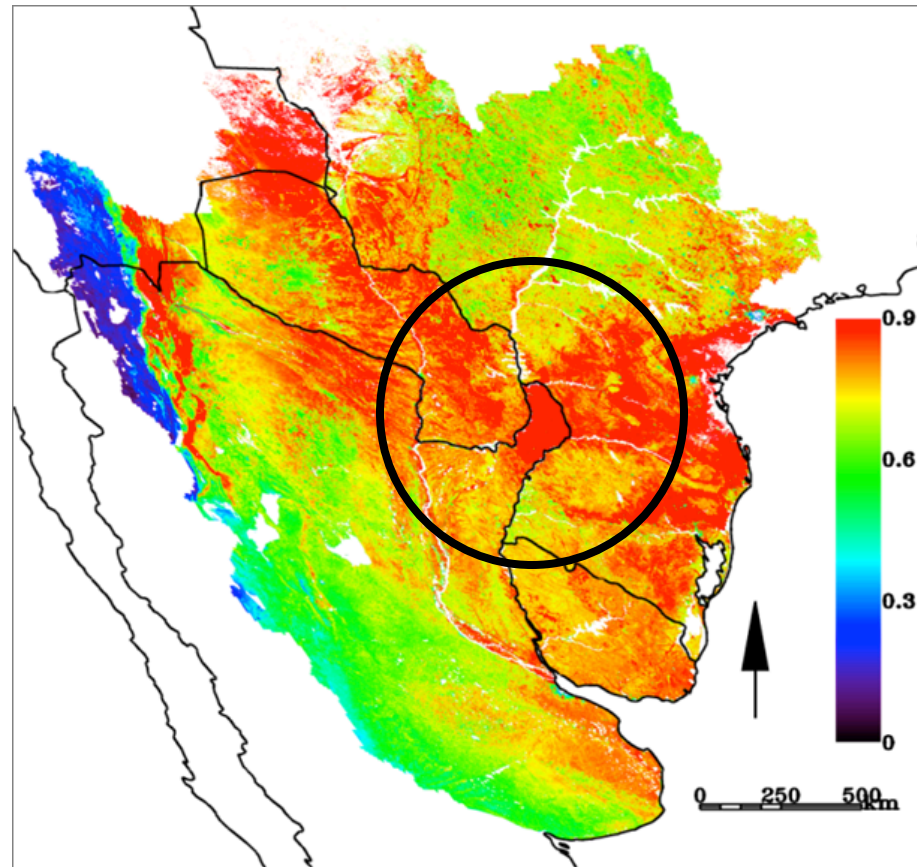
UMD/ICTP SPEEDY-VEGAS model

## Human System (Region n)

Effects and Feedbacks	
Policies	→
Population	→
Waste	→
Others	→



# Government policies are important!



The red (highest NDVI vegetation index) is in the **province of Misiones**, Argentina, that **protects the forest**.  
Compare Misiones with Brazil, Paraguay and the rest of Argentina!

# Human and Nature Dynamical model (HANDY) with Rich and Poor: for thought experiments

**Just 4 equations!**

Total population: Elite + Commoners  $x = x_E + x_C$

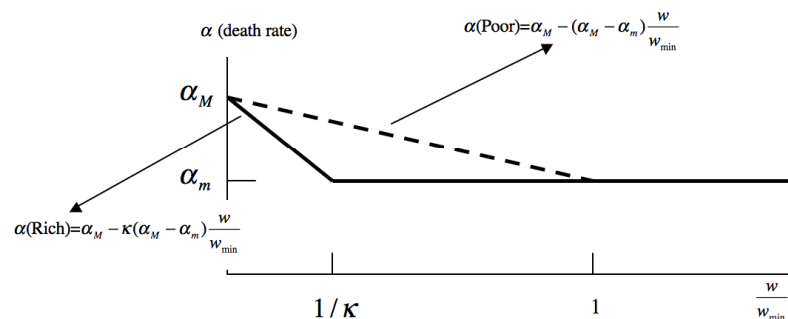
Nature equation: (only the Commoners produce)

$$\dot{y} = \text{Regeneration } \gamma y(\lambda - y) - \text{Production } \delta x_C y$$

The Wealth is managed by the Elites: Inequality factor  $\kappa \sim 100$

$$\dot{W} = \text{Production} - \text{Commoner consumption} - \text{Elite consumption} = \delta x_C y - s x_C - \kappa s x_E$$

Population equations: death rate  $\alpha$  depends on whether there is enough food:

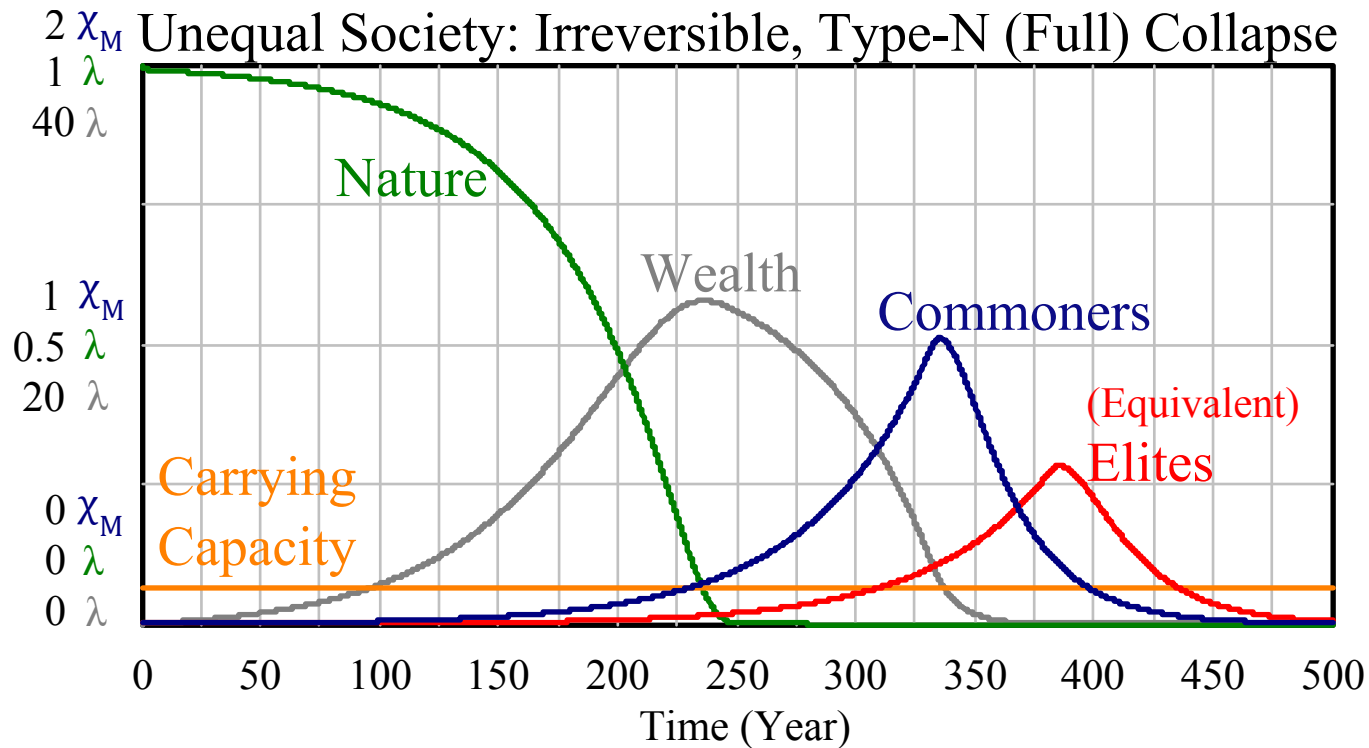


$$\dot{x}_C = -\alpha_C x_C + \beta_C x_C$$

$$\dot{x}_E = -\alpha_E x_E + \beta_E x_E$$

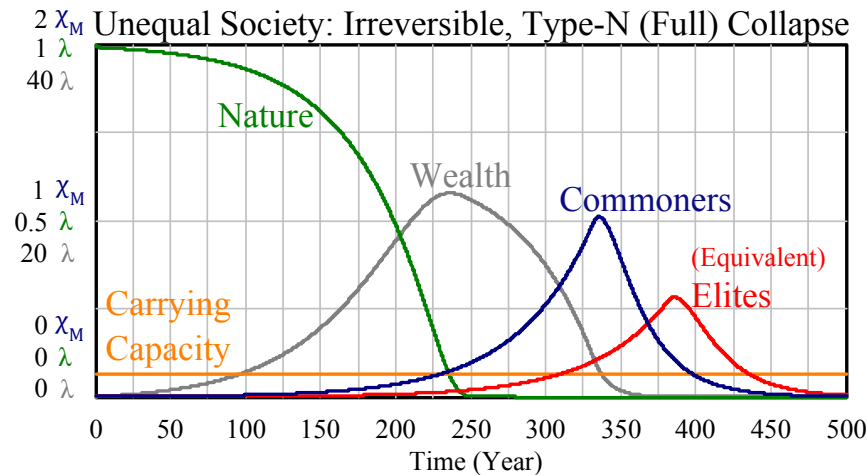
The **rich Elite** accumulates wealth from the work of everyone else (here referred to as the **Commoners**). When there is a crisis (e.g., famine) the elite can spend the accumulated wealth to buy food.

# Human and Nature Dynamical model (HANDY) with Rich and Poor: a thought experiment





# Human and Nature Dynamical model (HANDY) with Rich and Poor: a thought experiment

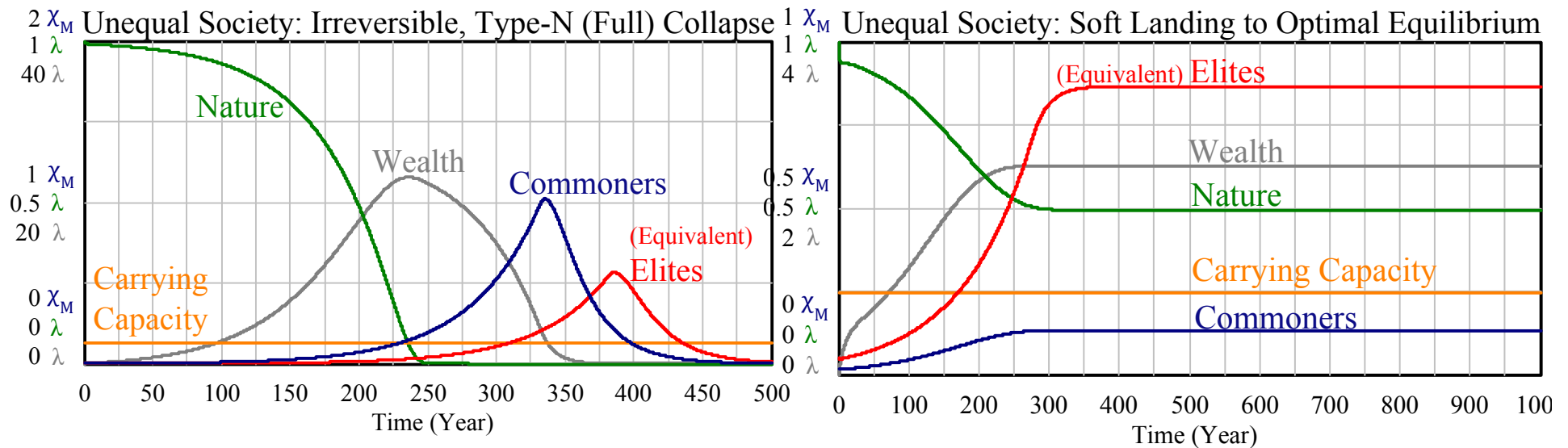


- Nature declines with population growth
- Using their wealth, the Rich can shield themselves from environmental degradation, which first affects the poor
- Eventually it reaches the upper classes as well, when it is too late to take preventive measures

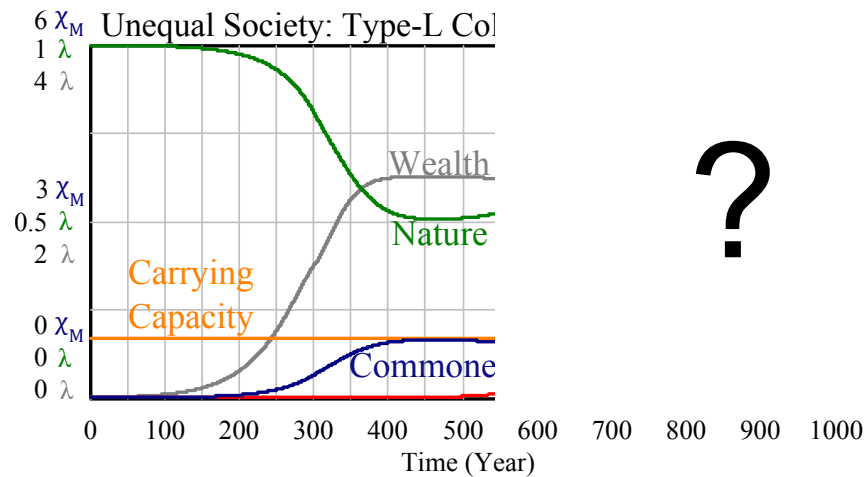
After 2-300 years, having surpassed the sustainable carrying capacity of the planet, the population is drawing down the accumulated capital to survive

This thought experiment shows how a crisis can happen rapidly, even though it appears that population is rising steadily without any problems, and that the wealthy would not feel the effects of the collapse until it is too late for the poor (and then it is too late for the rich as well!).

If we reduce the depletion per capita to its optimal value we can reach a steady state and survive well



Here we have a case with optimal depletion,  
and the Commoners have almost reached  
equilibrium

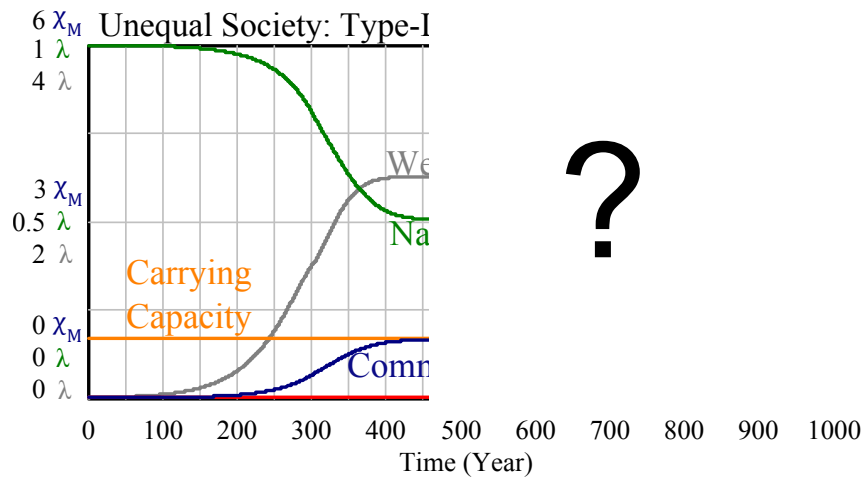


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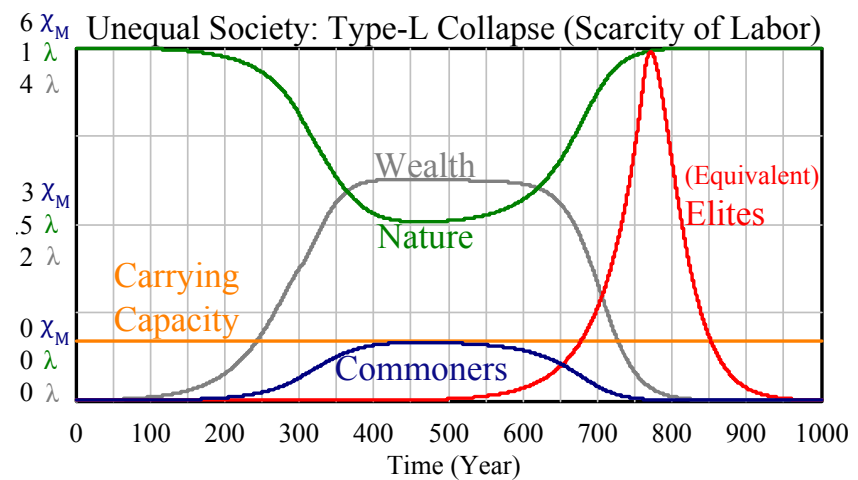
However, we  
introduced a very  
small seed of Elites:  
 $E(0)=0.01\%$

What will happen when the Elites grow?

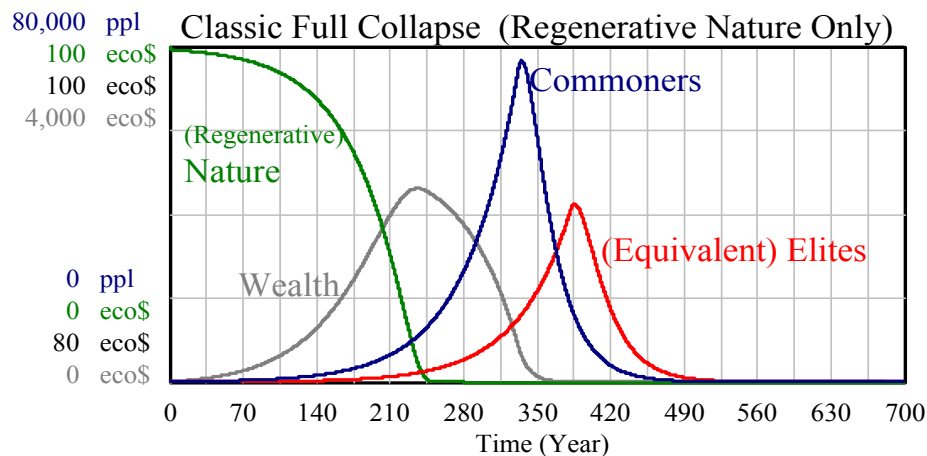
# After the Elites grow, they consume the wealth, Commoners collapse first, and the Elites collapse due to scarcity of Labor



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# Now we consider the impact of adding fossil fuels, i.e. nonrenewable energy to Nature

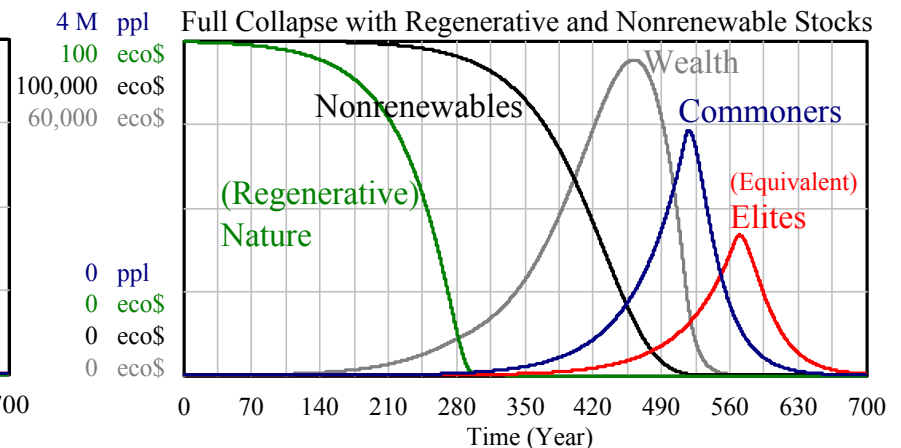
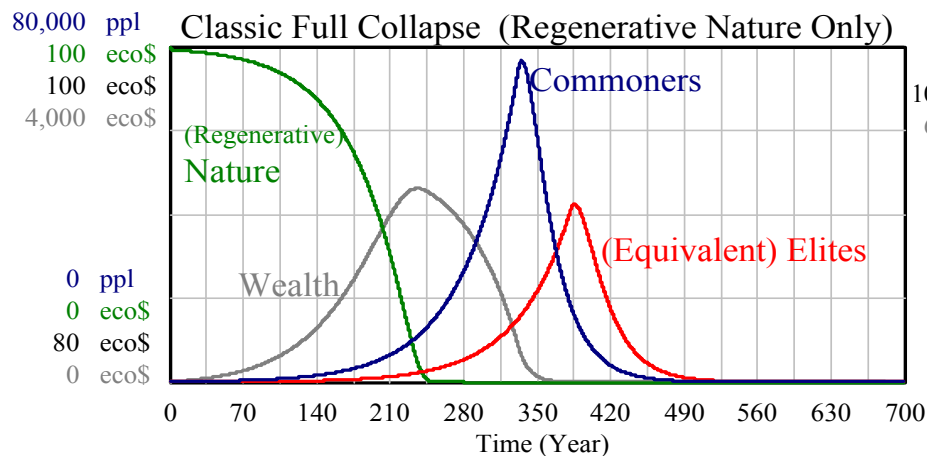


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This is the classic HANDY1 full collapse scenario, **with only regenerating Nature**

We then add to the **regenerating Nature** a **nonrenewable Nature**

# Impact of adding fossil fuels (nonrenewable) energy to Nature



This is the classic HANDY full collapse scenario, with only regenerating Nature

We then add to the regenerating Nature a nonrenewable Nature

**The collapse is postponed by ~200 years and the population increased by a factor of ~25!**



# Highlights of the HANDY paper

- HANDY is a 4-variable *thought-experiment* model for interaction of humans and nature with outcomes that agree with historical records of societal collapse
- The focus is on predicting long-term behavior rather than short-term forecasting
- The population includes Commoners who produce, and Elites who manage
- Carrying Capacity is developed as a practical measure for forecasting collapses
- HANDY models different types of societies, from Egalitarian to highly Unequal
- A sustainable steady state is shown to be possible in different types of societies
- But over-exploitation of **either** Labor or Nature results in a societal collapse

# SUMMARY

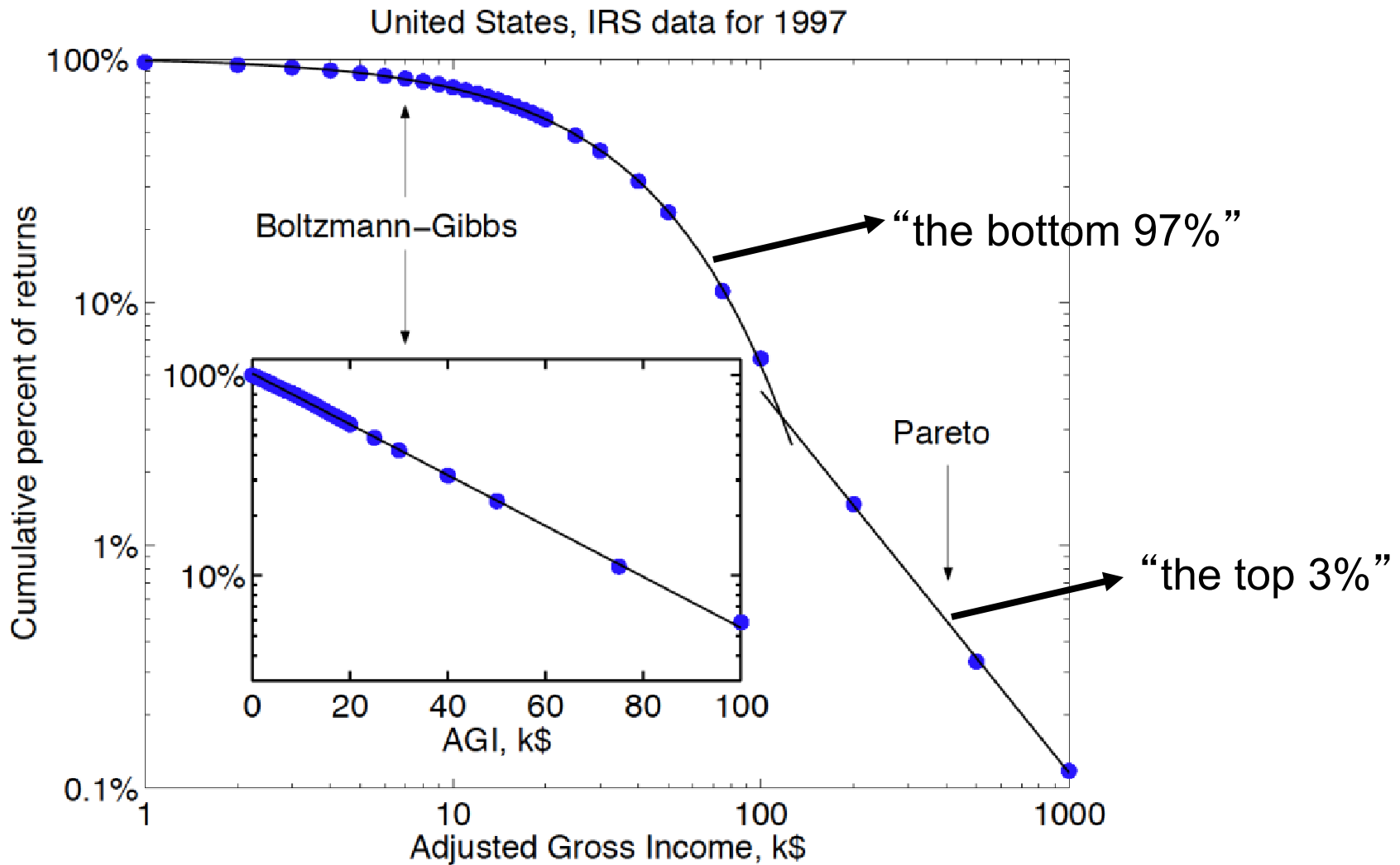
- The Human System is a **dominant** component of the Earth System.
- We need to couple Population and the Earth System with two-way feedbacks in order to model climate change (not currently done, Population comes from UN Tables).
- Two-way feedbacks and policies are essential in order to estimate long-term responses of the Earth System.
- HANDY is a “thought experiment” model of Nature/ Human interaction. HANDY can model different types of societies, from Egalitarian to highly Unequal.
- A sustainable steady state is shown to be possible in different types of societies. It requires lower level of inequality and sustainable depletion per capita.
- But over-exploitation of **either** Labor or Nature leads to societal collapse.

(extra slides)

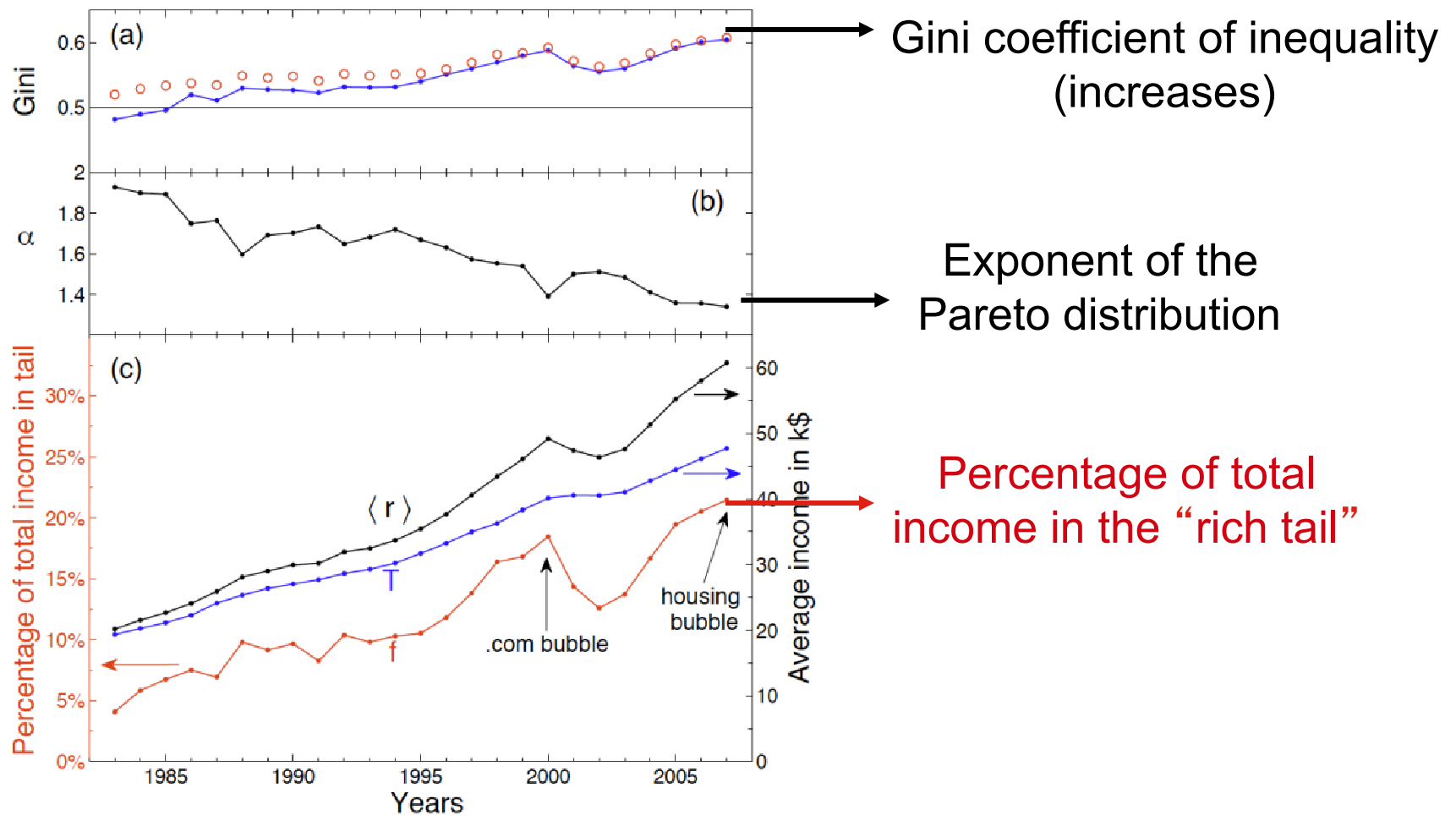
# Analogy between atomic distribution of energy and the distribution of income (Yakovenko et al., 2000, ...)

- Atoms in a gas are identical, but the probability distribution  $P(E)$  of their energies  $E$  is highly unequal, with few atoms having high energies and many atoms having low energies.
- In statistical physics,  $P(E)$  is given by the exponential Boltzmann-Gibbs distribution following from maximization of entropy in the ensemble of interacting atoms.
- Yakovenko applied a similar probabilistic approach to ensembles of interacting economic agents (i.e., people), with remarkable agreement with IRS data

Yakovenko (2000) applied a similar probabilistic approach to ensembles of interacting economic agents and obtained probability distributions that are in remarkable agreement with the empirical data



An analysis between 1983 and 2008 of IRS data shows that the inequality increased and all the growth went to the top 3%



# Population and climate: a study at the London School of Economics

Per dollar spent,  
**family planning** reduces **four times** as much carbon over the next 40 years as adopting **low-carbon technologies**

Concluded: Family planning is cost effective and should be **a primary method to reduce emissions**

Copenhagen: **no discussion** on population or family planning: it is a **taboo subject**

**New UN projection is higher**

