Crossing Disciplinary Boundaries to Understand Human Drivers of Environmental Threats*

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IF I HAD A HAMMER!

“GIVE A LITTLE BOY A HAMMER, AND HE WILL FIND THAT EVERYTHING HE ENCOUNTERS NEEDS POUNDING.”

THE LAW OF INSTRUMENT, *ABRAHAM KAPLAN* (1964:28)*

QUESTION: IF EVERYTHING IS TACKS, DOES ONE EVER THINK OF A HAMMER?

***A VERSION IS ALSO ATTRIBUTED TO MARK TWAIN: “TO A MAN WITH A HAMMER EVERYTHING LOOKS LIKE A NAIL.”**

OBSERVATION:

THE HUMAN DIMENSIONS OF GLOBAL ENVIRONMENTAL CHANGE RESEARCH HAS EMPHASIZED THE TACKS (IMPACTS OF HUMAN DRIVERS) RATHER THAN THE HAMMER ITSELF (DRIVERS —ANTHROPOGENIC SOURCES—OF IMPACTS):

- **LAND USE, LAND COVER CHANGE**
- **ECOLOGICAL RISK: VULNERABILITY, RESILIENCY, ADAPTATION**
- **INSTITUTIONAL ISSUES: (1) COMMON POOL/PROPERTY PRACTICES**
  (2) ACTIONS TO ADDRESS IMPACTS

Human Footprints on the Global Environment

Threats to Sustainability

edited by Eugene A. Rosa, Andreas Diekmann, Thomas Dietz, and Carlo C. Jaeger

MIT Press, 2010

Definition: Global Environmental Change

1. **CUMULATIVE EFFECTS** - EFFECTS THAT ARE LOCAL IN DOMAIN BUT SO WIDELY REP-LICATED THAT IN SUM THEY HAVE GLOBAL CONSEQUENCES.

   EXAMPLES: TROPICAL DEFORESTATION, DESERTIFICATION, SPECIES LOSS, DAMAGED LOCAL ECOSYSTEMS, AND RESOURCE EXHAUTION.

2. **SYSTEMIC EFFECTS** - EFFECTS THAT OCCUR ON LARGE SPATIAL SCALES OR ALTER THE FUNCTION OF LARGE SYSTEMS

CHANS - COUPLED HUMAN AND NATURAL* SYSTEMS

THESE ARE INTEGRATED SYSTEMS IN WHICH PEOPLE INTERACT WITH NATURAL COMPONENTS

A. THEIR COMPLEXITY IS NOT WELL UNDERSTOOD

B. DUE TO TRADITIONAL SEPARATION OF SOCIAL AND ECOLOGICAL SCIENCES

C. MUCH GREATER UNDERSTANDING OF H->N THAN N->H

*OR ENVIRONMENTAL SYSTEMS

REFERENCES:

LIU, JIANGUO (JACK) ET AL.. 2007. "COMPLEXITY OF COUPLED HUMAN AND NATURAL SYSTEMS." *SCIENCE* 317: 1513-1516.

LIU, JIANGUO (JACK) ET AL.. 2007. "COUPLED HUMAN AND NATURAL SYSTEMS." *AMBIO* 36: 639-649.

THE HAMMER: STIRPAT RESEARCH PROGRAM:

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EUGENE A. ROSA – WASHINGTON STATE UNIVERSITY

RICHARD YORK – UNIVERSITY OF OREGON

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ECOLOGICAL FIRST PRINCIPLES:

NATURE PROVIDES ECOLOGICAL CAPITAL AND SERVICES.

FACTORS IMPACTING THEM ARE:

FOR ALL SPECIES: ***(1) NUMBER OF MEMBERS**
(2) GEOGRAPHIC SPACE
***(3) RATE RESOURCES ARE CONSUMED**

FOR HIGHER ORDER SPECIES (HUMANS) ***(4) TECHNOLOGY**
(5) AMOUNT OF WASTE

***WHAT NORMAN MYERS CALLS THE "REDOUBTABLE TRIAD"**

I = PAT

Accounting Version

Impacts **(I)**

Population **(P)**

Affluence **(A) or C**onsumption

Technology **(T)**

Typical Application:

Basic Identity: $I = PAT$

Form: $T = I/(P*A)$ SOLVE FOR T

Data: Typically % Changes

Example (Commoner 1992)

From 1950 to 1967, following changes:

Synethic Pesticide Use	Population	Production/ Affluence	Technology
+266%	+30%	+5%	?

$T = 3.66/(1.3 \times 1.05) = 2.68$

$T = 2.68 - 1.00\ (100) = 168\%$ increase

STIRPAT (statistical form)

Stochastic Estimation of (accounting form)

Impacts by **I**

Regression on

Population **P**

Affluence **A**

Technology **T**

Plus the need to account for noise or error

THE COMPASS

IPAT: ACCOUNTING VERSION (OR IDENTITY)

IMPACTS TO THE ENVIRONMENT = f(P, A, T)

THE GPS

STIRPAT: STOCHASTIC VERSION (ACCOUNTING FOR ERROR)

IMPACTS TO THE ENVIRONMENT = f(P, A, T) + ε

STIRPAT ESTIMATION FORMULA:

(a) LOG I = LOG a + b Log P + c Log A + log e

OR

(b) LOG I = a + b Log P + c Log A + e

Where a = LOG a
e = LOG e

STIRPAT RESEARCH PROGRAM (NATION STATES)

STRESSORS EXAMINED (PUBLISHED):

- CO^2 (CARBON DIOXIDE)
- CH^4 (METHANE)
- NO_X (NITROGEN OXIDES)
- SO^2 (SULFUR DIOXIDE)
- ODS (OZONE DEPLETING SUBSTANCES)
- ECOLOGICAL FOOTPRINT (FT) - (TOTAL)
- ECOLOGICAL FOOTPRINT (FT) - (PARTS)

ADDITIONAL STRESSORS EXAMINED (NOT YET PUBLISHED):

- CARBON MONOXIDE
- NON-METHANE VOLATILE ORGANIC COMPOUNDS

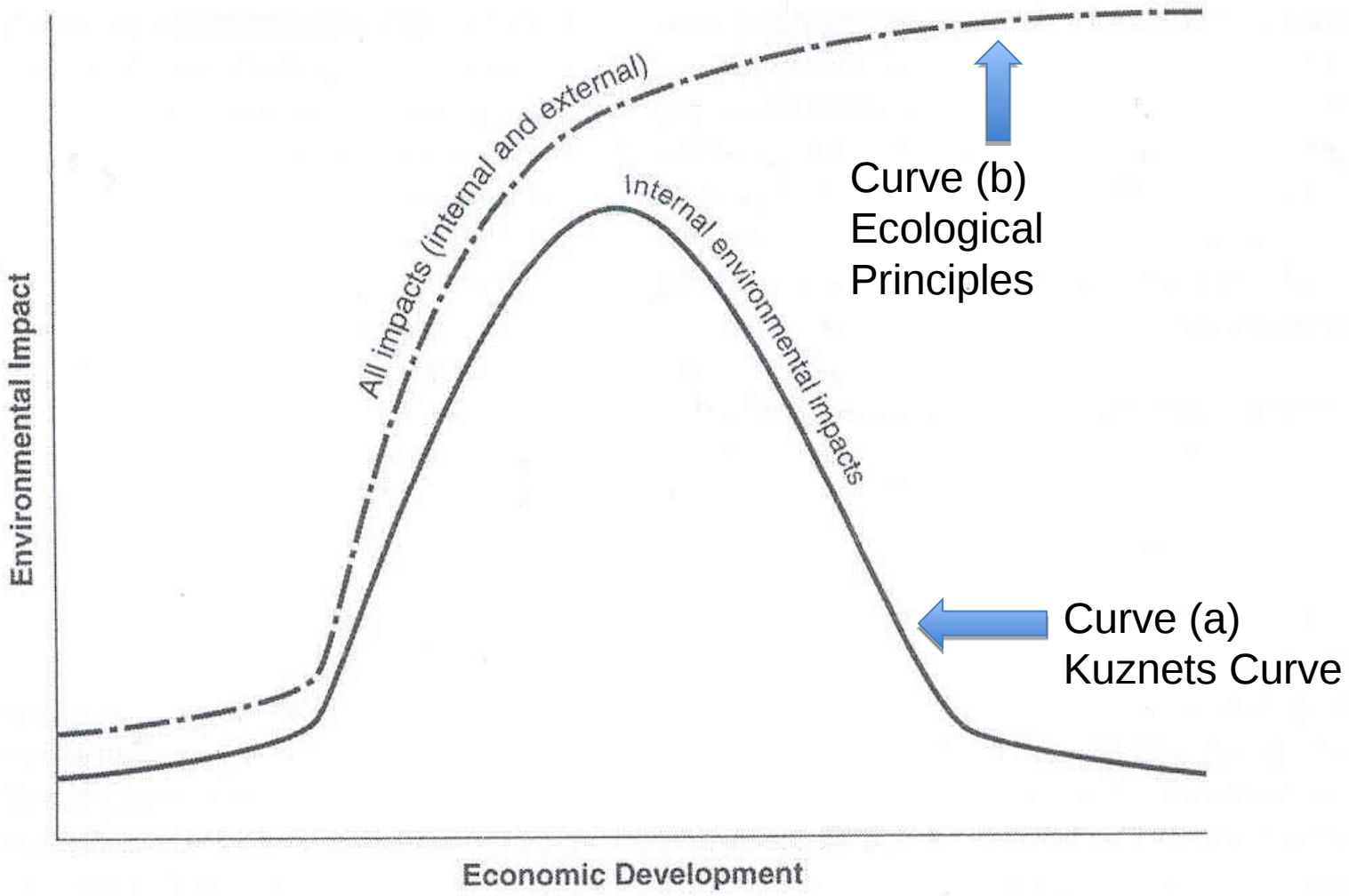


Figure 1. The Theoretical Effect of Economic Development on Environmental Impact

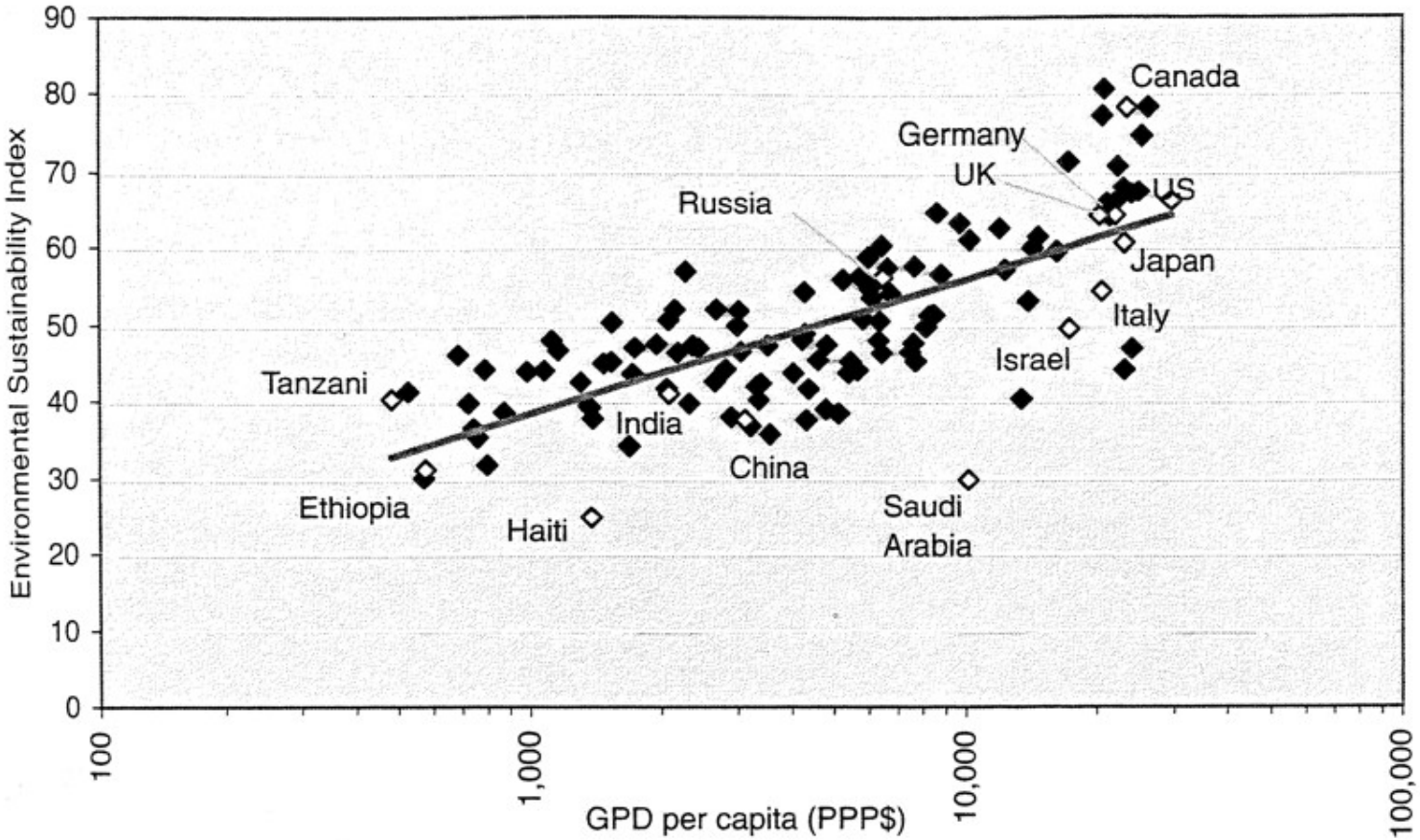


Figure 9 The connection for 117 nations between GDP per capita (current 1998 PPP$) and the 2001 Environmental Sustainability Index, measuring 22 environmental dimensions on 67 variables.[254] A best-fit line is displayed and various nations have been marked out. Source: WEF 2001a&b, World Bank 2000c.

ECOLOGICAL FOOTPRINT:

ΒΑΣΙΧ ΙΔΕΑ: ΤΗΕ ΧΥΜΥΛΑΤΙςΕ ΕΝςΙΡΟ ΝΜΕΝΤΑΛ ΙΜΠΑΧΤ ΧΑΝ ΒΕ ΧΟΝΣΙΔΕΡΕΔ Α ΦΥΝΧΤΙΟΝ ΟΦ ΧΟΝΣΥΜΠΤΙΟΝ ΛΕς ΕΛΣ

Α ΧΟΝςΕΡΣΙΟΝ ΟΦ ΧΟΝΣΥΜΠΤΙΟΝ ΙΝΤΟ Α ΒΙΟΠΗΨΣΙΧΑΛ ΜΕΤΡΙΧ (ΠΡΟΔΥΧΤΙςΕ ΛΑΝΔ ΑΡΕΑ)

ΑΝ ΟΠΕΡΑΤΙΟΝΑΛ ΜΕΑΣΥΡΕ ΟΦ ΠΛΑΝΕΤΑΡΨ ΛΟΑΔ (ΔΕΦΙΝΕΔ ΑΣ ΠΟΠΥΛΑΤΙΟΝ ΞΧΟΝΣΥ ΜΠΤΙΟΝ ΠΧ)

ΑΔΔΙΝΓ ΤΕΧΗΝΟΛΟΓΨ ΤΟ ΤΗΕ ΔΕΦΙΝΙΤΙΟΝ ΟΦ ΠΛΑΝΕΤΑΡΨ ΛΟΑΔ ΡΕΣΥΛΤΣ ΙΝ ΤΗΕ Ι=ΠΑΤ

THE ECOLOGICAL FOOTPRINT (EF):

THE ECOLOGICAL FOOTPRINT (EF) IN ANY GIVEN YEAR IS THE AMOUNT OF

BIOLOGICALLY PRODUCTIVE LAND (NATURE'S CAPITAL) NEEDED TO REGENERATE

HUMAN CONSUMPTION, LIVING SPACE, AND TO ABSORB WASTES.

IMPORTANT CAVEAT:

THE EF MEASURES STRESS, PRESSURE OR LOADS ON NATURAL CAPITAL AND SERVICES,

ECOLOGICAL FOOTPRINT (EF): ELEMENTS OF CONUMPTION*

FIVE COMPONENTS

1. FOOD
2. HOUSING
3. TRANSPORTATION
4. CONSUMER GOODS
5. SERVICES

INCLUDING AN ACCOUNTING FOR WASTES

ECOLOGICAL FOOTPRINT (EF):BIOPHYSICAL UNITS

SIX COMPONENTS:

1. **ARABLE LAND (GROWING CROPS)**
2. **PASTURE LAND (ANIMAL GRAZING)**
3. **FORESTED LAND (TIMBER PRODUCTS)**
4. **SEA SPACE (PRODUCTIVE FISHING GROUNDS)**
5. **BUILT-UP LAND (INFRASTRUCTURE FOR HOUSING, TRANSPORTATION, INDUSTRY, HYDROELECTRIC POWER)**
6. **ENERGY OR CARBON LAND (TO SEQUESTER CO_2 EMISSIONS)**

AGGREGATE EF: THE SEPARATE MEASURES CAN BE SUMMED INTO AN OVERAL ECOLOGICAL FOOTPRINT

Table 1. STIRPAT RESEARCH PROGRAM: EMPIRICAL STUDIES

Publication Date	Publication Outlet	Dependent Variables	Number of Nations	Data Year	Kuznets Curve	Noteworthy Features
1997	PNAS[1]	CO_2 Emissions	111	1989	>$10K	GDP/PC<$5K for 75% of Nations
2003	International Journal of Sociology & social Policy	1. CO_2 2. CH_4 3. GWP*	1. 137 2. 137 3. 137	1. 1991 2. 1991 3. 1991	n.s. n.s. + Quadratic	
2003	American Sociological Review	Total Ecological Footprint (EF)	142	circa 1996	+ Quadratic	No support for neo–liberal modernization theories
2003	Ecological Economics	1. CO_2 Emissions 2. Energy Footprint	1. 146 2. 138	1. 1996 2. 1999	>$61K[1] + Quadratic	[1]Turning point is well beyond the range of observations
2004	AMBIO	1. ODS** 2. CO2 3. CH4 4. Total EF 5. Forest EF 6. Grazing EF 7. Arable EF 8. Fishing EF 9. Built-up EF	1. 131 2. 146 3. 147 4. 142 5. 142 6. 142 7. 142 8. 142 9. 142	1. 1997 2. 1996 3. 1991 4. 1996 5. 1996 6. 1996 7. 1996 8. 1996 9. 1996	>$13K[1] >$34.8[2] n.s. + Quadratic + Quadratic n.s. n.s. n.s. n.s.	[1]Beyond the range of a vast majority of nations [2]Beyond the range of observations
2004	JIE	EF/GDP/Md***	139	1998-9	N.A.	Sensitivity analyses reveal the need for extraordinary gain in efficiency to counter footprint effects
2005	Globalization & The Environment	1. SO_2 2. NO_x	1. 138 2. 138	1. 1995 2. 1995	>$14.4K[1] >$23.3K[2]	[1]85% of nations are below this [2]99% of nations are below this
2007	Frontiers in Ecology and the Environment[3]	Total Ecological Footprint (EF)	128-135	2001	+Quadratic	

[1]Proceedings of the National Academy of Sciences
[2]Journal of Industrial Ecology
* GWP = Global Warming Potential (A combination CO_2 and CH_4)
** ODS = Ozone Depleting Substances (Chlorofluorocarbons (CFCs), halons, other fully halogenated CFCs, carbon tetracholoride, methyl, chloroform, HCFCs, and methyl bromide)
*** Md = The median of the EF/GDP Ratio

GENERAL FINDINGS:

FOR EVERY IMPACT EXAMINED WE FIND:

- **SUPPORT FOR CONTINUED IMPACT THEORIES (CURVE b)**
- **REJECTION OF NEO-LIBERAL /MODERNIZATION THEORIES OR THE KUZNETS CURVE (CURVE a)**

SPECIFIC FINDINGS:

FOR EVERY IMPACT EXAMINED:

- **POPULATION IS ALWAYS A LEADING DRIVER OF IMPACTS**

  (1) **CONSISTENTLY A PROPORTIONAL RELATIONSHIP (UNIT ELASTICITY)**

- **AFFLUENCE IS ALWAYS ALSO A LEADING DRIVER**

  (1) **FOR CO_2 THE RELATIONSHIP IS ALWAYS ELASTIC (COEFICIENT ≈ 1.5)**

  (2) **FOR OTHER IMPACTS THE RELATIONSHIP IS INELASTIC (COEFICIENTS OF .26 TO .94)**

- **OTHER CONTRIBUTING FACTORS: (1) POPULATION COMPOSITION, (2) LATTITUDE, AND (3) URBANIZATION**

ELEVEN INDEPENDENT AND CONTROL VARIABLES: (* = SMALL, SIGNIFICANT EFFECTS)

(1) *NON-DEPENDENT POPULATION (% OF POPULATION BETWEEN 15 A 65)

(2) LAND AREA PER CAPITA

(3) *LATTITUDE (CLIMATIC ZONES)

(4) % OF GDP IN NON-SERVICE SECTORS

(5) WHETHER SOCIETY IS CAPITALIST (VS. MIXED CAPITALIST OR CAPITALIST-STATIST)

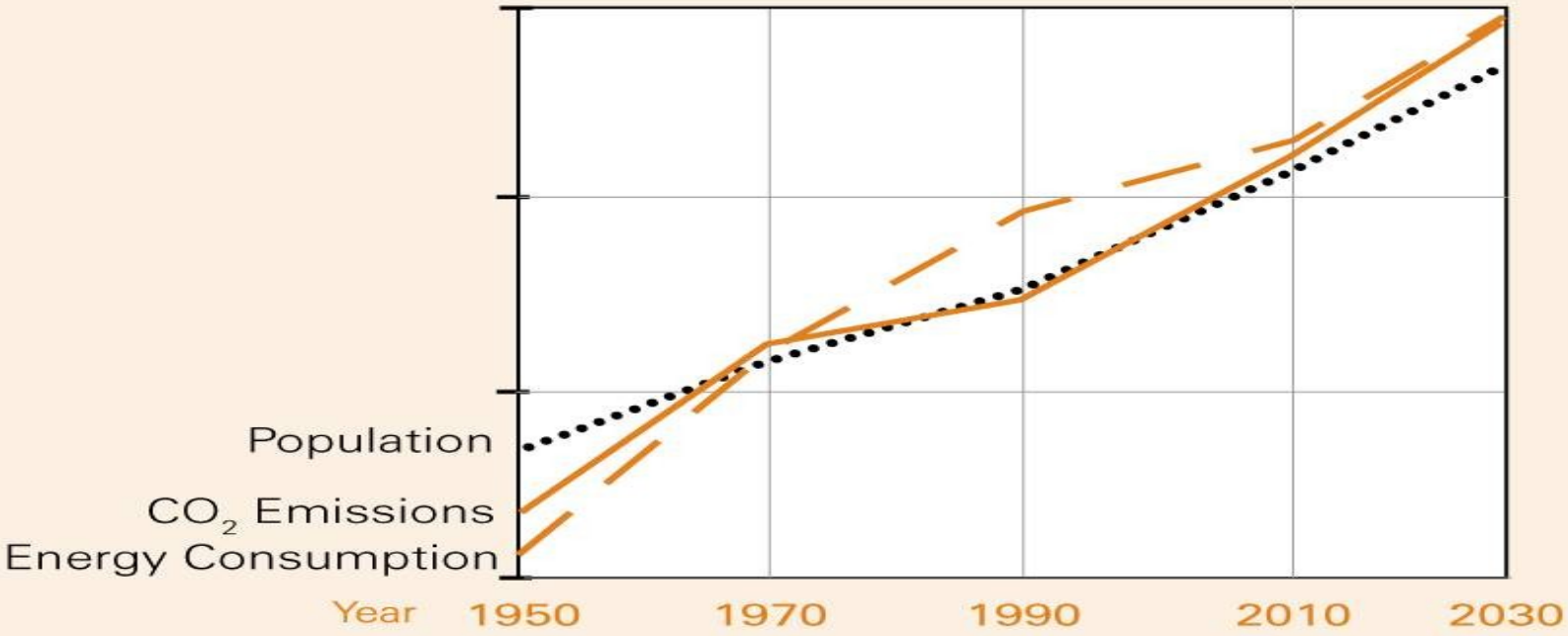
(6) *% URBAN POPULATION

(7) COUNTRY'S POSITION IN WORLD SYSTEM (CORE, SEMI-PERIPHERY, PERIPHERY)

(8) DIRECT FOREIGN INVESTMENT

(9) POLITICAL RIGHTS (FAIR AND OPEN ELECTIONS)

U.S. Population, CO_2 Emissions, & Energy Consumption Per Capita



Projections based on mid-range data estimates.
CO_2 emissions in metric tons, and energy consumption in Btus, per person.

Source: Center for Environment and Population (CEP), www.cepnet.org, based on information from US Census Bureau, US EIA, WRI, 2008

FOR ALL THESE STUDIES THE TECHNOLOGY FACTOR IS CONTAINED IN THE ERROR TERM OF THE STOCHASTIC EQUATION:

- **THE ERROR TERM COMPRISES NOT ONLY TECHNOLOGY BUT ALL OTHER VARIABLES (e.g. CULTURAL PRACTICES) NOT EXPLICITLY SPECIFIED IN THE EQUATION.**

- **THIS EXAGGERATES THE ESTIMATED EFFECTS OF TECHNOLOGY.**

WE HAVE ADDRESSED THIS ISSUE IN OUR WORK IN PROCESS:

- **INDEX OF TRANSPORTATION INFRASTRUCTURE (KILOMETERS OF PAVED ROADS, KILOMETERS OF RAIL LINES, AND ANNUAL AIR PASSANGERS PER CAPITA)**

- **INDEX OF COMMUNICATION INFRASTRUCTURE (NUMBER OF**

Longitudinal Analysis: Panel Analysis of Pooled Cross-Sections (Ecological Footprint EF)

	Population	Dep.Ratio	GDPpc	GDPpc^2	%Urban	%Urban^2	Exports %GDP	Imports %GDP	Const.	Within R^2	Number Observ.	Number Countr.
Total EF	0.98* (0.19)	-0.31* (0.07)	-0.21* (0.08)	0.03* (0.01)	-0.72* (0.13)	0.12* (0.02)	-0.06* (0.01)	0.07* (0.01)	1.31* (0.44)	.848	2247	65
Energy[1] EF	0.99* (0.03)	-0.48* (0.13)	-0.28 (0.16)	0.05* (0.01)	-1.60* (0.27)	0.23* (0.04)	-0.06* (0.02)	0.09* (0.02)	0.22 (0.83)	.824	2247	65
Material[2] EF	1.00* (0.19)	-0.12* (0.05)	0.18* (0.15)		-0.33* (0.10)	0.08* (0.02)	-0.05* (0.09)	0.05* (0.01)	-0.92* (0.36)	.813	2247	65
Food EF[3]	0.99* (0.18)	-0.12* (0.06)	0.25* (0.07)	-0.01* (0.00)	-0.40* (0.11)	0.10* (0.02)	-0.05* (0.01)	0.05* (0.01)	-0.85* (0.39)	.790	2247	65
Forest EF[4]	1.10* (0.05)	-0.11 (0.16)	-0.58* (0.21)	0.06* (0.01)	-0.18 (0.10)		-0.08* (0.03)	0.09* (0.03)	-1.82 (1.04)	.348	2247	65

[1]Amount to sequester CO_2 + Fuelwood + Nuclear

[2]Total EF minus Energy EF +

[3]Cropland + Pasture Land + Fishing Area

[4]Timber + Fuelwood

Years: 1961 - 2003

***P ≤.05**

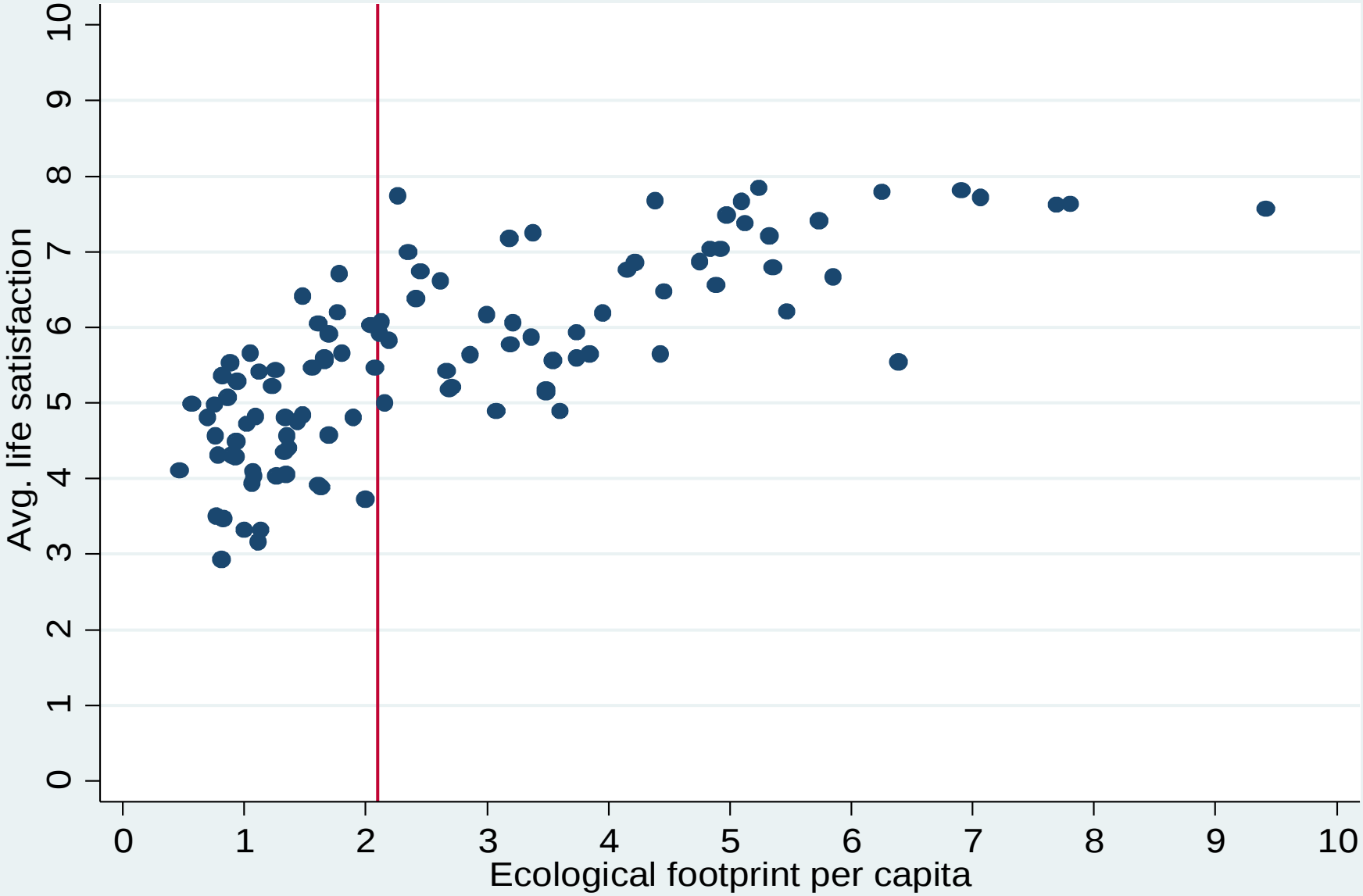
TRANSITION (TIPPING POINT) TO ACCELERATED CONSUMPTION?

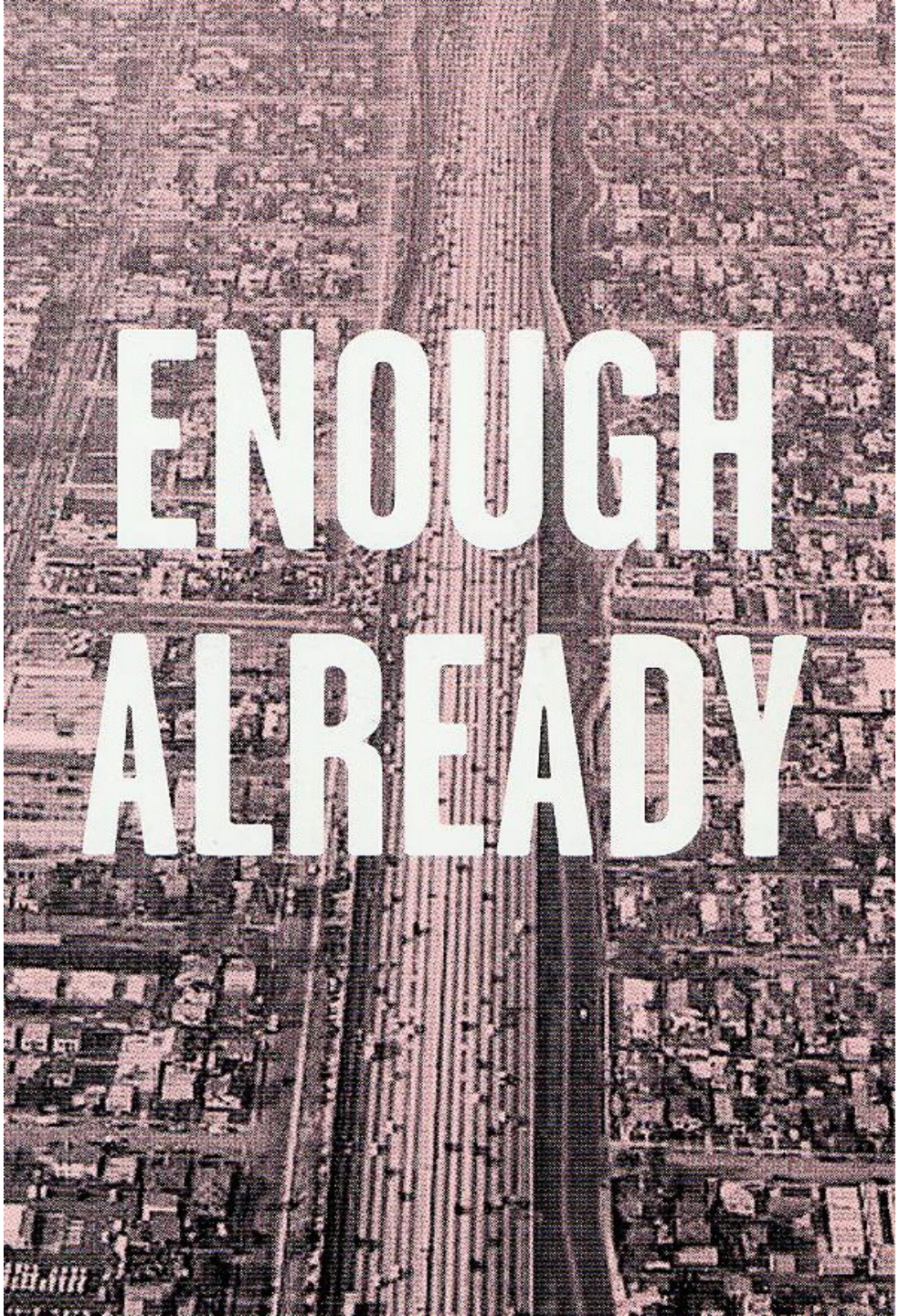
Population of the "New Consumer" Countries (2006)

China	1,328,474,000
India	1,151,751,000
Brazil	189,323,000
Russia	143,221,000
Mexico	105,342,000
Turkey	73,922,000
South Korea	48,050,000
Argentina	39,134,000
Malaysia	26,114,000
Total	3,105,331,000

Source: United Nations Statistics Division

Scatterplot of Average Life Satisfaction Regressed on Ecological Footprint per capita.





THE LIMITS OF MODELS:

IT IS IMPOSSIBLE TO SIMULTANEOUSLY MAXIMIZE GENERALITY, REALISM, AND PRECISION IN ANY MODEL.

THIS LIMITATION RESULTS IN THREE OPTIONS:

(1) SACRIFICE GENERALITY TO REALISM AND PRECISION

(2) SACRIFICE REALISM TO GENERALITY AND PRECISION

(3) SACRIFICE PRECISION TO REALISM AND GENERALITY

Source: Levins, Richard. 1966. "The Strategy of Model Building in Biology. *American Scientist* 54:421-431.