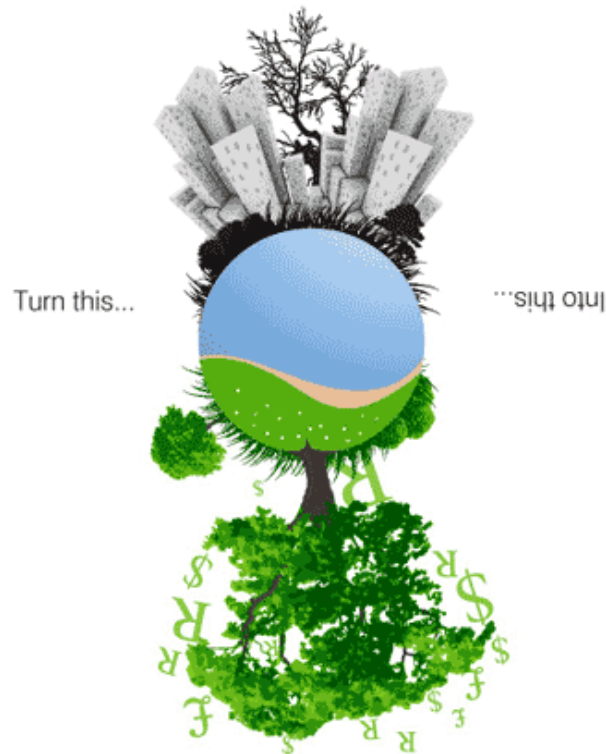


# Are We Richer Greener?



**Jesse Ausubel & Smriti Rao**

**Thanks to Paul Waggoner**

**Program for the Human Environment, The Rockefeller University**

**Dec 2, 2008**

# ImPACT Identity: A formal way of examining sustainability

P (population)



X

A (affluence as  
GDP/population)



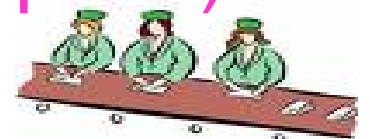
Im (impact) = X

C (consumption/GDP)



X

T (technology as  
impact/consumption)



Falling C = *Dematerialization*

Falling T = *Efficiency*

# The Sustainability Plane

Environment

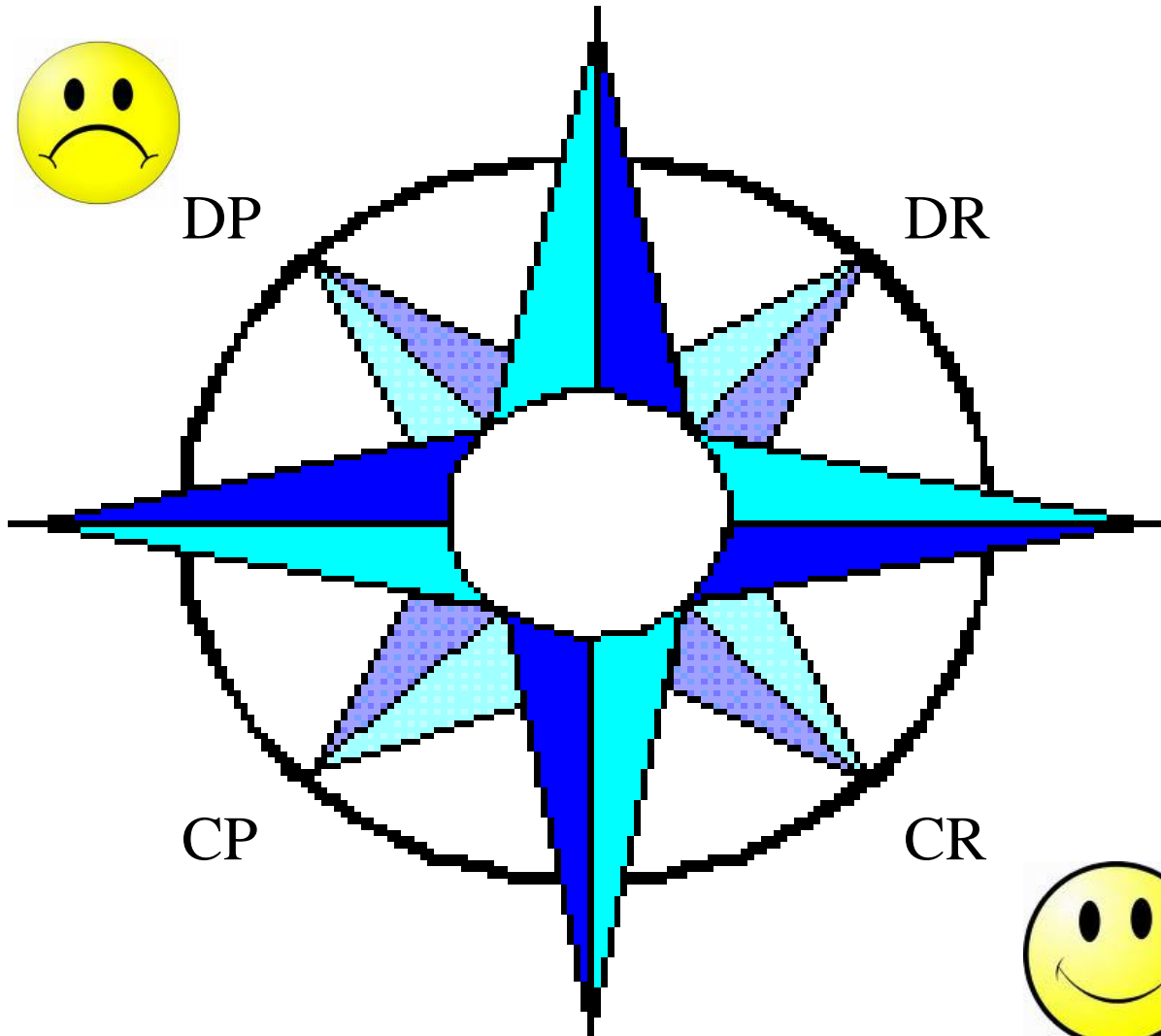
Dirty



DP

DR

Poor



Rich

CP

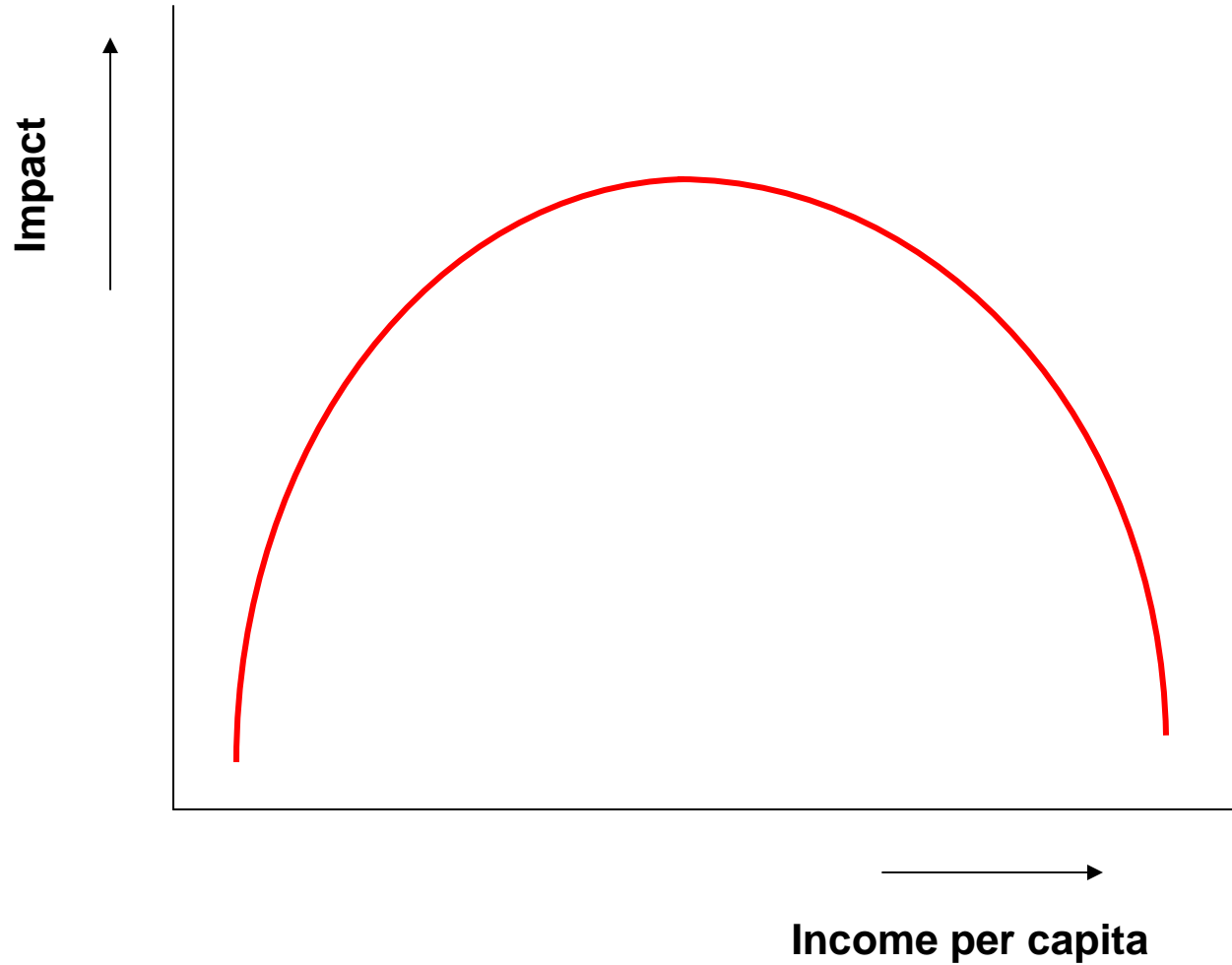
CR

Clean

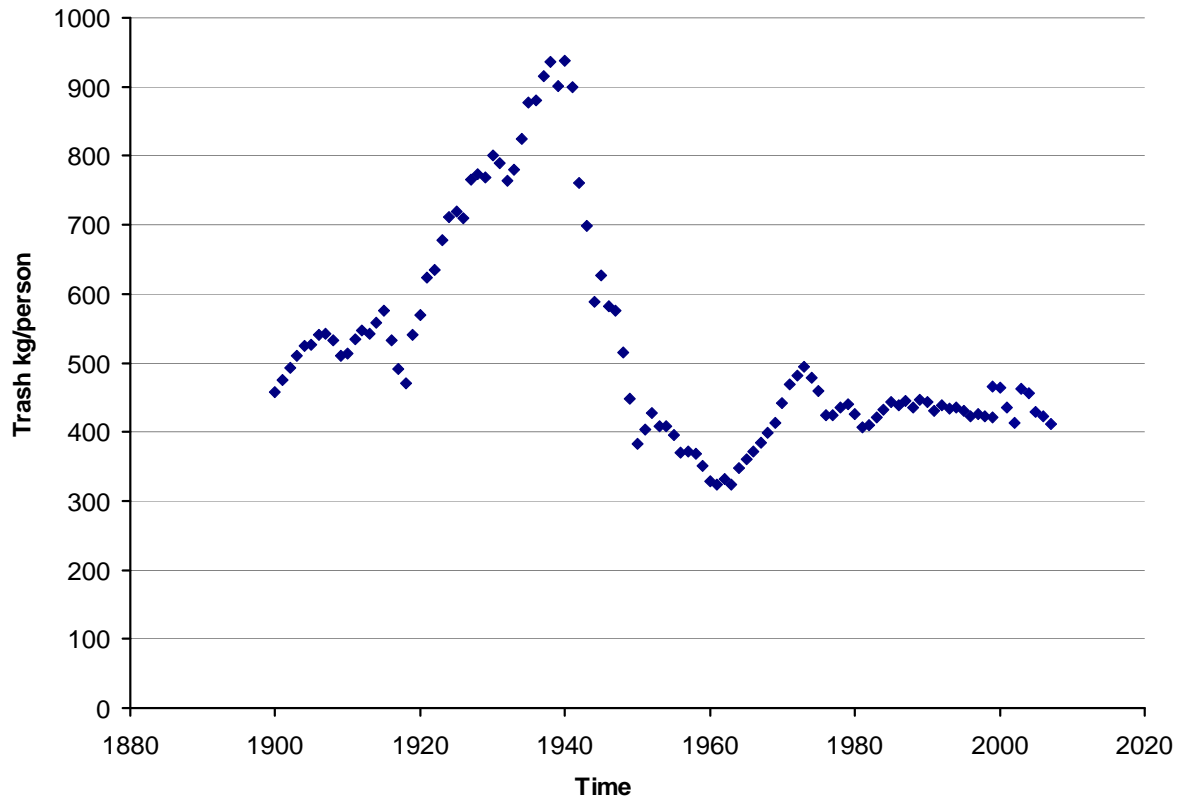


Income (or development)

# Environmental Kuznets Curve

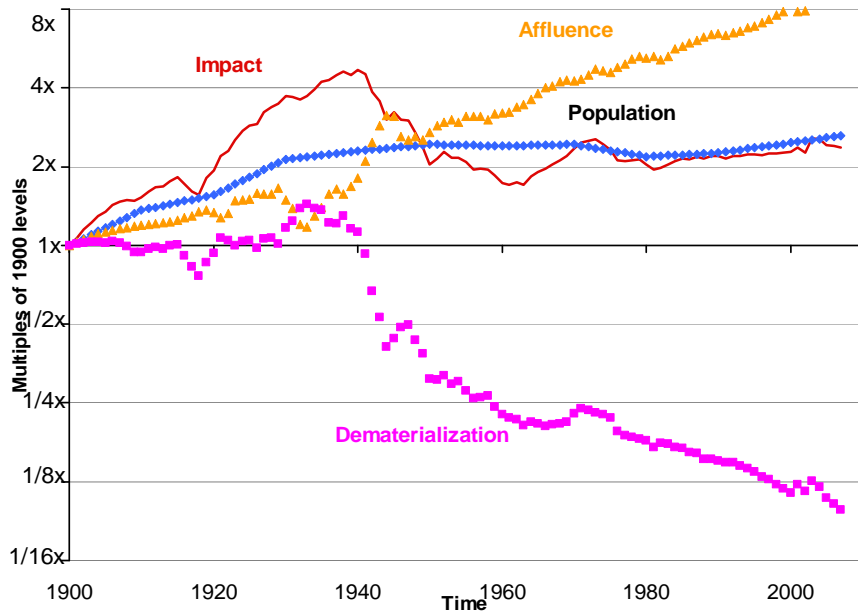


# Impact as NYC trash per person



Source: Walsh, 2002 (1900-1998)  
N.Y. Department of Sanitation (1999-2007)

# NYC trash on the Sustainability Plane

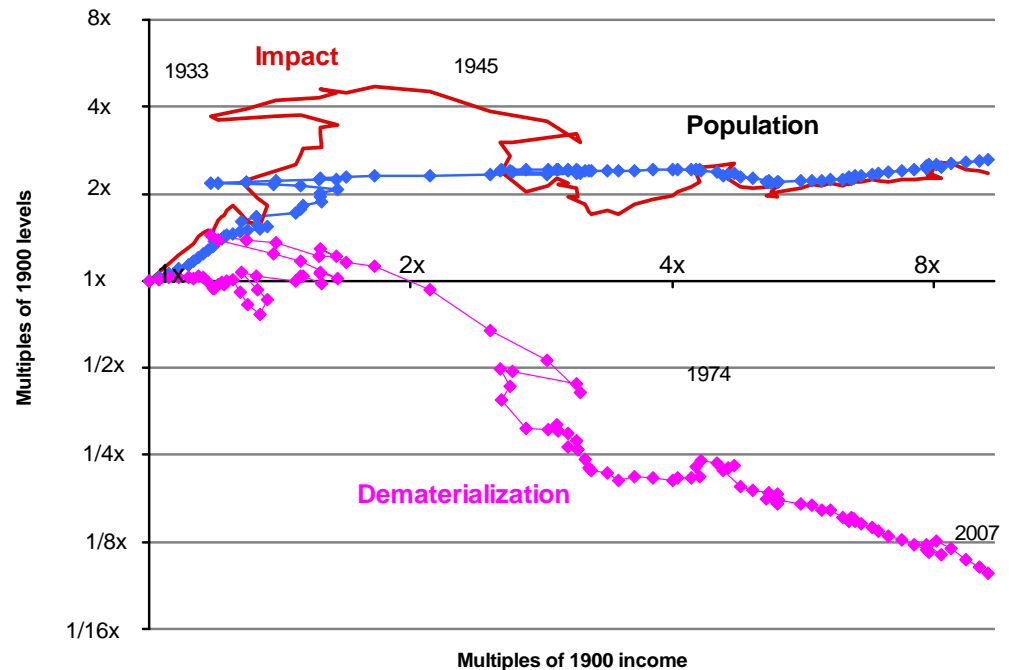


← Trends with *time* of Impact & 3 Levers

Dematerialization defined as  $C \times T$   
(better behavior & technology)

Impact can also be calculated as the sum of annual rates of change of P, A, C, T

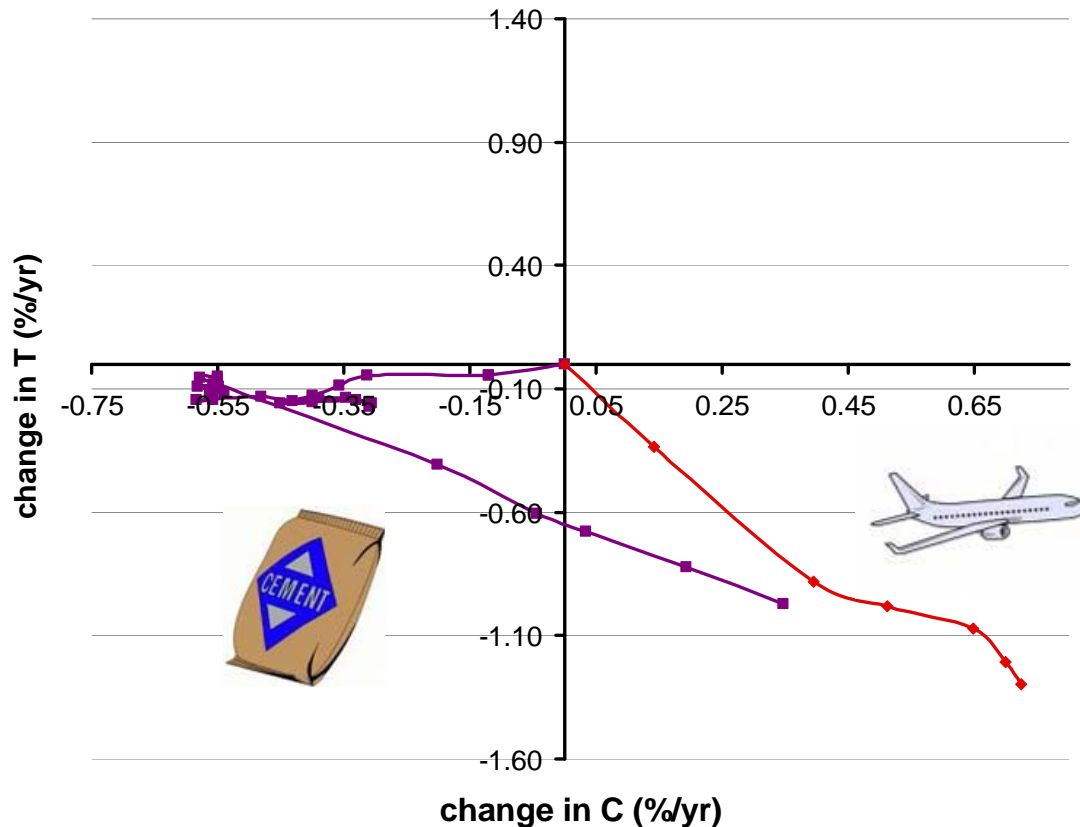
→ Trends with *income* of Impact & 3 Levers



Source: Ausubel & Waggoner, 2003

# Do environmentally better behavior (C) and better technology (T) move in synch?

## Plotting changes in behavior vs changes in technology



### US Air Travel

Data from 1970-2006

Source: <http://www.census.gov>  
<http://www.airlines.org>

### US Cement Use

Data from 1964 to 2006

Source: U.S Geological Survey  
<http://www.usgs.gov/>



# Behavior (C) vs Technology: recent CO<sub>2</sub> emissions and lumber – consumers mattering more

## US Carbon emissions (as CO<sub>2</sub>)

Data from 1980 to 2000

Source: Energy Information Administration (EIA)

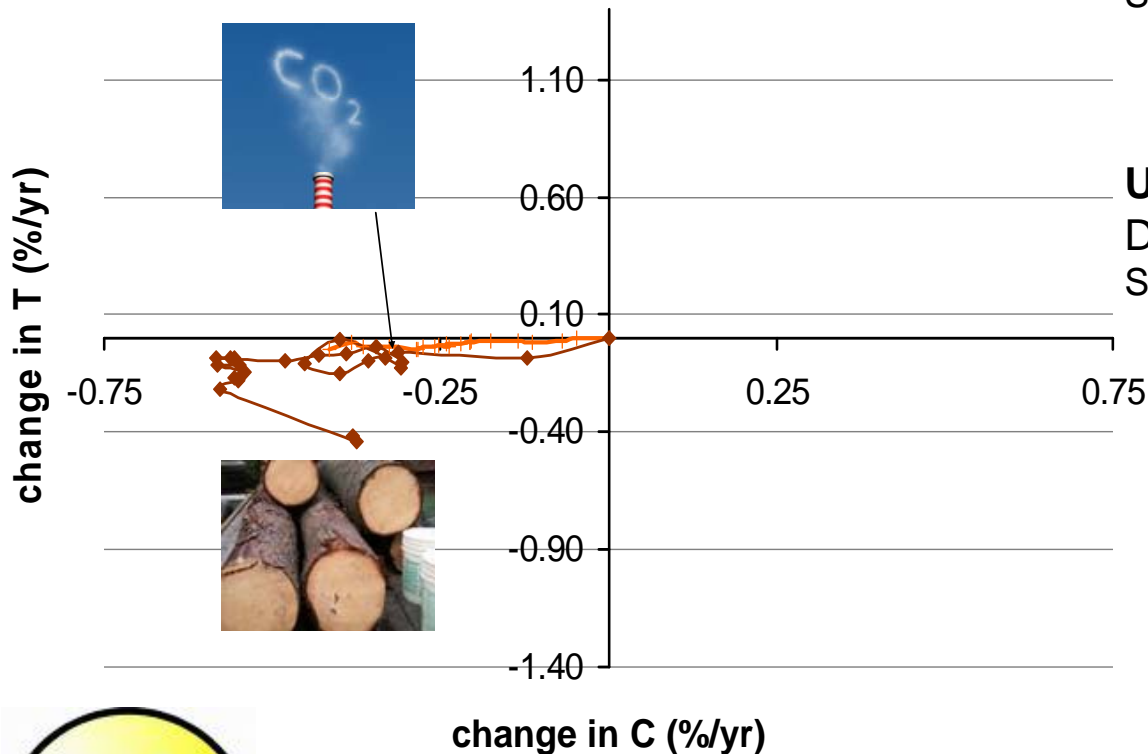
<http://www.eia.doe.gov/>

## US Lumber use

Data from 1965-2002

Source: US Department of Agriculture, Forest Service

<http://www.fs.fed.us/>





# Behavior (C) and technology (T) both aiming for sustainability: US land and water use

## Land under Cultivation

Data from 1965 to 2005

Source: FAO

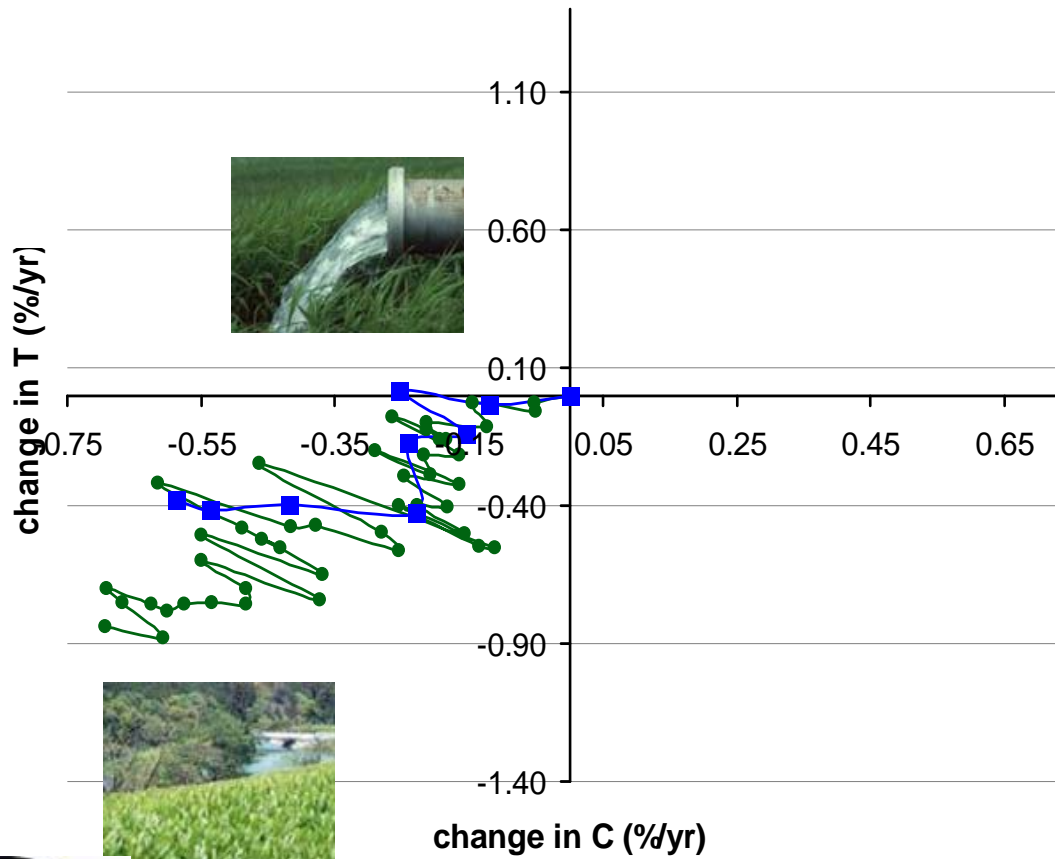
<http://faostat.fao.org>

## Water Used for Irrigation

Data from 1961 to 2000

Source: U.S Geological Survey

<http://www.usgs.gov/>



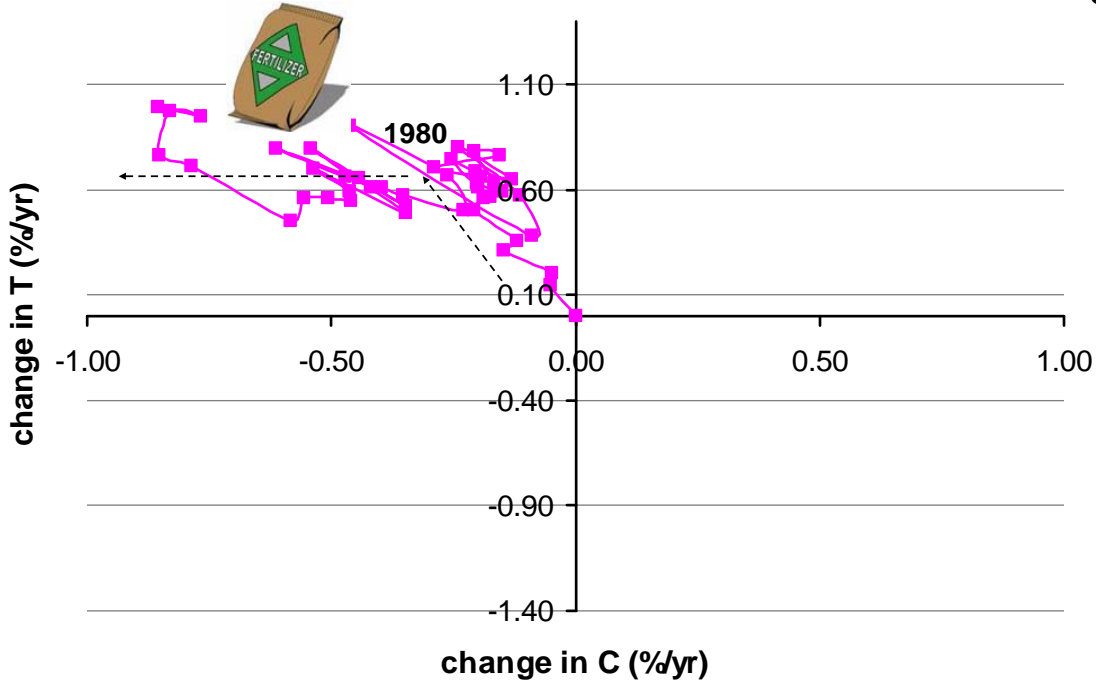
# Behavior & technology offsetting, maybe rounding Kuznets curve: US fertilizer use

## Nitrogenous Fertilizers

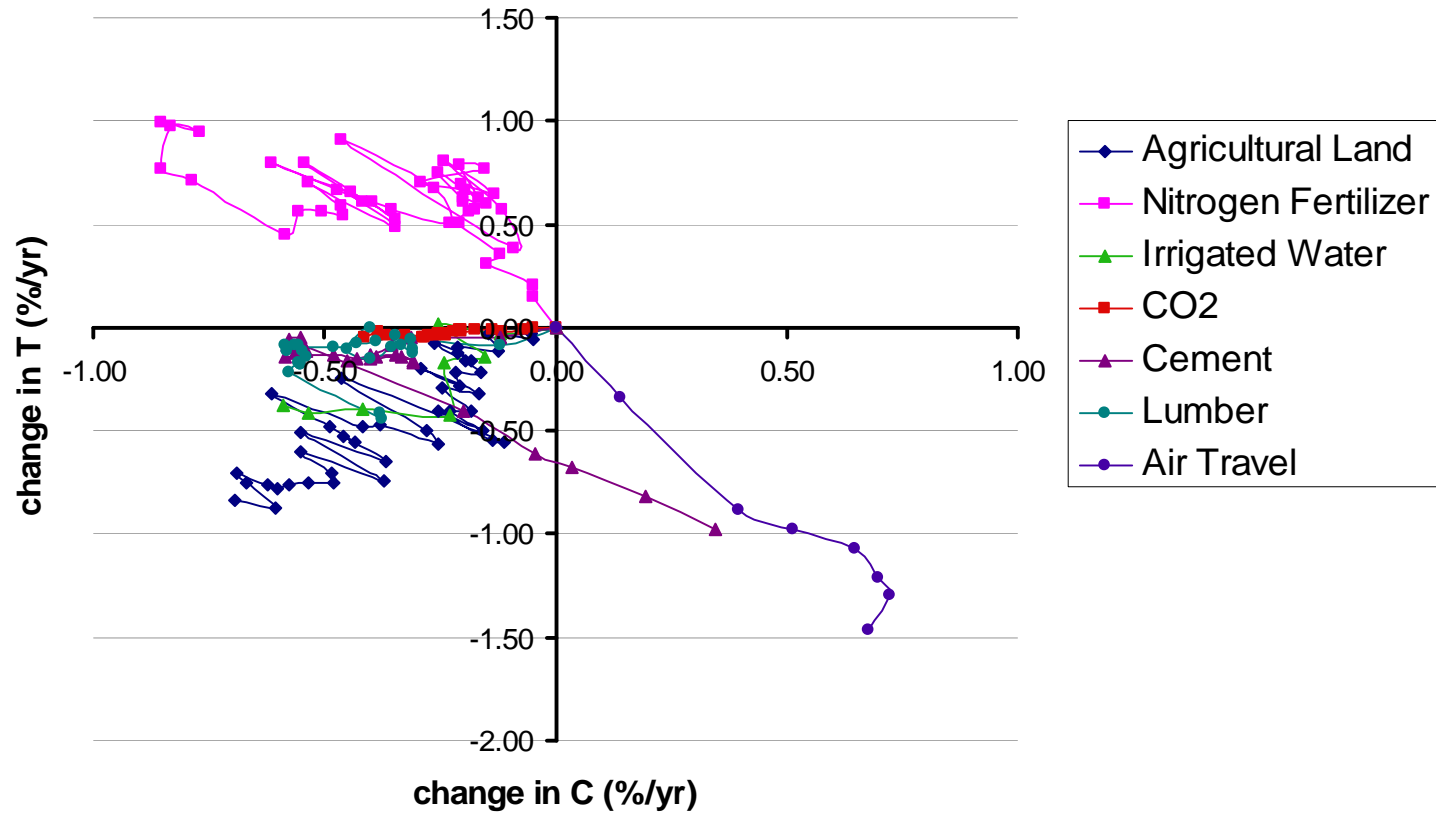
Data from 1961 to 2006

Source: FAO

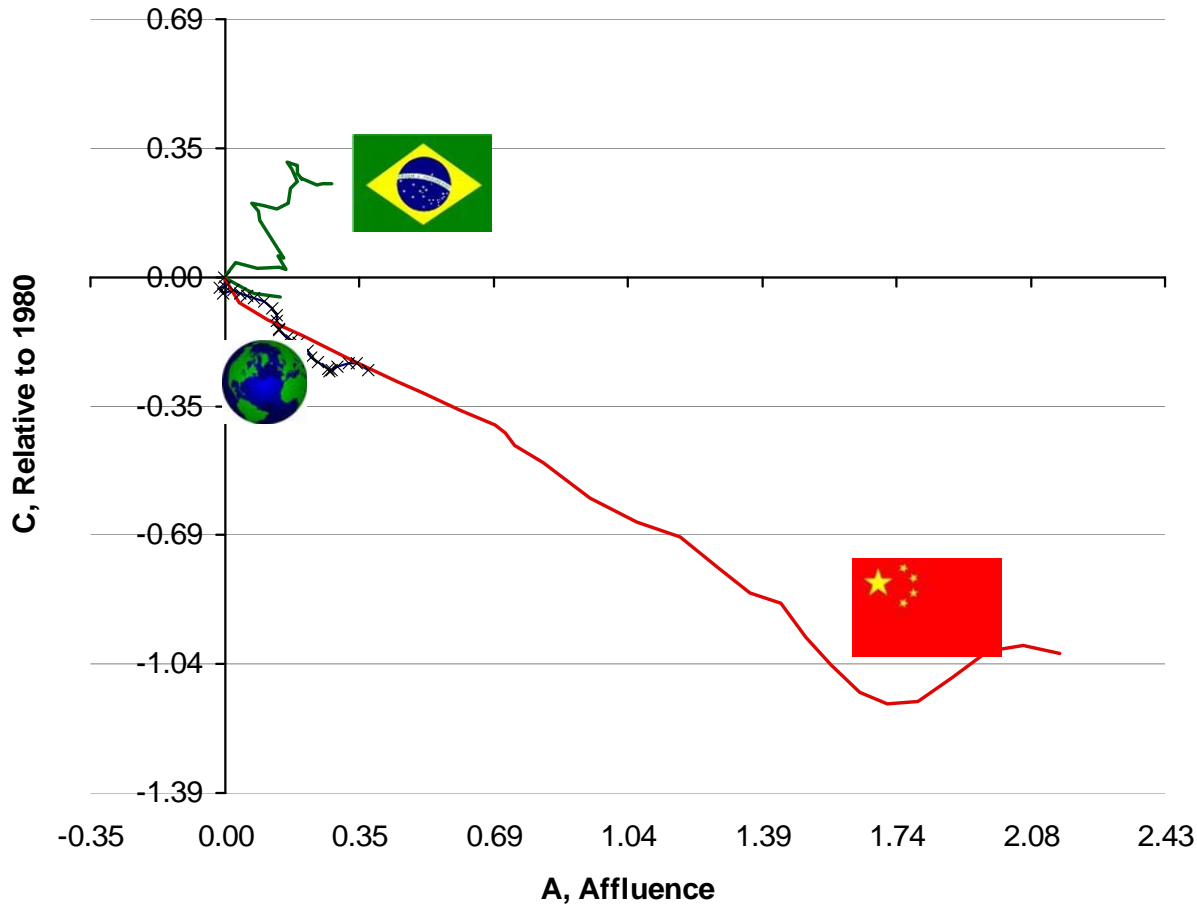
<http://faostat.fao.org>



# Variety: As Americans grew richer, 7 diverse paths of behavior & technology



# Dematerialization on the Sustainability Plane: Energy for Brazil, China, and Earth



Data from 1980 to 2006  
Source: US Department of Energy (DOE)  
<http://www.energy.gov/>  
British Petroleum (BP)  
[www.bp.com](http://www.bp.com)



# Dematerialization of energy: World with and without China - roles of behavior (C) and technology (T)



Data from 1980 to 2004

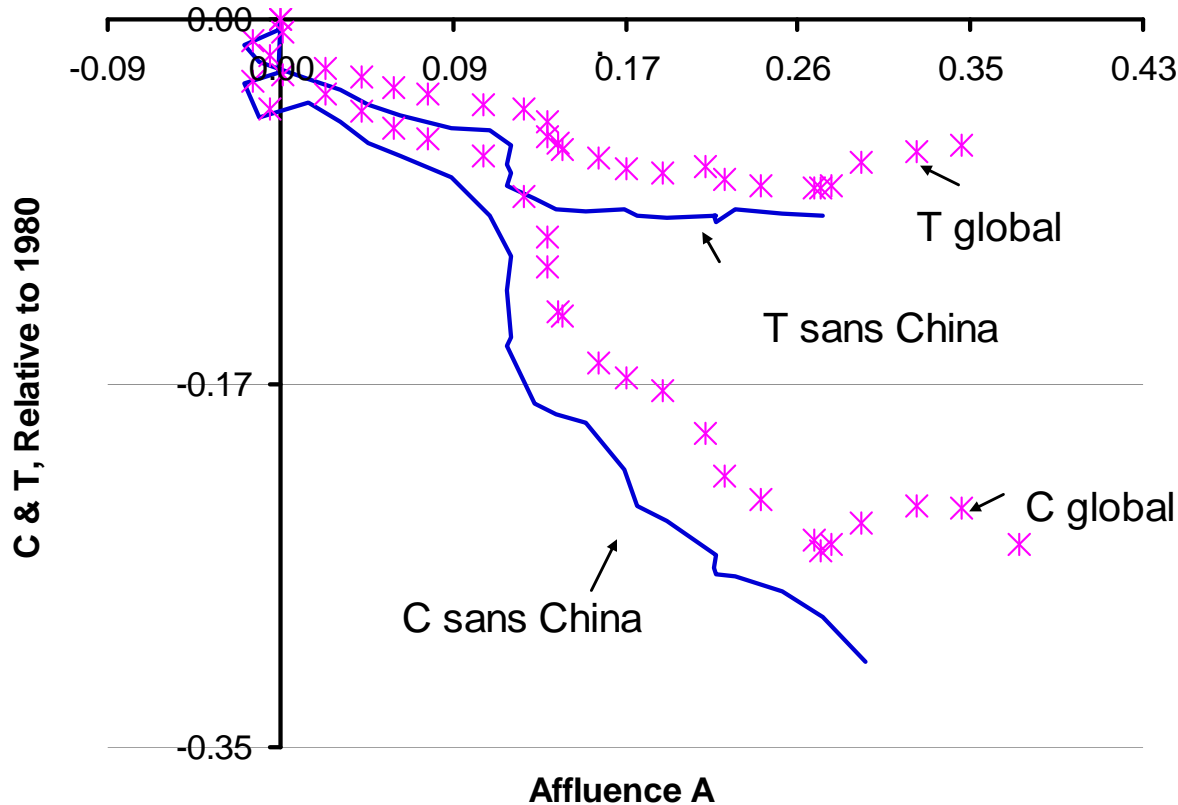
Source: US Department of Energy (DOE)

<http://www.energy.gov/>

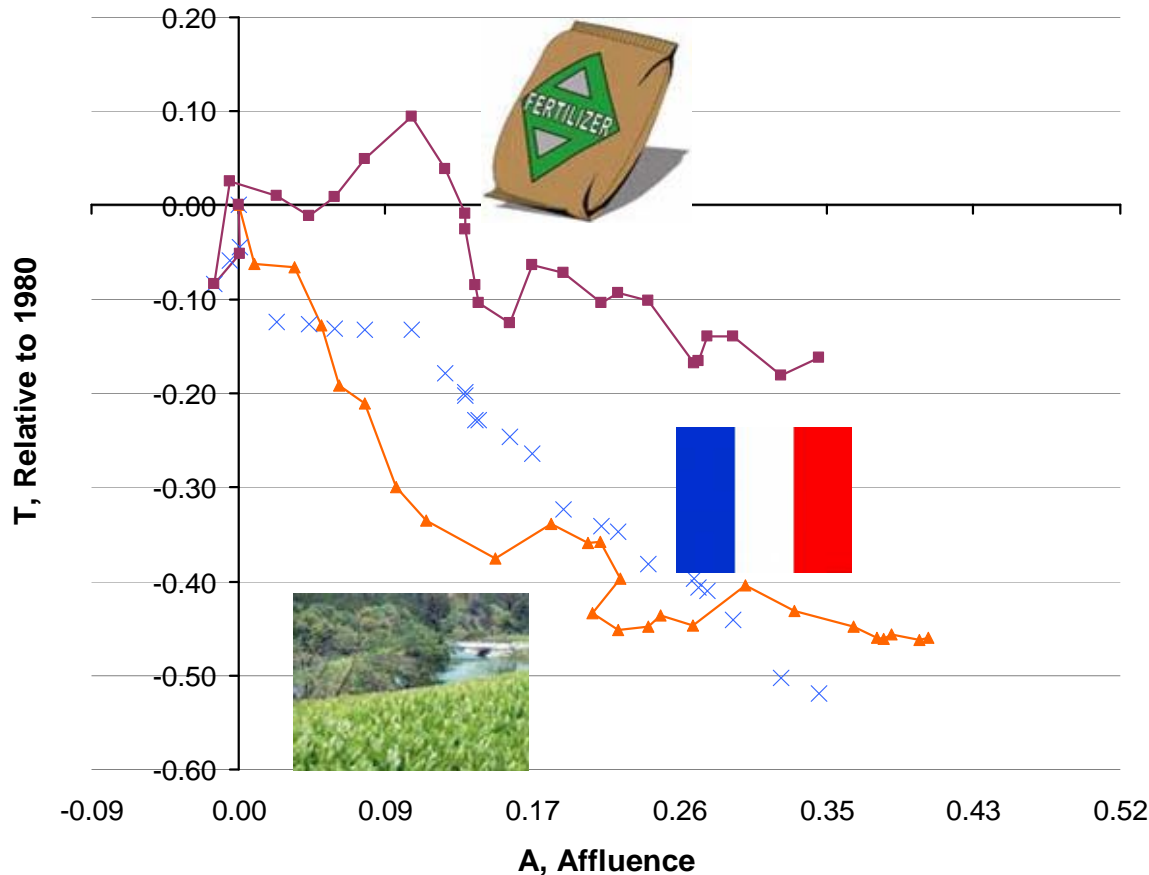
\*extended to 2006

British Petroleum (BP)

[www.bp.com](http://www.bp.com)



# Improvement of technology (T) with affluence: Global fertilizer & land, and French energy



## Fertilizer use per crop

Data from 1980 to 2005

Source: FAO

<http://faostat.fao.org>

## Agricultural land

(cropland per crop production index)

Data from 1980 to 2005

Source: FAO

<http://faostat.fao.org>

## French carbon per energy

Data from 1980 to 2006

Source: US Department of Energy (DOE)

<http://www.energy.gov/>

British Petroleum (BP)

[www.bp.com](http://www.bp.com)

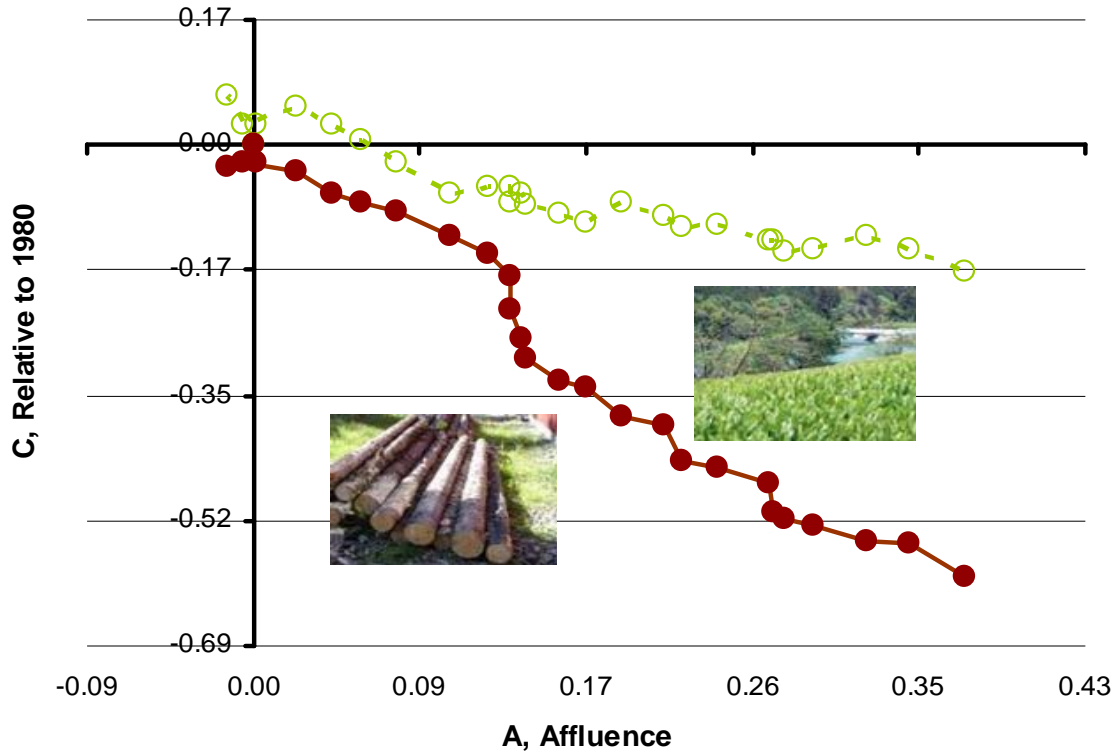


# With riches, persistent dematerialization (as reduced consumption/GDP) of global land & lumber

Data from 1965 to 2005

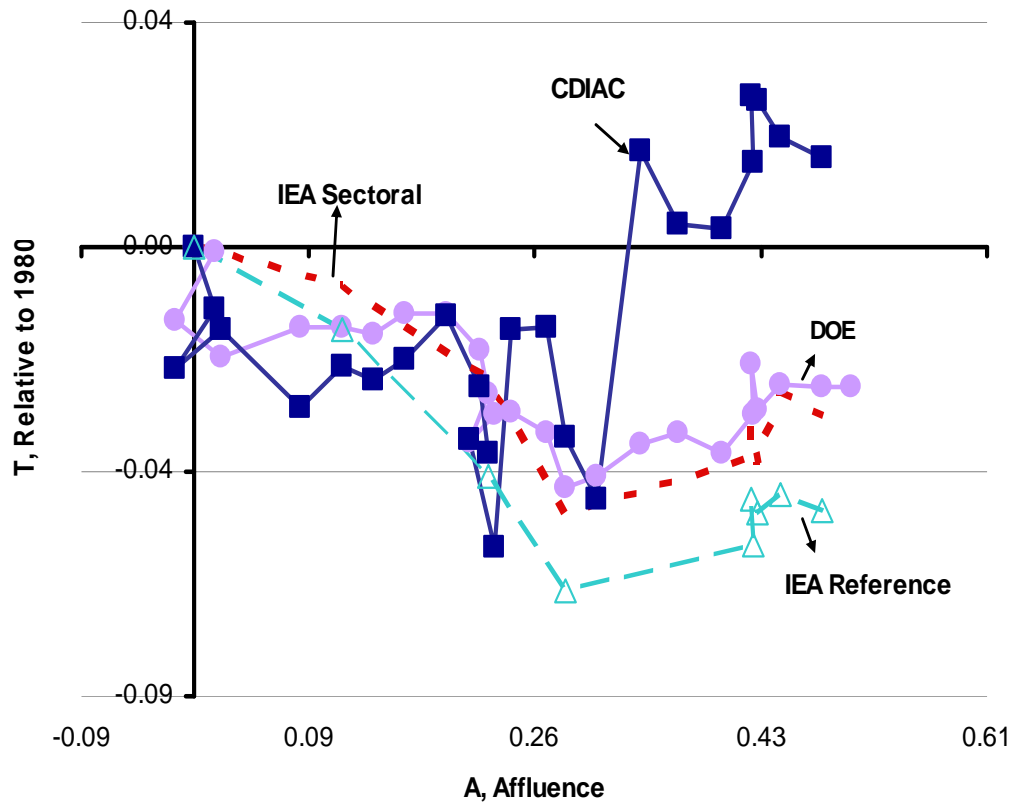
Source: FAO

<http://faostat.fao.org>



# Caution: reports differ!

## USA carbon emissions per energy (T)



Data from 1980 to 2004  
\* to 2005 (DOE)



Source: Carbon Dioxide Information Analysis Center (CDIAC)  
<http://cdiac.ornl.gov/>

International Energy Agency (IEA)  
<http://www.iea.org/>

\*Reference Reports \*Sectoral Reports

US Department of Energy (DOE)  
<http://www.energy.gov/>





# Caution: methods differ!

## Indian dematerialization (C) and carbon emissions/energy (T) with biomass or not

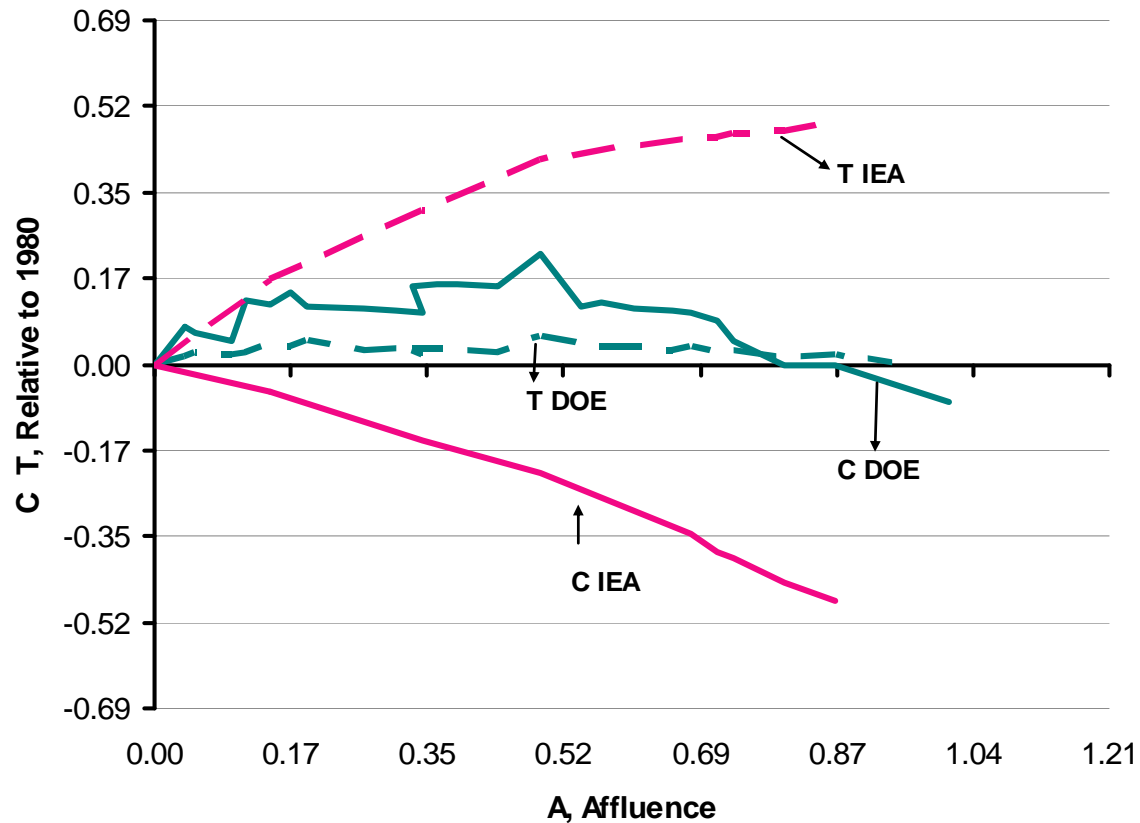
Data from 1980 to 2006

Source: International Energy Agency (IEA)

<http://www.iea.org/>

US Department of Energy (DOE)

<http://www.energy.gov/>





# Caution per brief changes: China energy

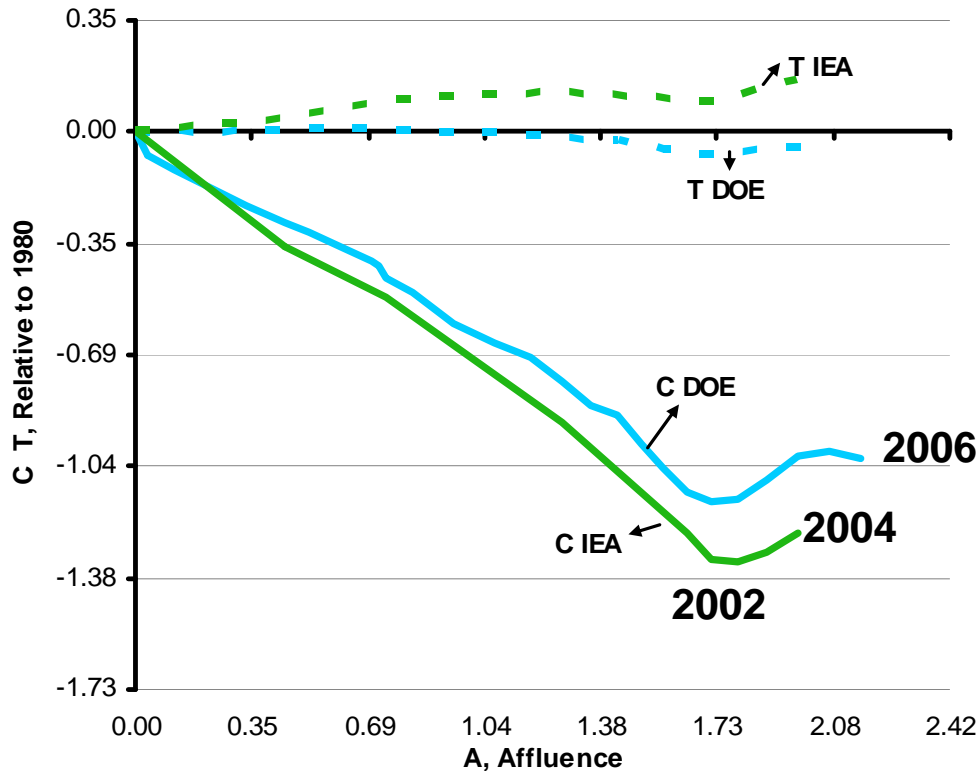
Data from 1980 to 2006

Source: International Energy Agency (IEA)

<http://www.iea.org/>

US Department of Energy (DOE)

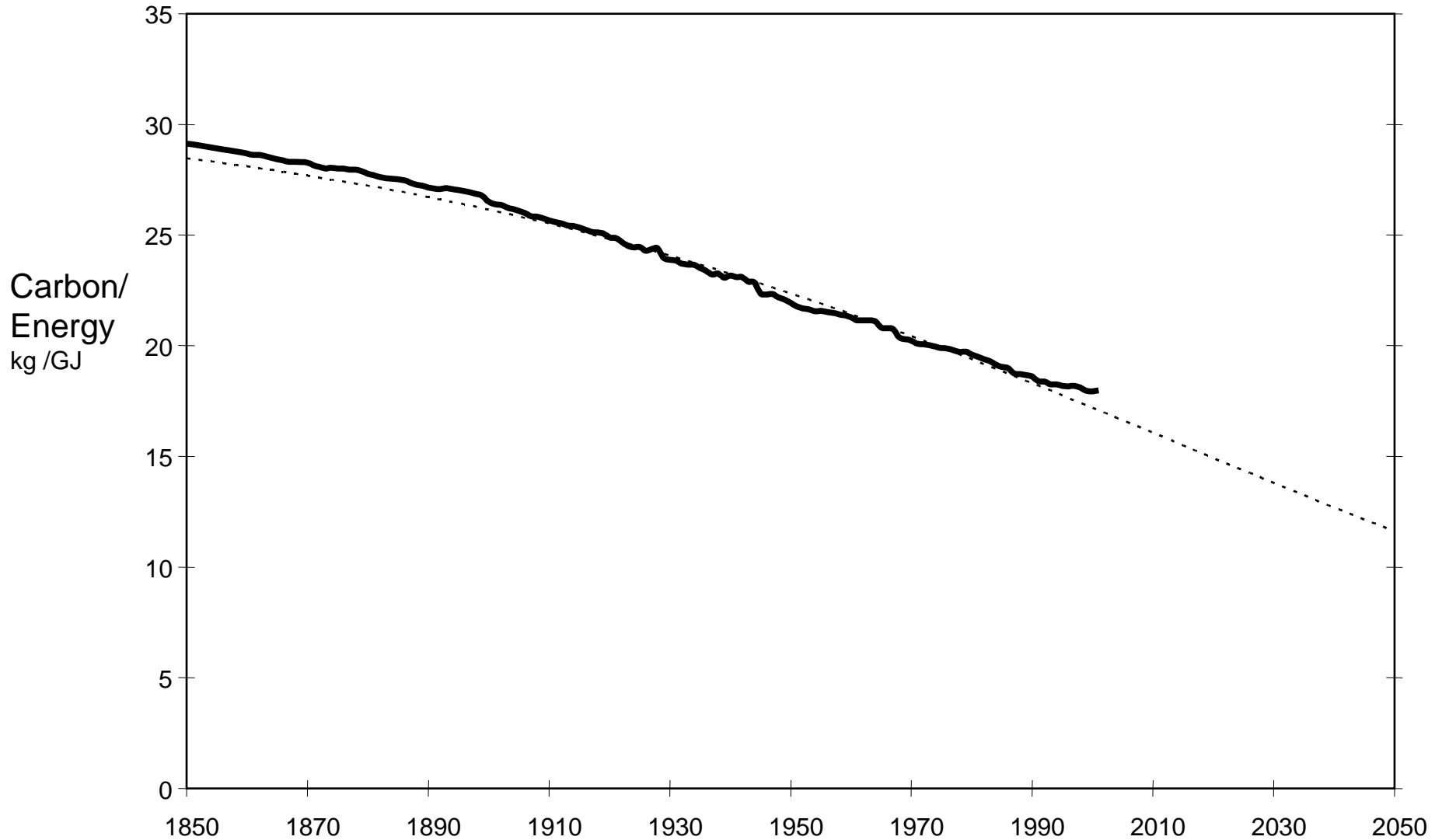
<http://www.energy.gov/>



**After 2-year hiatus, dematerialization resumed**

# Since 1850: Decarbonization (T) of Global Primary Energy

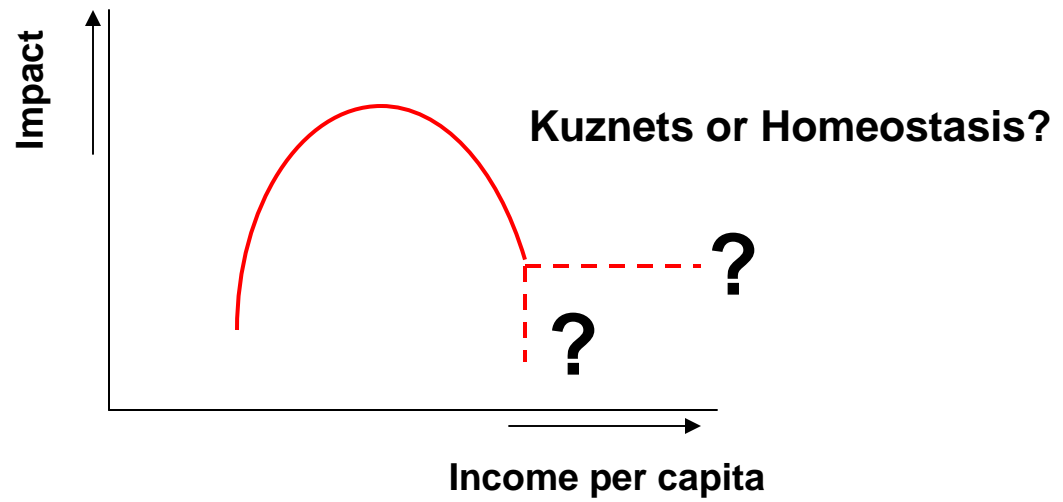
Viewed as Declining Carbon Intensity of All Primary Energy



Data sources: IIASA, BP (1965-2001), CDIAC [http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm)

# In the end

- Sustainability can be examined and monitored with simple, quantitative formalisms
- Graphing behavior C vs. efficiency T shows diverse patterns; neither consumers nor producers need wait to mitigate impacts
- Graphing C & T shows relative leverage of consumers and producers
- Riches (Affluence) often evoke improvements in Consumer behavior and Technology (efficiency) that offset impacts. As luxuries become staples, consumer behavior commonly dematerializes.
- The System seems to find levels that it tolerates, as NYC trash per capita, and rates at which it persists for long periods through changes in politics
- So, Richer does tend to be Greener but perhaps not green enough, depending on long-term consequences
- **Kuznets** (Very rich will be very green) **or Risk Homeostasis** (When we wear seatbelts, we drive less safely, so the accident rate changes less than intended)? An open question!



**Thank You**

<http://phe.rockefeller.edu>

