A New Look at the Environmental Kuznets Curve

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Today's Agenda

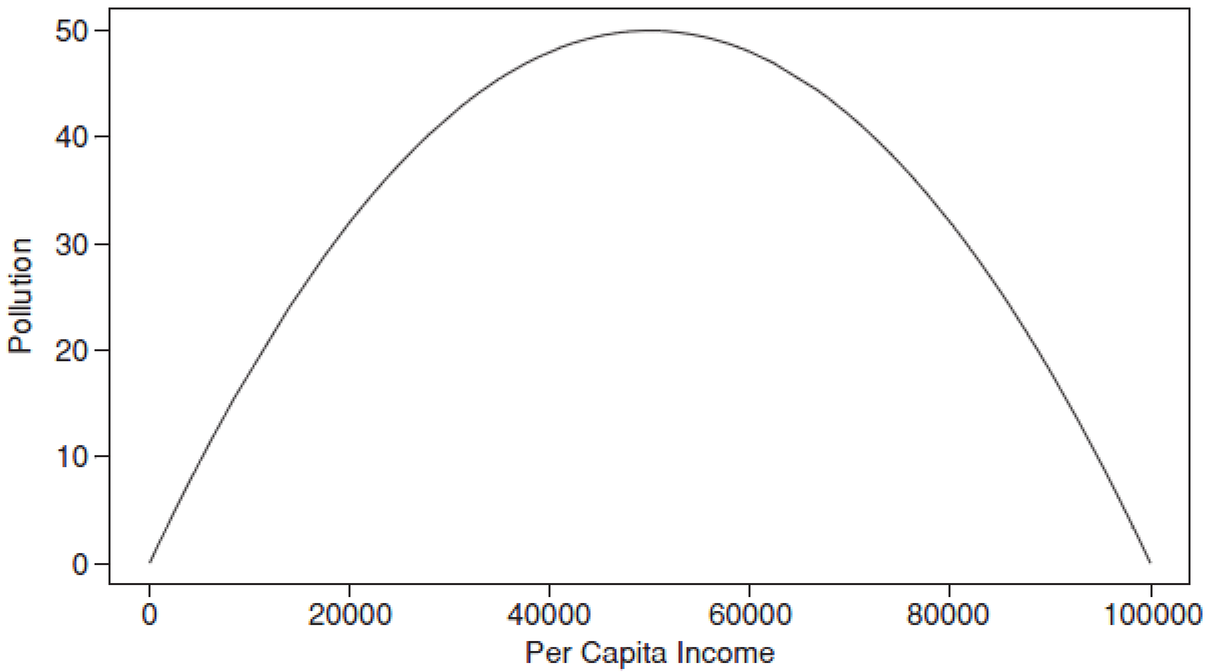
- *Emphasis on empirical issues*

- Brief review of issue, theory
- Data issues
- Newly compiled data
- Preliminary results
- Discussion

- The proposition that there may be a “U-shaped” path (or “inverted U-shaped” path”) for the environment with rising income per capita

- Several theoretical models indicate this is possible

- Evidence is mixed; many observers skeptical.



I Stylized environmental Kuznets curve.

Sketch of theory:

- from "THE ENVIRONMENTAL KUZNETS CURVE FROM MULTIPLE PERSPECTIVES" William K. Jaeger and Van Kolpin* April 3, 2008 (Also a FEEM Working Paper from April 2008
- Similar mathematically to Stokey (1998); also John and Pecchino (1994), Seldon and Song (1995)

- Key elements:
  - Endowment of environmental quality is initially relatively abundant compared to income and "commodities"
  - Growth in income enables greater consumption relative to (diminished) environmental quality
  - The possibility of a "turning point" depends on the substitutability in preferences and in production technology

Intuition for EKC possibility

Figure 3. Efficient allocation of an environmental endowment at various income levels

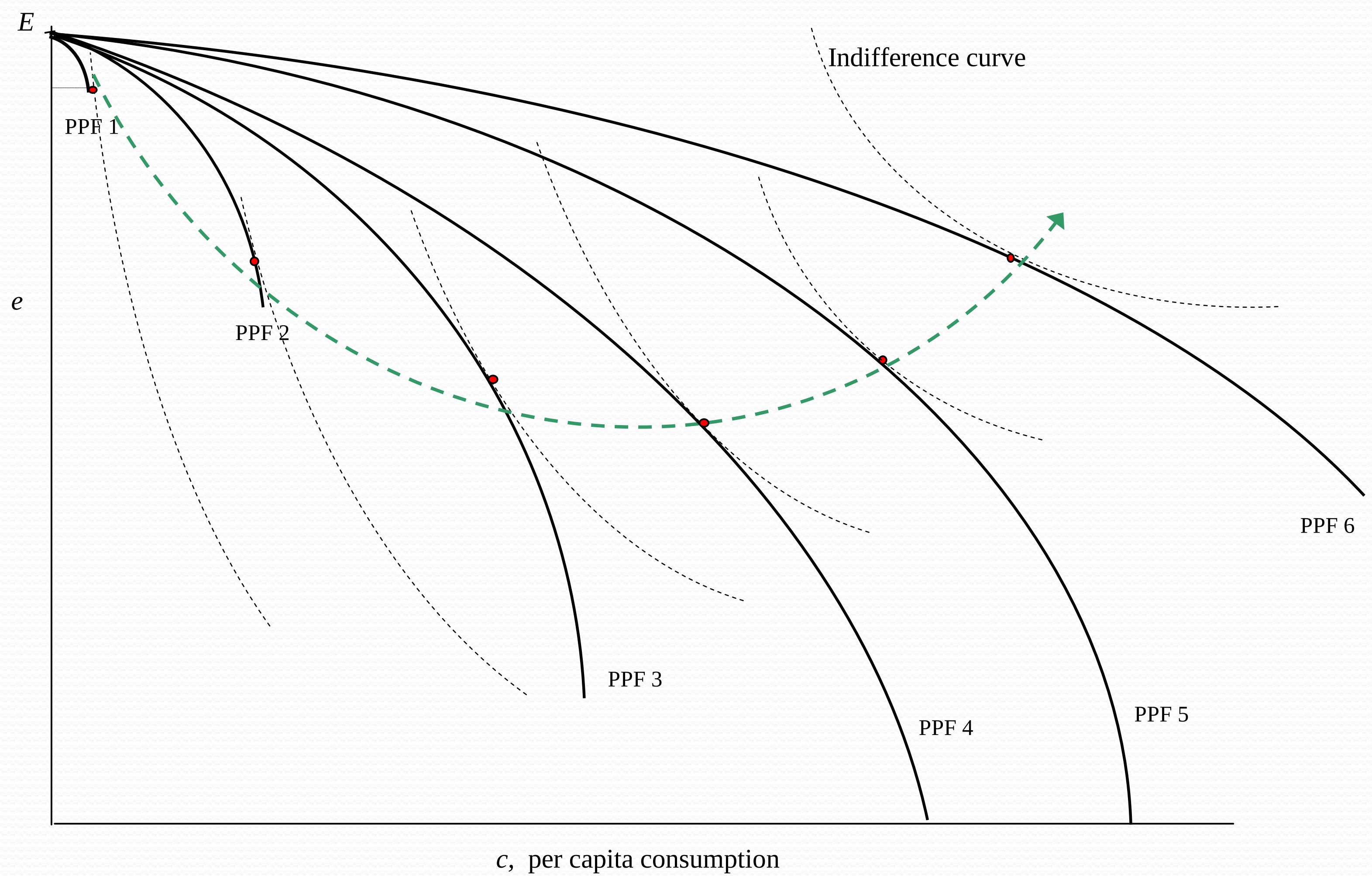
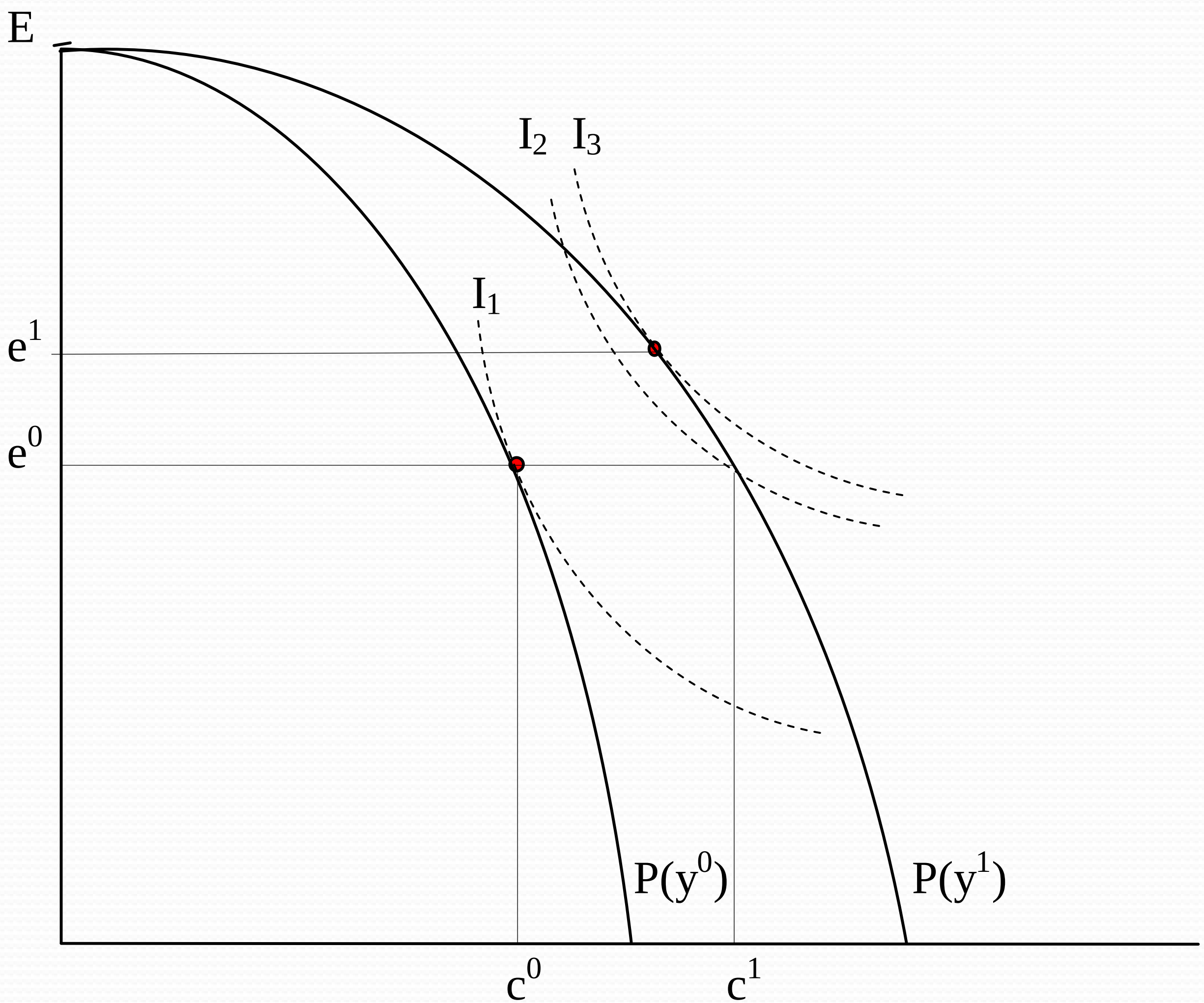


Figure 1. PPF expansion: Indifference curve I_2 is less steep than $P(y^1)$ at the level of environmental quality e^0.



Basic model:

- x_1 and x_2 represent levels of inputs 1 and 2
- The per capita production function is $c=c(x_1,x_2)$ where $c(x_1,x_2)$ represents the quantity of private good
- Environmental quality is $e=E-d(nx_1)$, where
  - E represents the initial endowment of environmental quality,
  - n is the population size, and
  - d represents a differentiable, increasing, and convex environmental degradation function.
- Each agent's budget constraint is $x_1+x_2=y$;
  - where y is per capita income.

General findings:

- THEOREM 1: A parametric change will increase optimal environmental quality if and only if the change increases production elasticity relative to consumption elasticity at the initially optimal environmental quality level.

- Theorem is applied to three different models

CES Version of the model

- We assume both production and utility functions are CES:
- Let $c(x_1,x_2) = (a_1 x_1^{\alpha} + a_1 x_2^{\alpha})^{1/\alpha}$

  and $u(c,e) = (b_1 c^{\beta} + b_2 e^{\beta})^{1/\beta}$

- where $\alpha,\beta \leq 1$, $\alpha,\beta \neq 0$, and $a_1,a_2,b_1,b_2 > 0$.
- this model is symmetric in both production and utility; production is homothetic in x_1 and x_2, and utility is homothetic in c and e.

Results for CES model – with rising income per capita

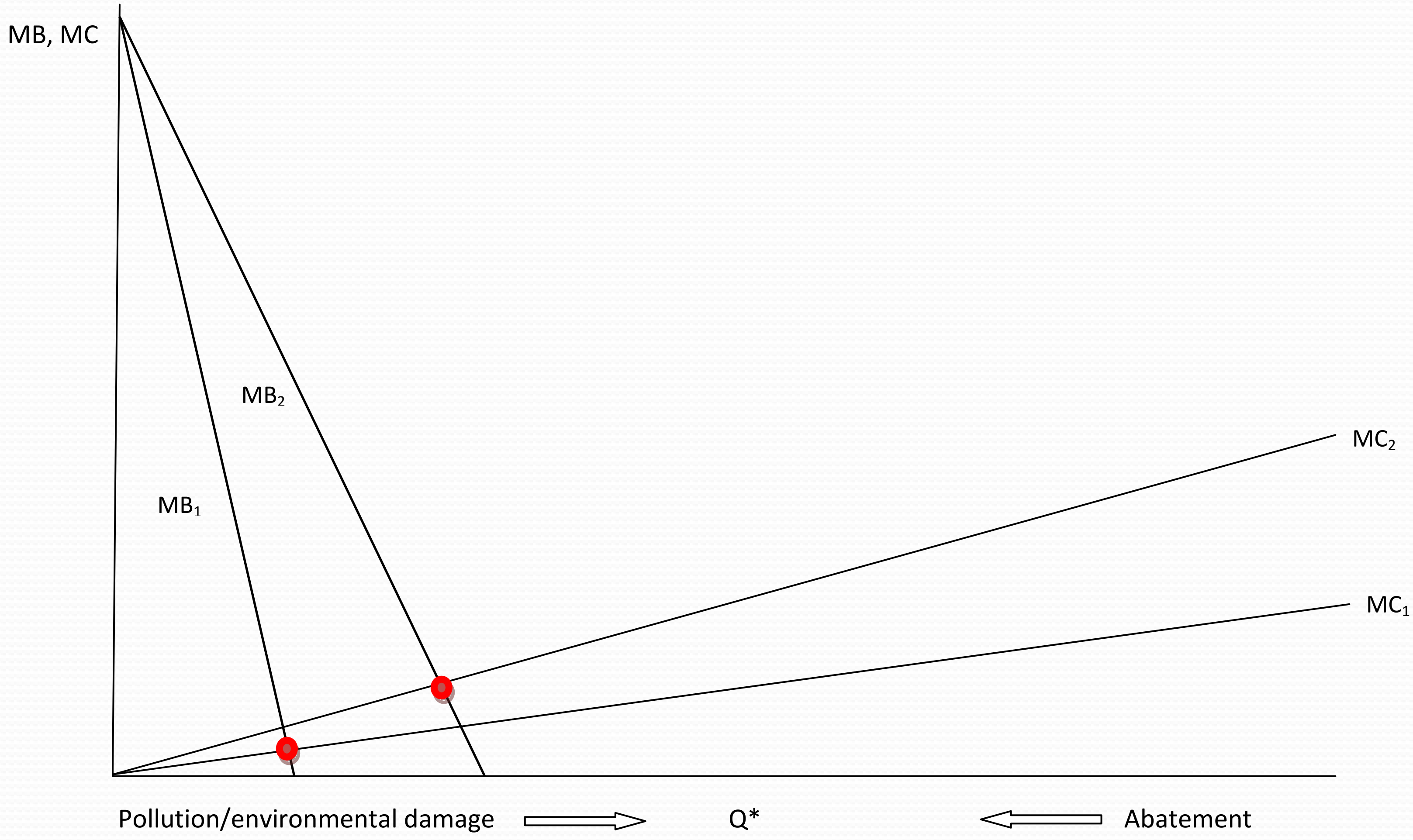
- By Theorem 1 we may conclude the income trajectory of e must be eventually increasing whenever $\beta < \alpha$, or equivalently, whenever the elasticity of substitution in the production function (i.e., $1/(1-\alpha)$) exceeds the corresponding elasticity of substitution in the utility function (i.e., $1/(1-\beta)$).

Results for CES model – with rising population (holding income per capita fixed)

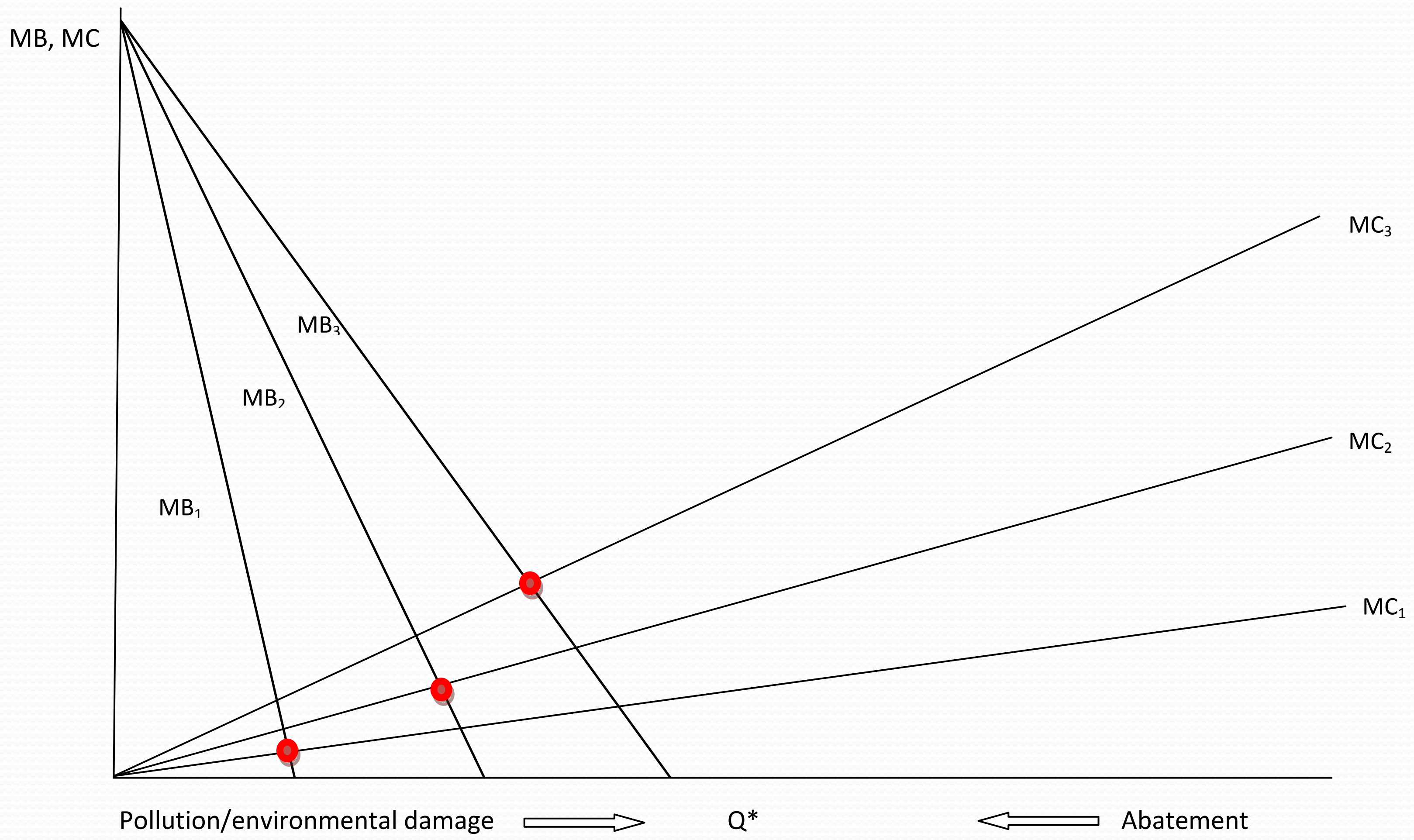
- If both functions reflect CES substitution possibilities that are inelastic, (i.e., $\alpha,\beta < 0$), then this implies consumption elasticity exceeds production elasticity in the limit
  - it follows environmental quality must be eventually decreasing.
  - in all other cases, environmental quality must be eventually increasing.

Is there intuition for the population results?

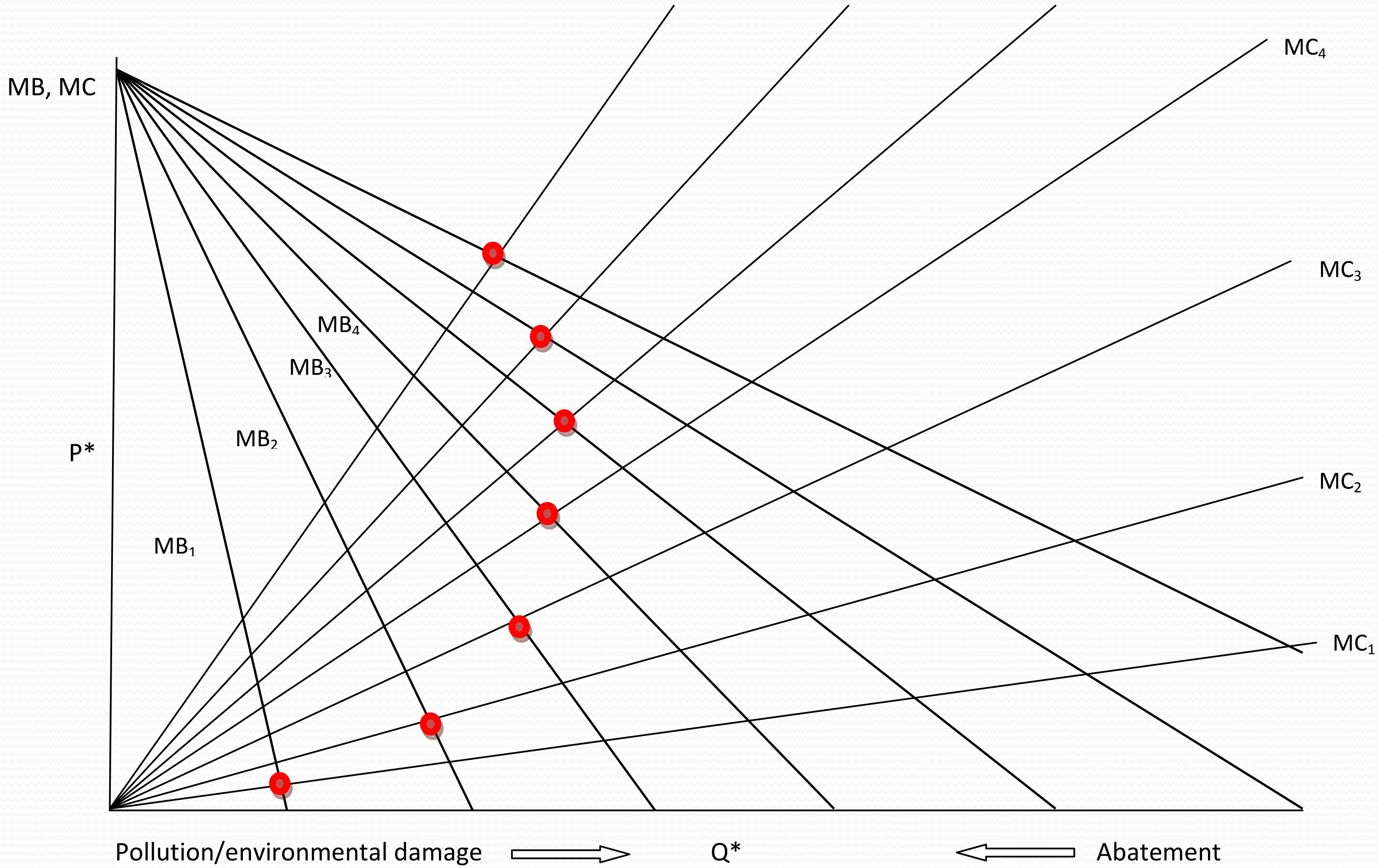
Population growth and the trajectory of optimal environmental allocations



Population growth and the trajectory of optimal environmental allocations



Population growth and the trajectory of optimal environmental allocations



Observations from theory

- Results suggest the *possibility* of an EKC without making heroic assumptions

- The production possibilities frontier incorporates whatever influences a government or other coordinating institution is capable of exerting.

- Parameters in both utility and production will vary by pollutant and community.

Empirical evidence

Many studies, no consensus, much controversy:

- Recent survey: R. Carson, "The Environmental Kuznets Curve: Seeking Empirical Regularity and Theoretical Structure" Review of Environmental Economics and Policy, volume 4, issue 1, winter 2010, pp. 3–23.
- Stern, D.I. (2004), "The Rise and Fall of the Environmental Kuznets Curve", World Development, 32, 1419-1439.
- Marzio Galeotti, Matteo Manera & Alessandro Lanza, "On the Robustness of Robustness Checks of the Environmental Kuznets Curve," FEEM Working Paper 22.2006

From Richard Carson, REEP 2009:

"On the main message taken from Grossman and Krueger's work by the economics profession—that trade and higher income levels would make for a better environment—the supporting evidence is scant, fleeting, and fragile. Desperately sought, causality has yet to be conclusively found."

Empirical issues (air pollution):

- Most studies have used GEMS/AIRS data, but its data quality is questionable
- GEMS was discontinued by UNEP in early 1990s.
- In many cases, data for a city has been combined with country-level values for income per capita and, in some cases, land area (to compute population density)
- Estimation issues: model specification questions

UNITED NATIONS ENVIRONMENT PROGRAMME ENVIRONMENTAL OBSERVING AND ASSESSMENT STRATEGY REFERENCE PAPER ANNEXES

REVIEW OF PAST ACTIVITIES, PRESENT GAPS AND LESSONS LEARNED

"The USEPA donated database, software, maintenance, and other labour to provide a home and distribution center for GEMS/Air data. USEPA rarely received data directly from the 48 participating GEMS countries. Instead this data passed through the GEMS/AIR office of WHO in Geneva. … GEMS/Air has never received data from the vast bulk of air quality monitoring stations in the world. …. As a result, the GEM/AIR database cannot provide answers to many pertinent questions about trends in global air quality or the extent of exposed populations. In addition, there does not appear to have been quality control efforts, such as inter-calibration of equipment, to insure comparability of data among countries. "

Objectives and focus of current study:

- Acquire data for sites with site-specific environmental, income and population density data
- Include the largest possible sample across geographical units and years
- So far, sources are concentrated in USA, Europe, Canada

Data from Europe

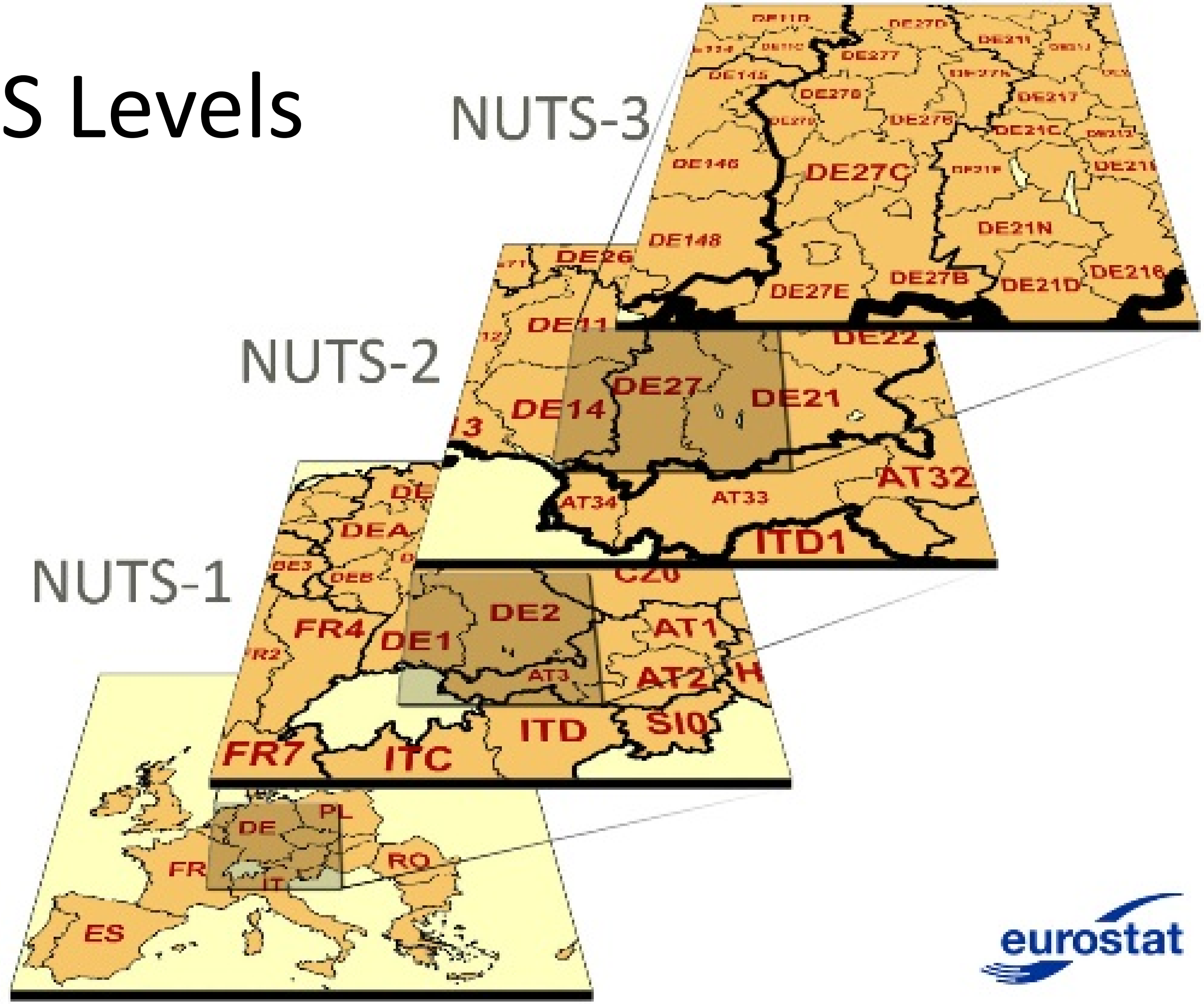
- The NUTS classification is a hierarchical system for dividing up the economic territory of the EU for the purpose of :
  - The collection, development and harmonisation of EU regional statistics.
  - Socio-economic analyses of the regions.

LEVELS:

NUTS 1: major socio-economic regions

- NUTS 2: basic regions for the application of regional policies
- NUTS 3: as small regions for specific diagnoses

NUTS Levels



eurostat

BELGIQUE - BELGIË / LUXEMBOURG - NUTS level 3

The NUTS Regulation lays down the following minimum and maximum thresholds for the average size of the NUTS regions.

Level	Minimum	Maximum
NUTS 1	3 million	7 million
NUTS 2	800 000	3 million
NUTS 3	150 000	800 000

Main data sources

- Economic data:
  - Eurostat – NUTS-3
  - US Bureau of Economic Analysis, NOAA
  - CANSTAT
- Environmental data
  - EU AirBase (SO_2, PM_{10}, others)
  - US EPA AirData (SO_2, PM_{10},, others)
  - NAPS (SO_2) (Canada)

Compiling EU AirBase data

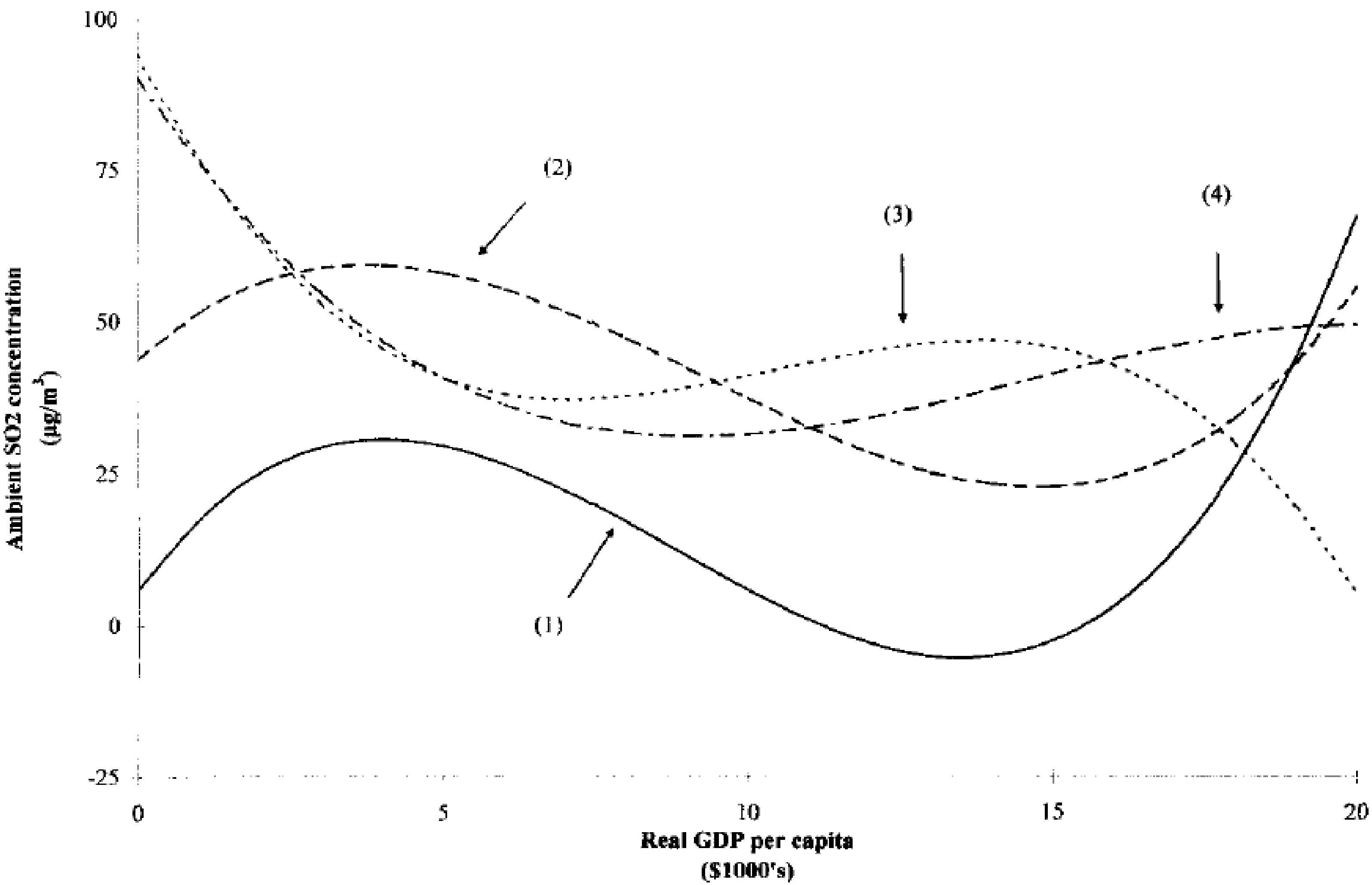
- Pull all SO_2, PM_{10} data for all stations, years
- Use latitude and longitude in ArcGIS to overlay with NUTS-3 regions.
- Use filters to select "background" stations (omit some stations such as traffic, industry, other)
- Compute mean values by year for each NUTS-3 region
- Combine with data on income, pop. for each NUTS-3

Table 1. Data Comparisons for SO2 Estimations				
	Current Study	Grossman & Krueger*	Harbaugh, Levinson, Lewis*	Antweiler, Copeland, Taylor*
Number of observations	21,298	1,352	2,401	2,555
Number of countries	23	42	45	43
Number of localities	1585	77	102	108
Years (maximum by country)	37	12	22	26
Income per capita -- mean	26,200	12,617	15,842	14,780
Income per capita -- minimum	1,800	1,040	1,285	1,090
Income per capita -- maximum	184,860	29,064	30,408	27,180
Pop. density - mean (pers/km2)	454	3.35	2.75	63
Pop. density - min (pers/km2)	0.02	0.002	0.002	1
Pop. density - max (pers/km2)	27,114	24.7	24.7	276

* Income per capita, and in some cases population density, are not site specific; but based on national values.

From Harbaugh et al.

FIGURE 1.—PLOT OF TABLE 3 REGRESSIONS DIFFERENT DATA SETS FOR SULFUR DIOXIDE



Reduced form model

$$SO_2 = \alpha + \beta_1 Y + \beta_2 Y^2 + \beta_3 Y^3 + \beta_4 P \quad + \beta_5 P^2 + \beta_6 P^3 + \beta_7 T + \varepsilon$$

Where:
Y = income per capita, moving average for *t* and previous 5 years
P = population density, persons/KM^2
T = trend (year)

Table 2. Results for SO2 model estimations												
	Model 1: Fixed effects, smoothed pop.			Model 2: Random effects estimator			Model 3: pop-avg. est., year dummies			Model 4: pop-avg. estimator, weighted		
Independent variables	Coeff.	Std. error	sig.	Coeff.	Std. error		Coeff.	Std. error		Coeff.	Std. error	
Income per capita, moving avg. (t-5 to t)	31.63	12.88	**	25.89	3.73	***	39.92	12.40	***	43.85	7.58	***
Income (ma)^2	-71.81	27.50	***	-62.95	7.99	***	-86.29	26.00	***	-92.46	17.49	***
Income (ma)^3	28.16	11.56	**	26.71	4.60	***	34.61	10.68	***	43.54	10.19	***
Population density	3.24	0.68	***	2.56E-03	2.10E-04	***	3.13	0.62	***	1.63	0.29	***
Pop density^2	-0.33	0.13	***	-2.33E-07	3.30E-08	***	-0.32	0.11	***	-0.13	0.05	***
Pop density^3	1.06E-02	4.05E-03	***	6.92E-12	1.07E-12	***	1.04E-02	3.68E-03	***	4.22E-03	1.55E-03	***
Year	-0.28	0.02	***	-0.27	4.95E-03	***	-0.41	0.04	***	-0.17	0.01	***
Intercept	6.11	1.66	***	6.83	0.48	***	10.36	1.90	***	3.83	1.02	***
# of observations	21298			21298			21298			21298		
# of groups	1738			1738			1738			1738		
R^2 (within)	0.232			0.22			0.235			0.264		
Hausman chi^2	596			486			--			220		

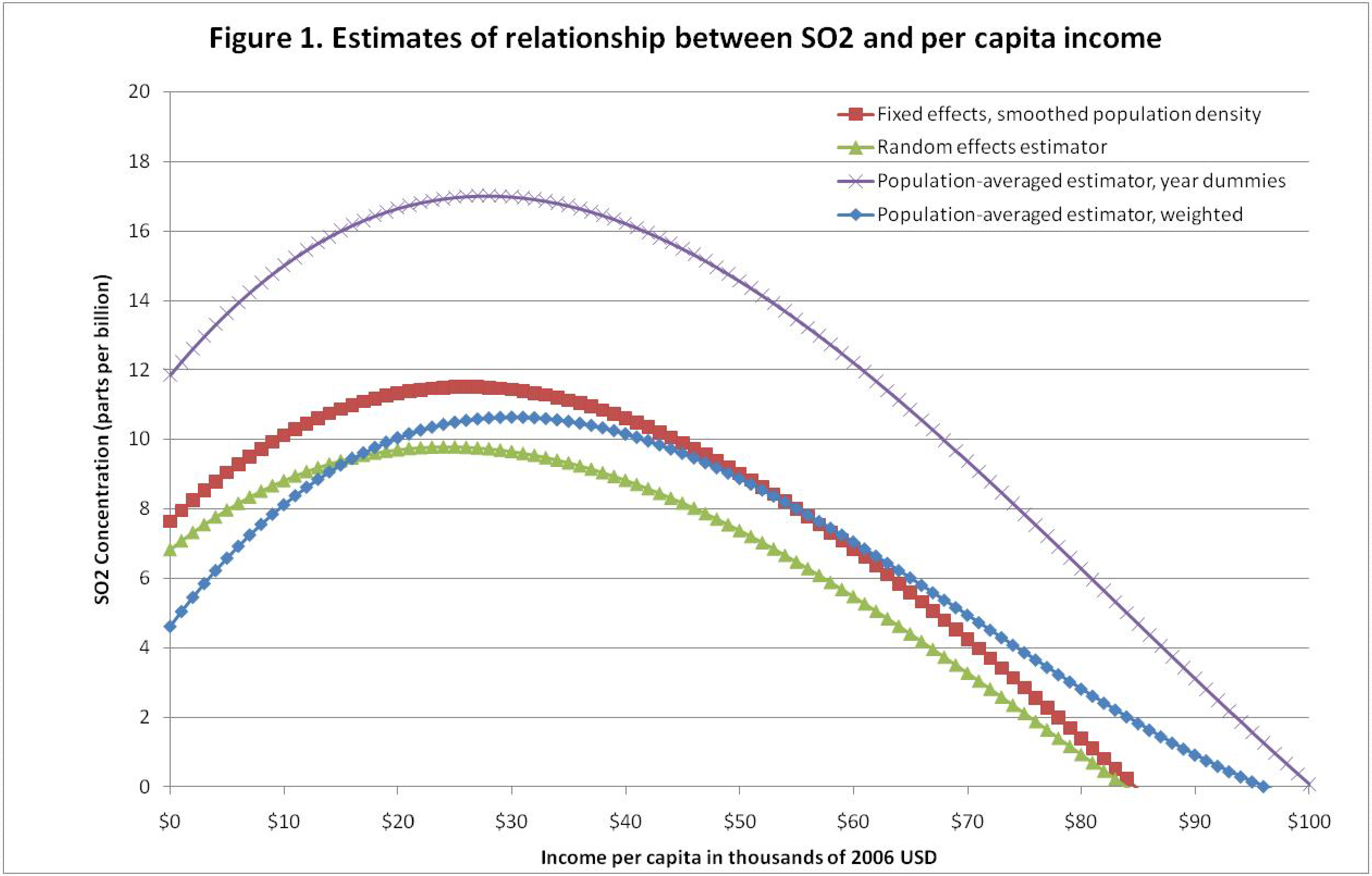
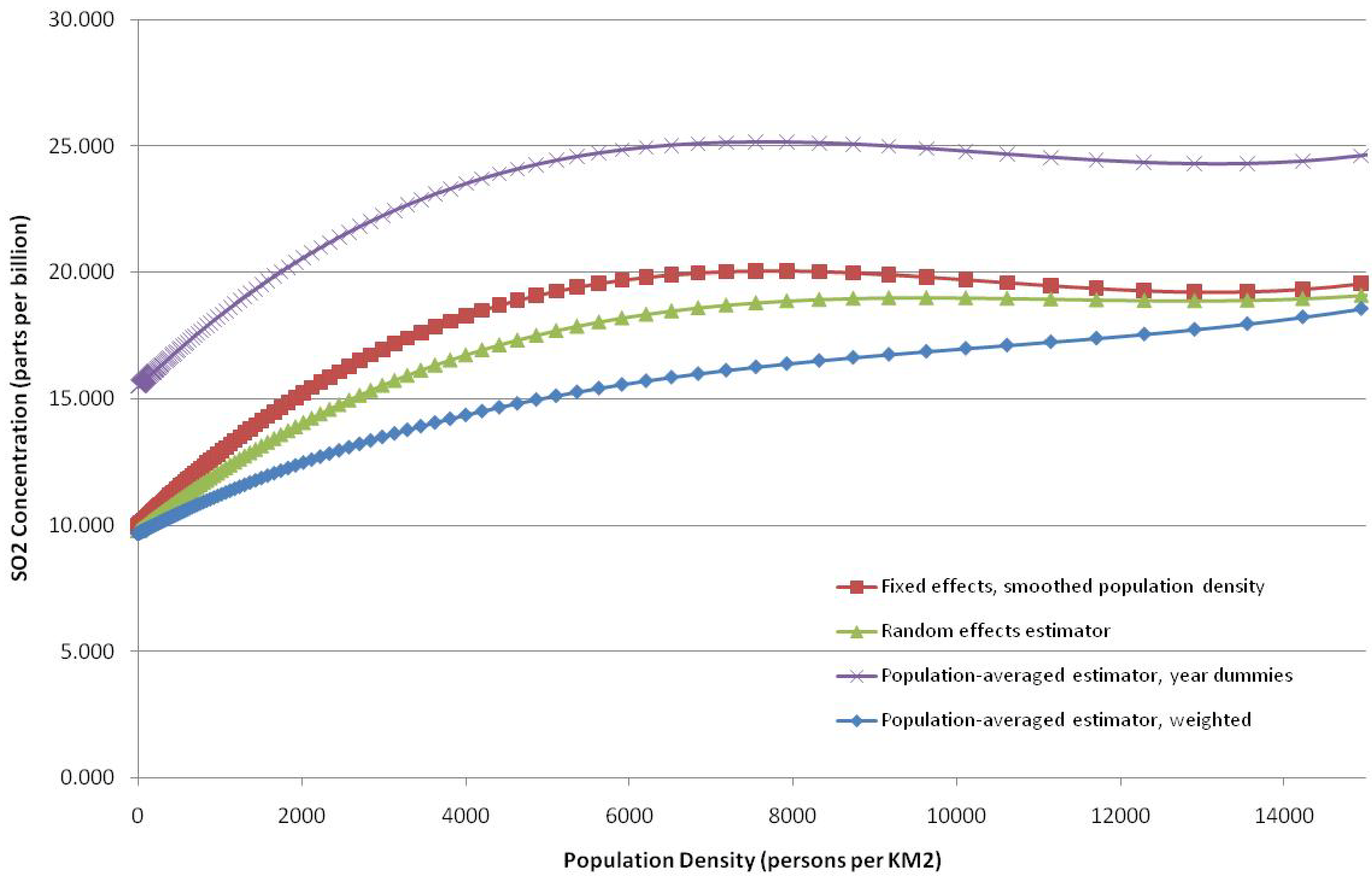


Figure 1. Estimates of relationship between SO2 and per capita income
20
18
16
14
12
10
8
6
4
2
0
SO2 Concentration (parts per billion)
$0
$10
$20
$30
$40
$50
$60
$70
$80
$90
$100
Income per capita in thousands of 2006 USD
Fixed effects, smoothed population density
Random effects estimator
Population-averaged estimator, year dummies
Population-averaged estimator, weighted

Figure 2. Estimates of relationship between SO2 and Population Density



Discussion

- Empirical issues
  - Data quality from GEMS
  - Use of national values for income per capita
  - Misspecification and population density
  - Lags and asymmetry of causal relationships
- Conceptual issues
  - Theory is robust as a "possibility"
  - No basis to expect uniformity across pollutants
  - Too much focus on the turning point
  - Most studies find a declining trend – this is important!