The Relationship between Environment and Economic Development and Environmental Performance Evaluation in China

Shaofeng Chen

Institute of Policy and Management
Chinese Academy of Sciences

June 14, 2012

Institute of Policy and Management(IPM), Chinese Academy of Sciences(CAS)

http://www.casipm.ac.cn/

- Founded in 1985
- Aiming at offering consultative services to central authorities, CAS, local governments and enterprises
- Research Fields:
  - Development strategy
  - Development and reform policy
  - Public administration
  - S&T management
  - State-of-the-art theories and methodologies of related disciplines

- **5 Research divisions**
  - **S&T policy**
  - **Management science and engineering**
  - **Sustainable development**
  - **S&T management and evaluation**
  - **Innovation and entrepreneurship policy**
- **Staffs**
  - **About 130 staffs**

CAS Sustainable Development Strategy Study Group

http://www.china-sds.org/

Prof. WenYuan Niu
Former-Leader

Prof. Yi Wang
Current- Leader
Deputy director of IPM

- **Founded in 1998**
- **Interdisciplinary team with expert network**
- **Objectives**
  - ➢ **Conducting research of the key strategical demand and great problems facing China sustainable development**
    - ✓ **Providing theoretical support for implementation of China sustainable development strategy;**
    - ✓ **Providing policy consultants and suggestions for decision-maker and related department of government**

- **First task:**

  China Sustainable Development Strategy Annual Report

  (Published by the end of February each year)

- **Research Fields:**
  - Sustainability Theory and Assessment
  - Integrated Management of Water Resource and River Basin
  - Energy and Climate Change strategy and policy including low-carbon economy
  - China's Global Strategy and Policy

China Sustainable Development

Strategy Report:1999-2012

- **CSDR Themes**

1999: Strategic designing/planning of SD

2000: Assets and liability Analysis of Sustainability

2001: Sustainability and modernization

2002: Capacity building of Sustainability

2003: Comprehensive national strength & Sustainability

2004: Establish the Well-off Society

2005: Sustainable urban development

- **CSDR Themes**

  2006: Building REEF Society

  2007: Water: Governance and Innovation

  2008: Policy review and outlook

  2009: China’s approach towards a low carbon future

  2010: Green development and Innovation

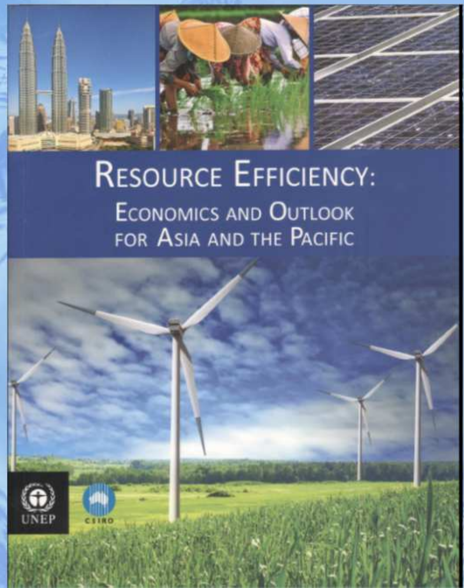
  2011: Greening Economic Transformation

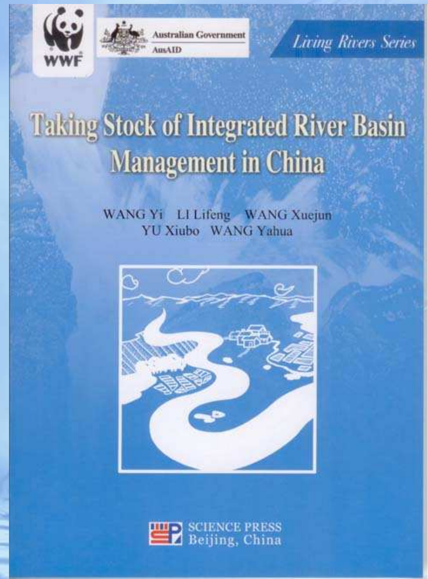
  2012: China’s Sustainable Development in the Shifting Global Context

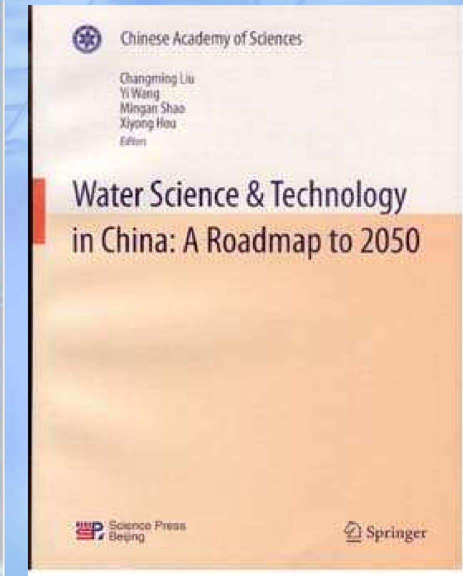
- **Social impacts**

  To provide for representatives of National People’s Congress (NPC)and National Committee of the Chinese People’s Political Consultative Conference(CPPCC)

Other publications







Towards a Sustainable Asia: Green Transition and Innovation

Resource Efficiency : Economics and Outlook for Asia and the Pacific

Taking Stock of Integrated River Basin Management in China

Water Science & Technology in China: A Roadmap to 2050

Official Website

http://www.china-sds.org

China Sustainable Development Database

http://www.chinasd.csdb.cn

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Outline

- Relationship between environment and economic development: EKC hypothesis
- Three inverted U shaped curves hypothesis based on IPAT : concept model
- Empirical study on three inverted U shaped curves hypothesis
- Environmental performance evaluation in China : methodology and application
- Conclusions and Discussion

Relationship between environment and economic development : EKC hypothesis

EKC hypothesis

- **Environmental Kuznets curve hypothesis (Grossman et al, 1991)**
  - Inverted U-shaped relationship between environmental degradation and economic growth
  - Environmental degradation increases in the early stages of economic growth and then decreases once a threshold level of income per capita is reached
- **Mixed empirical study results**
  - Different environmental indicators selected
  - Different models used
  - Time –series analysis neglected etc

EKC hypothesis

- **According to Chimeli (2007) , time-series evidence on growth and the environment suggests an environmental Kuznets curve (EKC), whereas longitudinal studies fail to produce robust estimates for the EKC**
- **It is necessary to study the relationship between environment and economic development conducted from long-term perspective**

Three inverted U shaped curves hypothesis based on IPAT

IPAT identity

- **IPAT identity** (Ehrlich et al, 1970;Commoner et al, 1971) used to analyze relationship between environment and development:

  ➢Environmental impacts as the function of population, affluence and technology

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

Where, “I” is environmental impacts; “P is population; “A” is affluence, and ”T” is technology expressed by the intensity of environmental impacts, i.e., the environmental impacts or resource consumption per unit GDP

➢ From this perspective, to improve eco-efficiency is also the premise and foundation to realize green development or environmentally sustainable development

IPAT identity

- Further discussion on IPAT identity

Social policies   Economic policies   Technical policies   resource and environmental policies

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

- **Population amount**
- **Population composition** (urbanization)
- **Population quality** including awareness

Scale effect

- **Total investment**
- **Total consumption**
- **Import and export**

- **Structure effect** (Service, Knowledge or information industry)
- **Technical effect** (cleaner product and techniques)
- **Institutional effect**

Three inverted U shaped curves hypothesis based on IPAT

- **IPAT identity : I = P × A × T**

$$\dot{I}/I = \dot{P}/P + \dot{A}/A + \dot{T}/T$$

- ➢ Based on variation of T

$$\dot{T}/T \geq 0$$

$$\dot{T}/T < 0$$

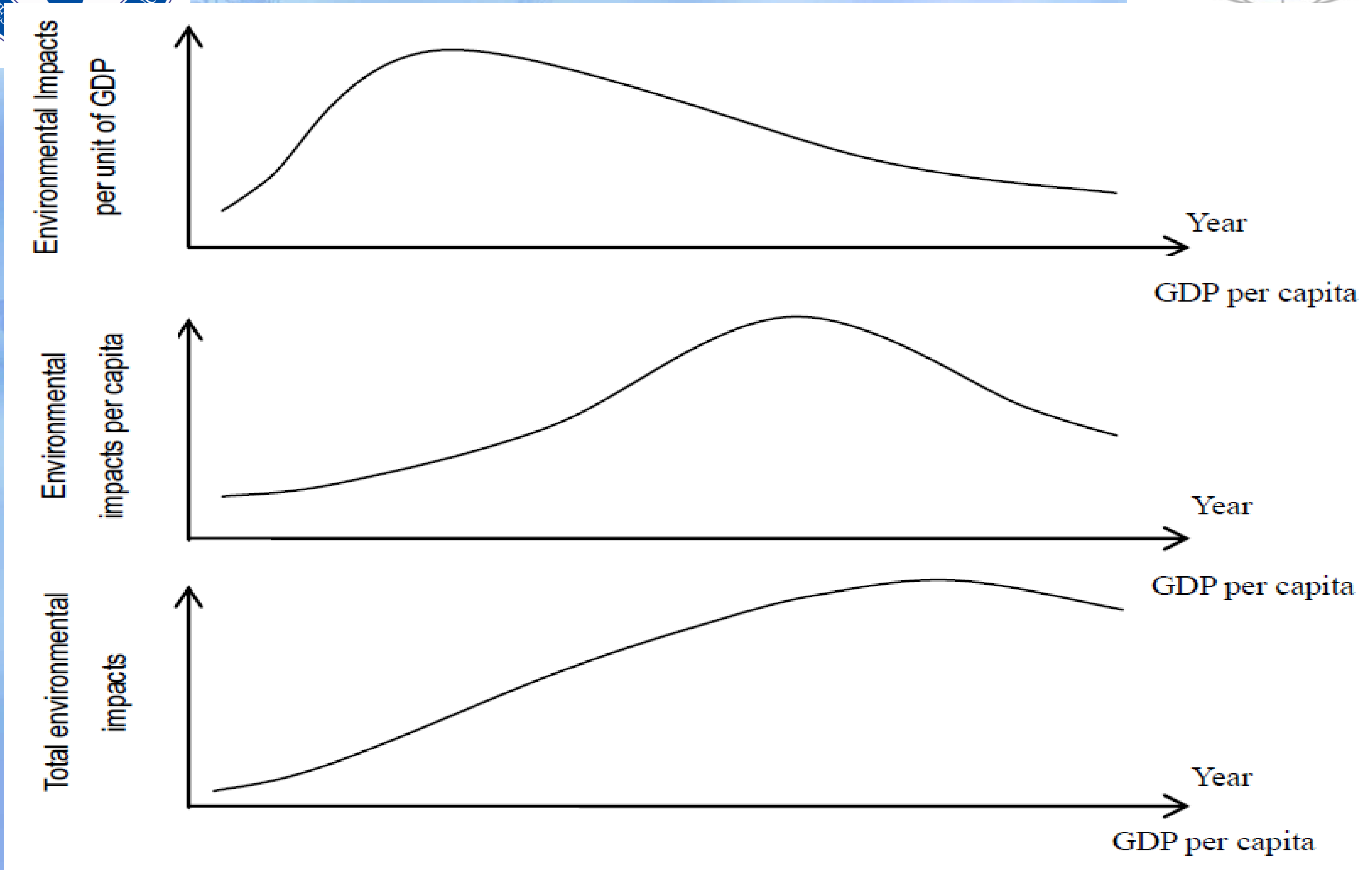
$$\dot{A}/A \leq \left|\dot{T}/T\right| < \dot{P}/P + \dot{A}/A$$

$$\left|\dot{T}/T\right| \geq \dot{P}/P + \dot{A}/A$$

Three inverted U shaped curves hypothesis based on IPAT

- **Environmental change process along with economic development or over time generally follows successive three inverted U shape curves or undergoes “three peaks” in the long run**
  - **Inverted-U shape curve or peak of environmental impacts per unit of GDP**
  - **Inverted-U shape curve or peak of environmental impacts per capita**
  - **Inverted-U shape curve or peak of Total environmental impacts curve or peak**

Concept model of three inverted U shaped curves hypothesis

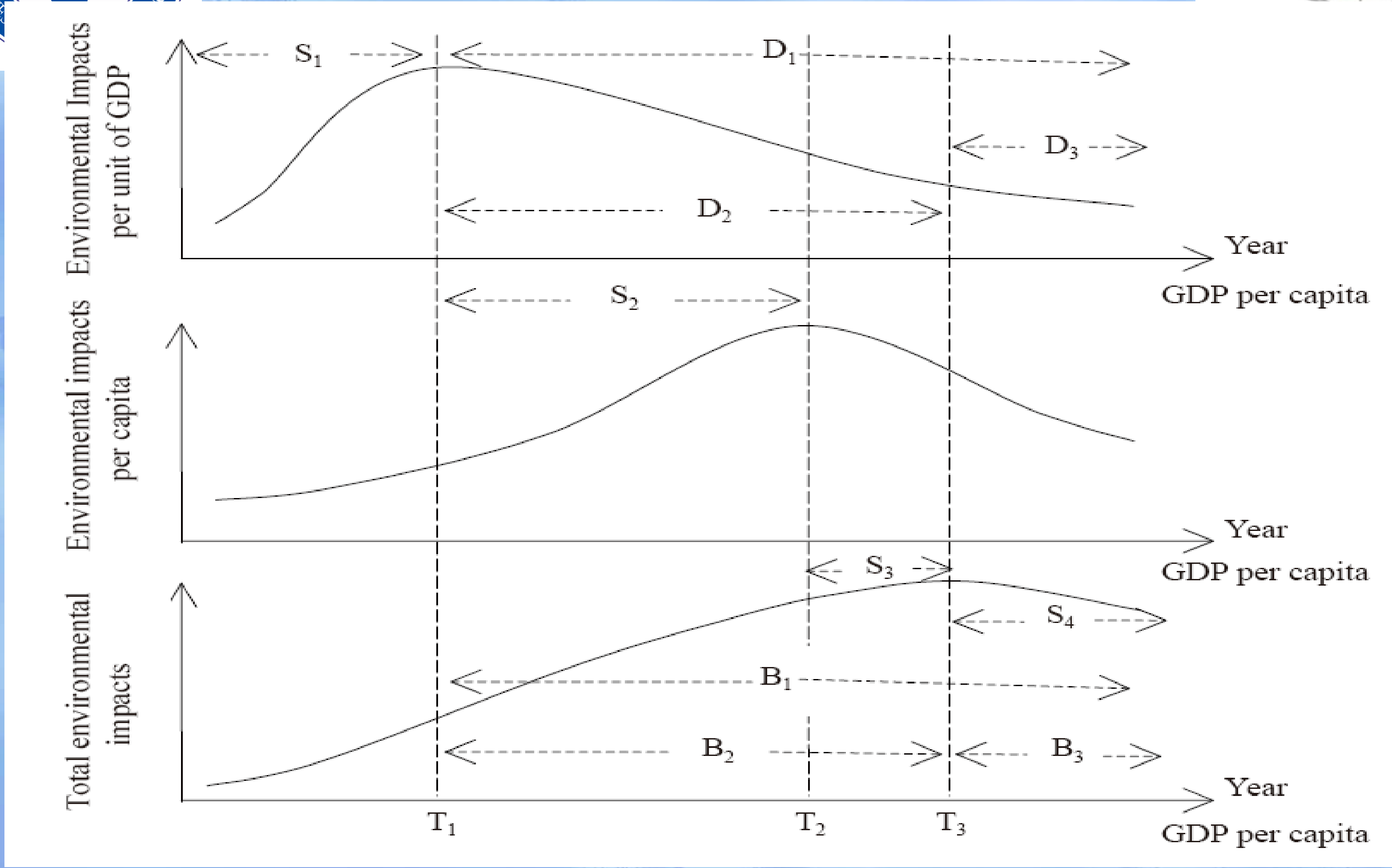


The evolutionary trend of three inverted U shape of environmental impacts

Three inverted U shaped curves hypothesis based on IPAT

- **The peak values have divided the evolution of environmental and resources impacts into four stages:**
  - **Environmental impact intensity pre-peak stage or materialization stage (Stage S_1)**
  - **Stage between peak of environmental impact intensity and peak of per capita environmental impacts (Stage S_2)**
  - **Stage between peak of per capita environmental impacts and peak total environmental impacts (Stage S_3)**
  - **Stage of steady declining of total environmental impacts (Stage S_4)**

Concept model of three inverted U shaped curves hypothesis



The evolutionary trend of three inverted U shape of environmental impacts

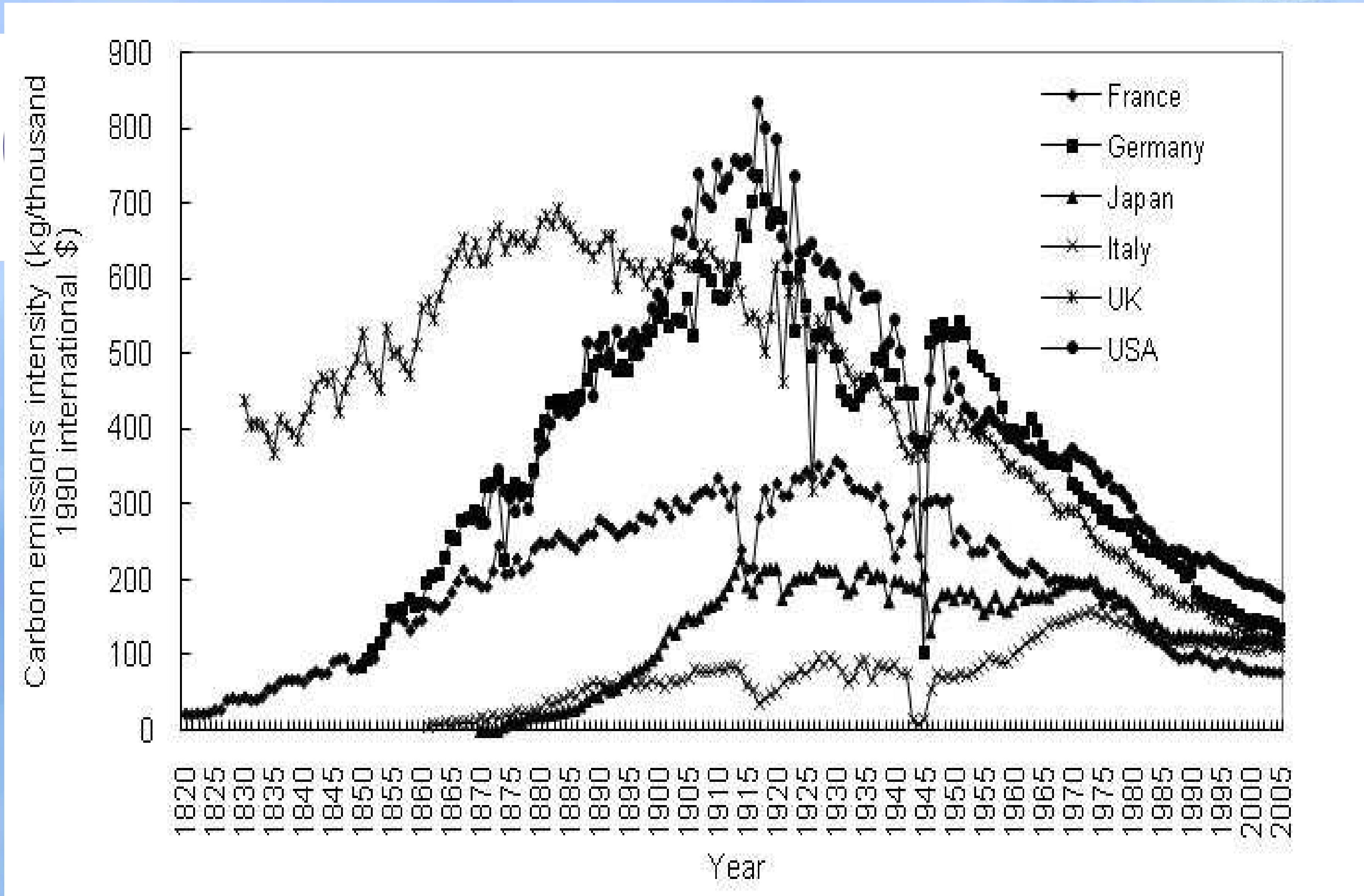
Three inverted U shaped curves hypothesis based on IPAT

- **Different drivers are at work during different stages of environmental evolution:**
  - In stage S_1, the growth in resource consumption or pollutant discharge is driven more by the proliferation and application of technology that increases resource consumption or pollutant discharge.
  - In stage S_2, economic growth plays a leading role.
  - In stage S_3 and stage S_4, technological progress in resource conservation or pollution reduction plays a significant role in reducing resource consumption or pollutant discharge.

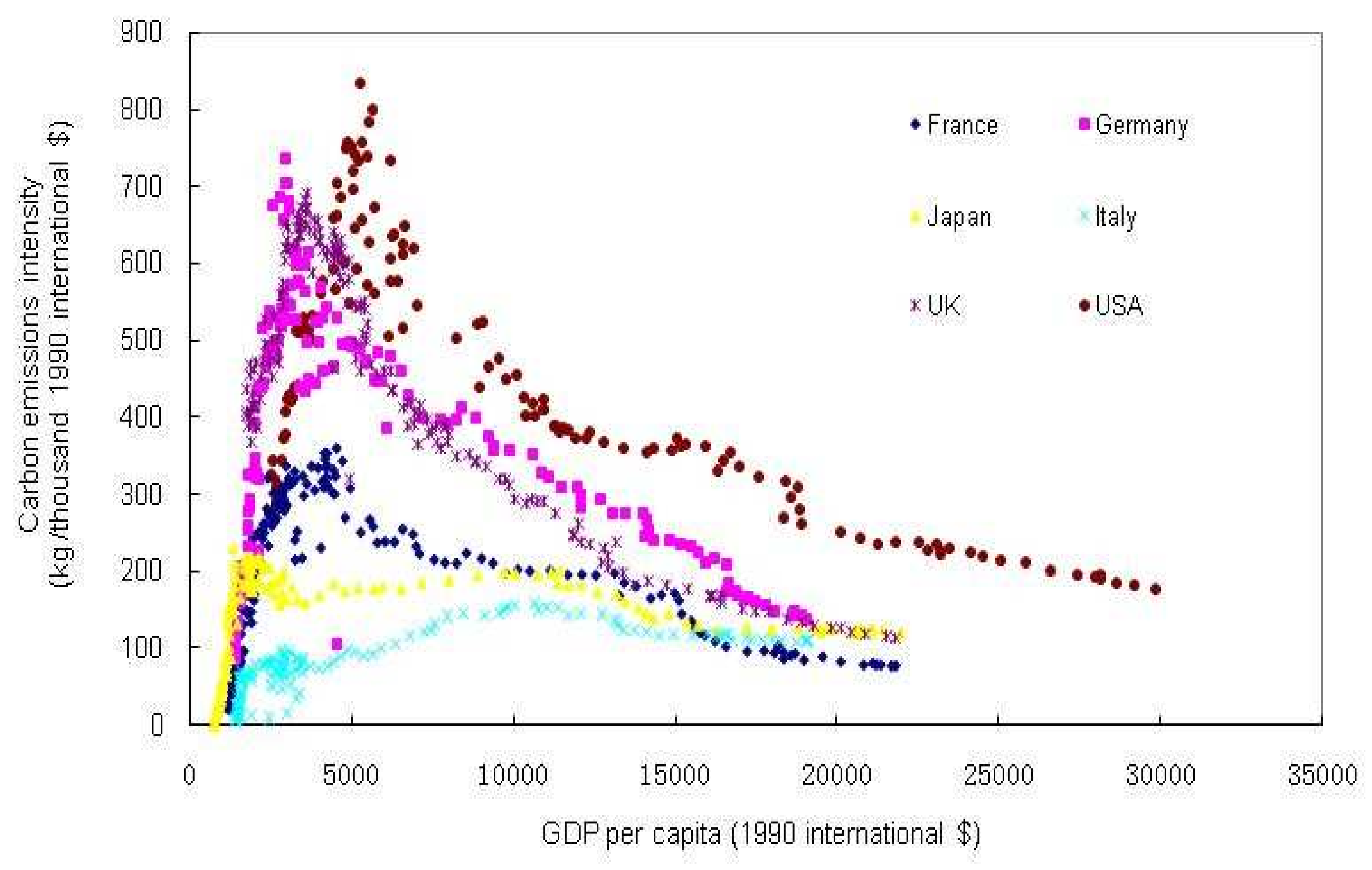
Three inverted U shaped curves hypothesis based on IPAT

- **The Aforementioned based on theoretical deduction**
- **Fluctuations (including rebound effect) may happen to curves of three inverted U shape in reality due to the impact of various factors such as economic fluctuation, structural adjustment, policy or system change, upper limit for technology or economy (Vehmas et al., 2007) and uncertainties etc.**

Empirical study on three inverted U shape curves hypothesis- taking carbon emission as an example

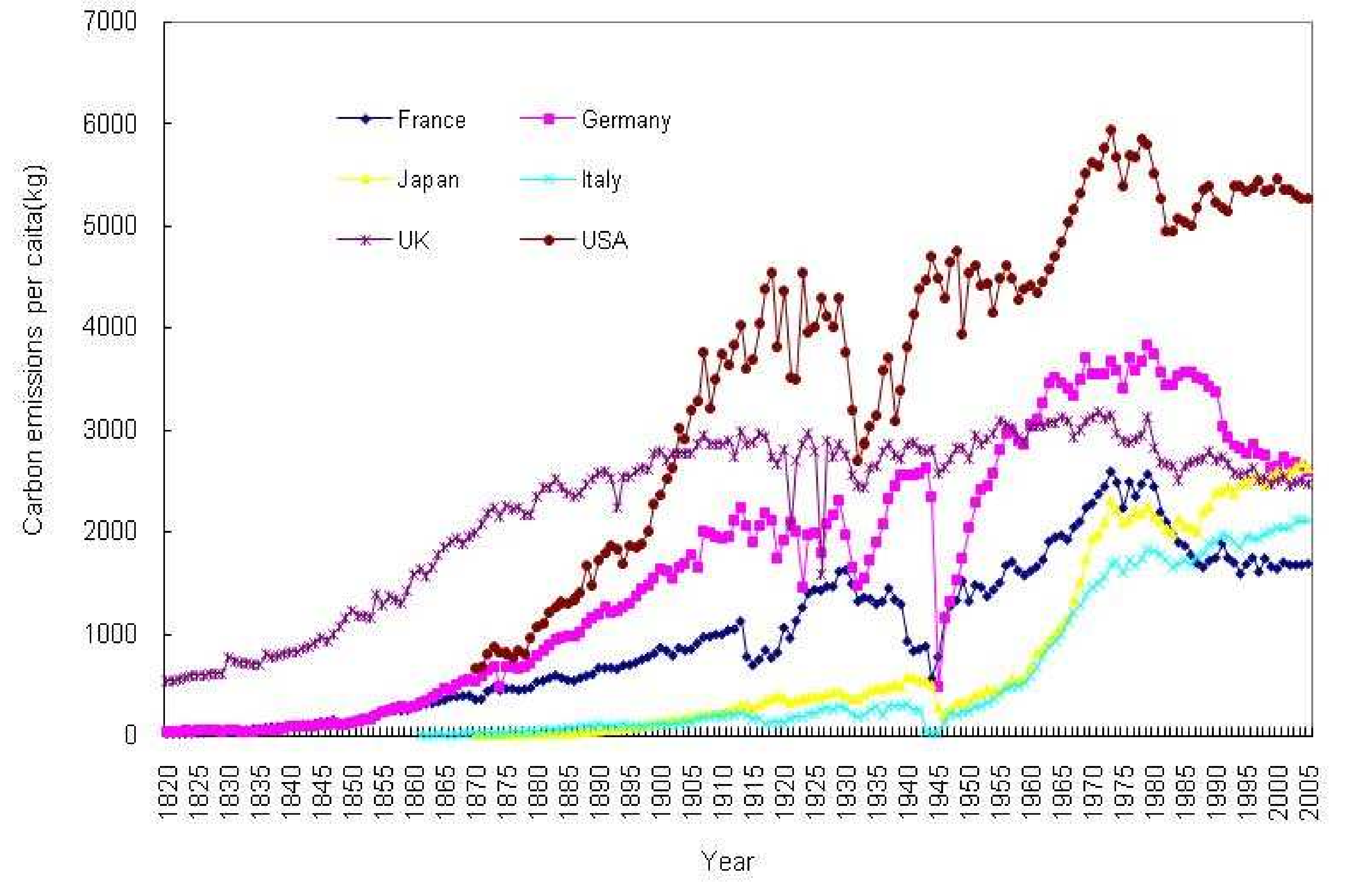


The historical trend of carbon emissions intensity in 6 developed countries
Data source: CDIAC,2008



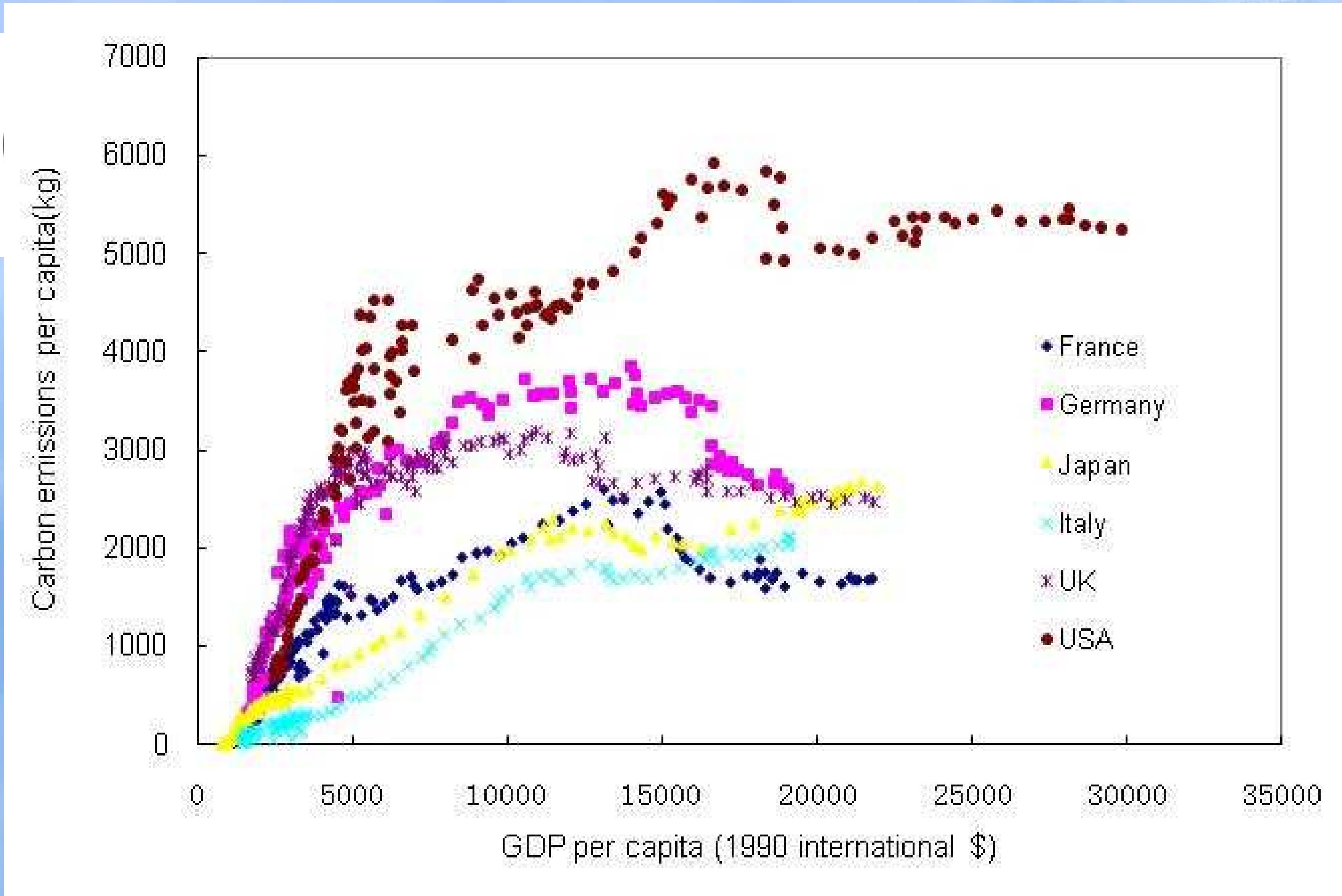
The relationship between carbon emissions intensity and GDP per capita in 6 developed countries

Data source: CDIAC,2008 ;Maddison, 2008



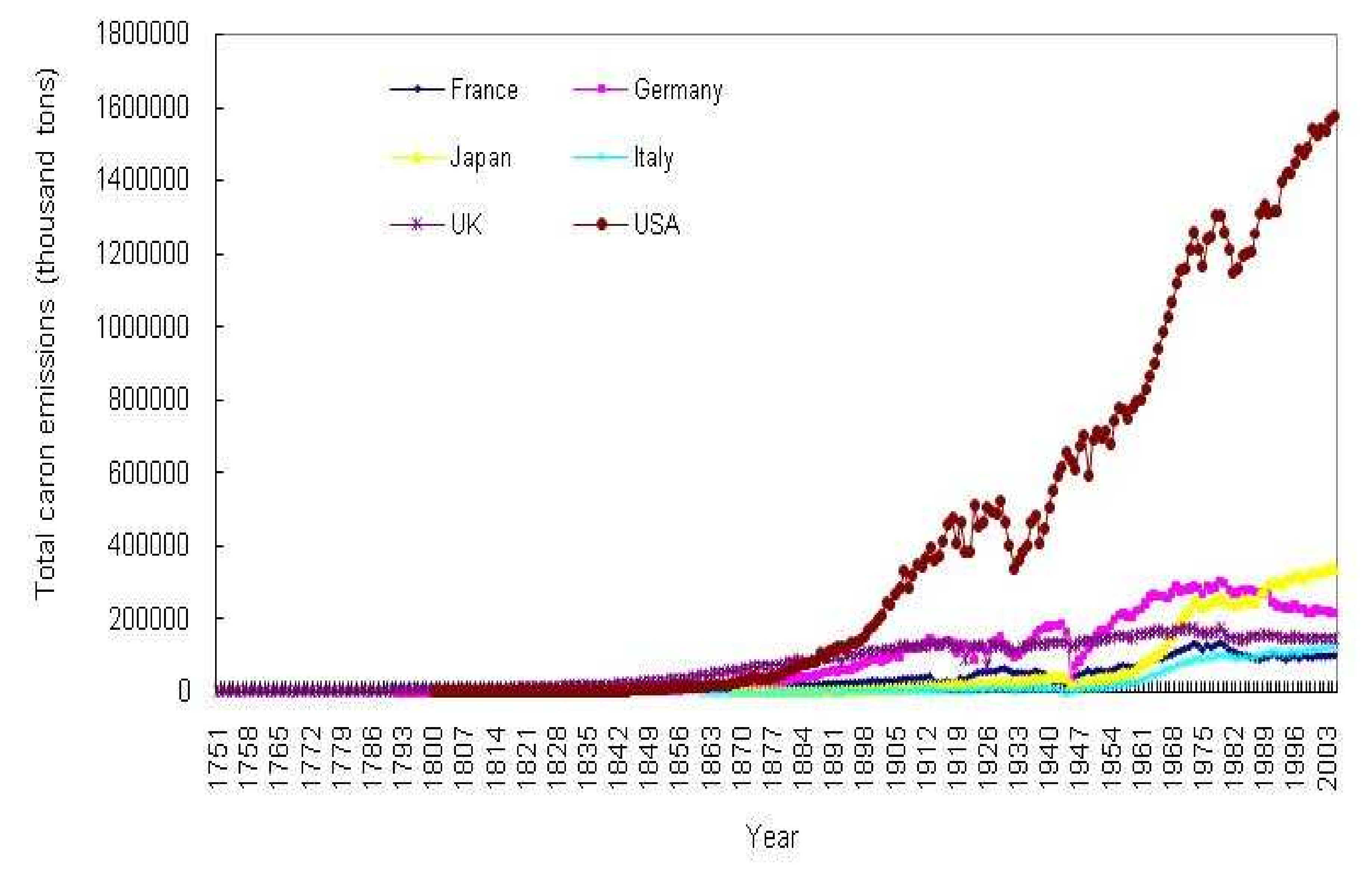
The historical trend of carbon emissions per capita in 6 developed countries

Data source: CDIAC,2008



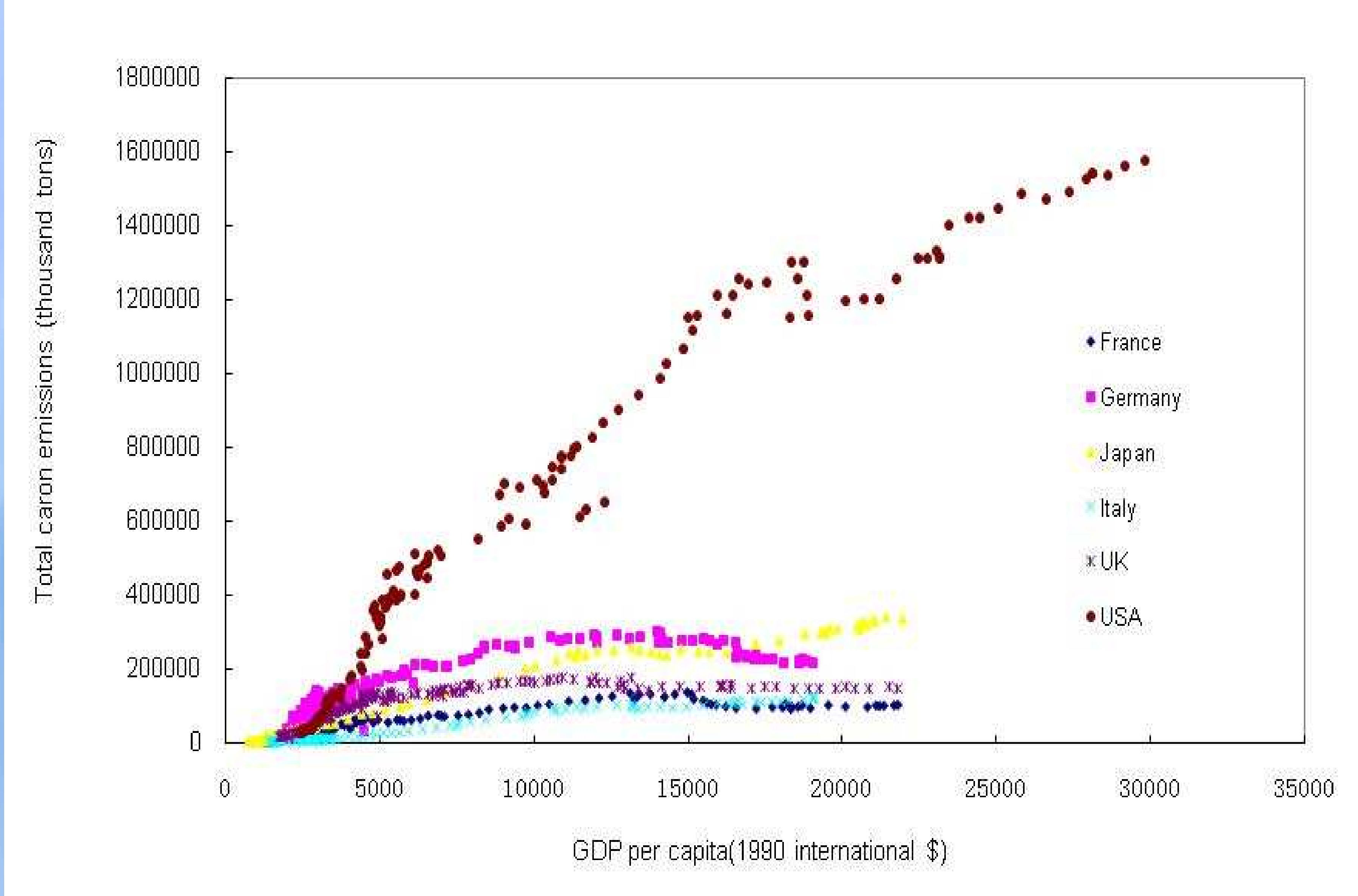
The relationship between carbon emissions and GDP per capita in 6 developed countries

Data source: CDIAC,2008; Maddison, 2008



The historical trend of total carbon emissions in 6 developed countries

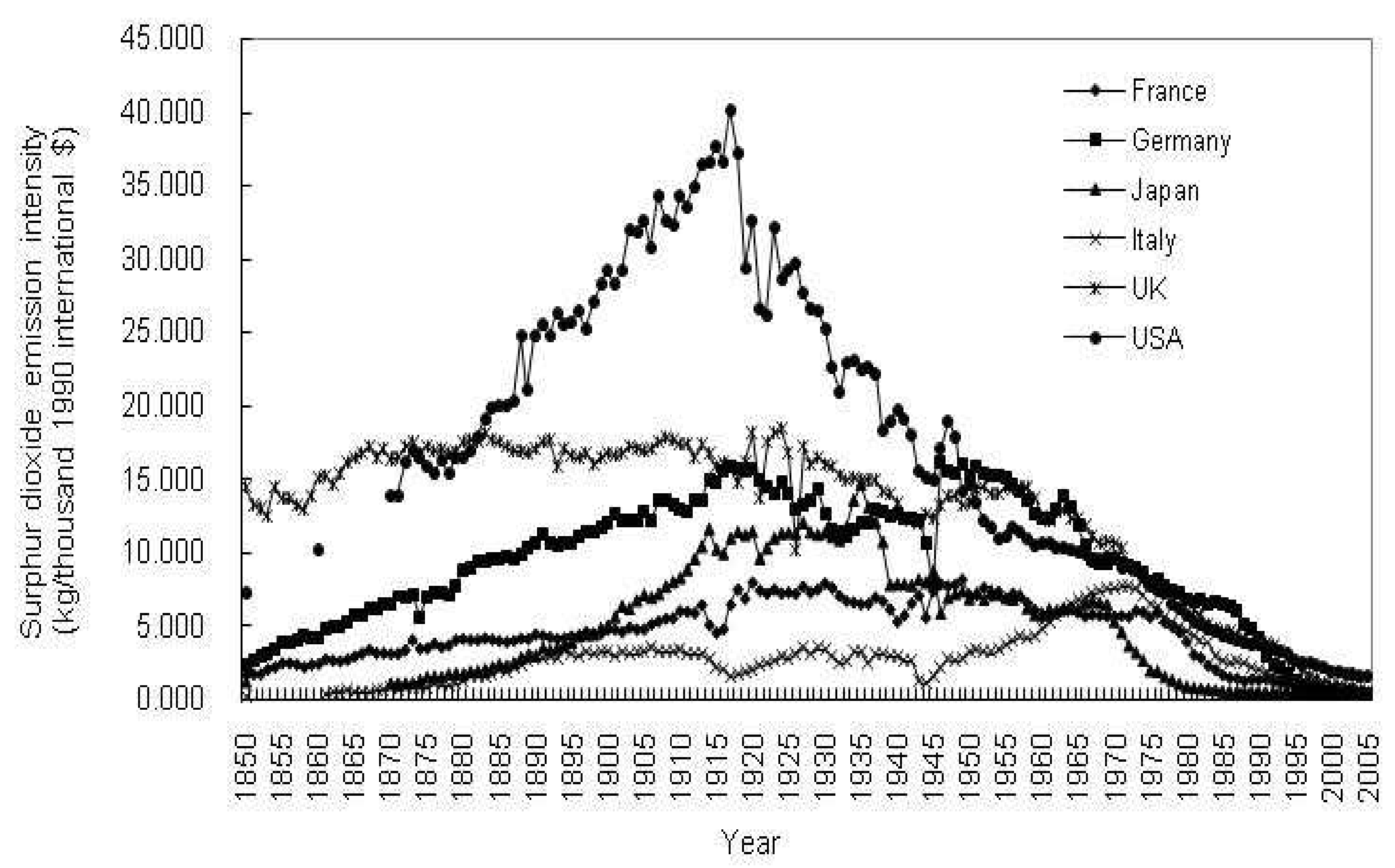
Data source: CDIAC,2008



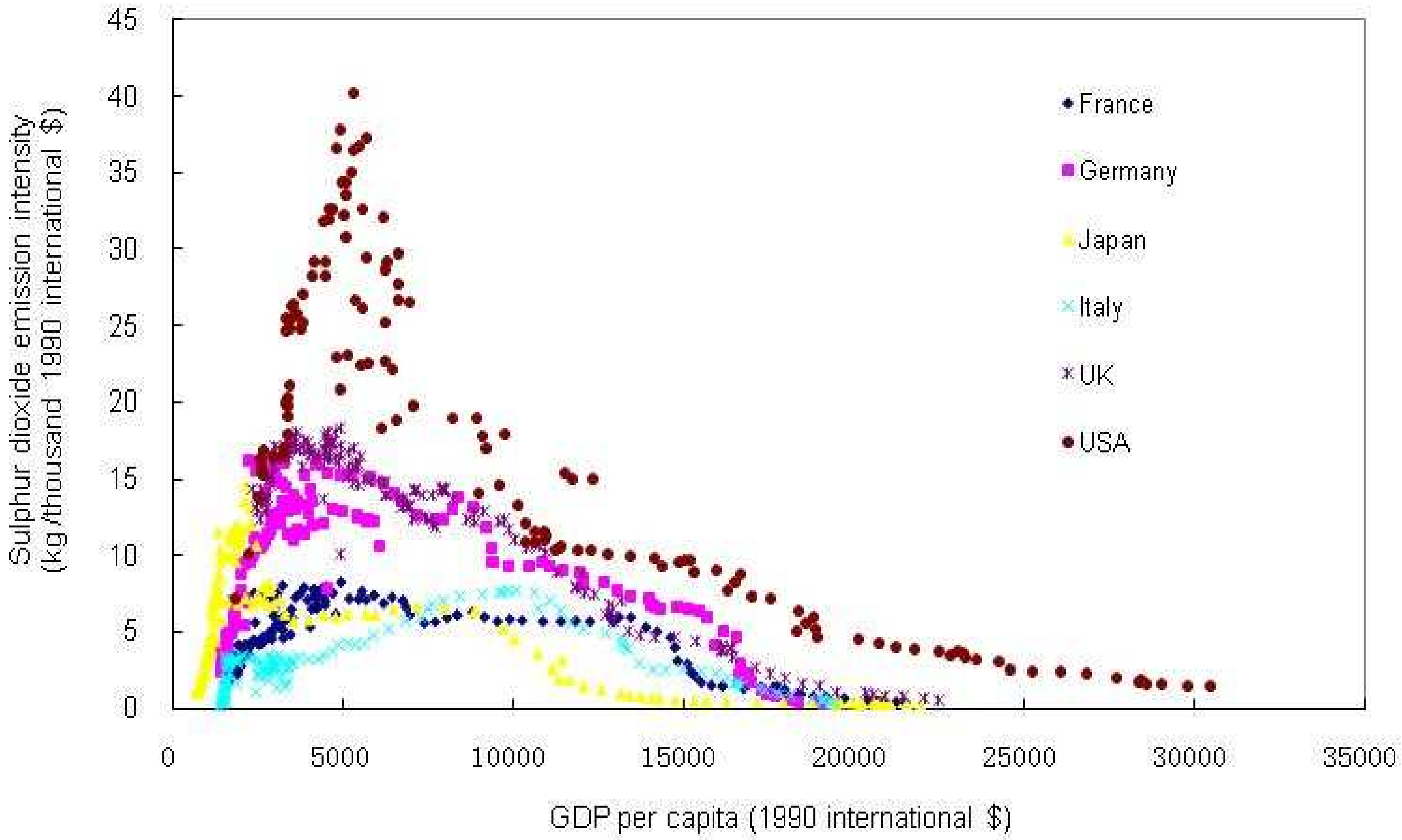
The relationship between total carbon emissions and GDP per capita in 6 developed countries

Data source: CDIAC,2008; Maddison, 2008

Empirical study on three inverted U shape curves hypothesis- taking sulphur dioxide emission as an example

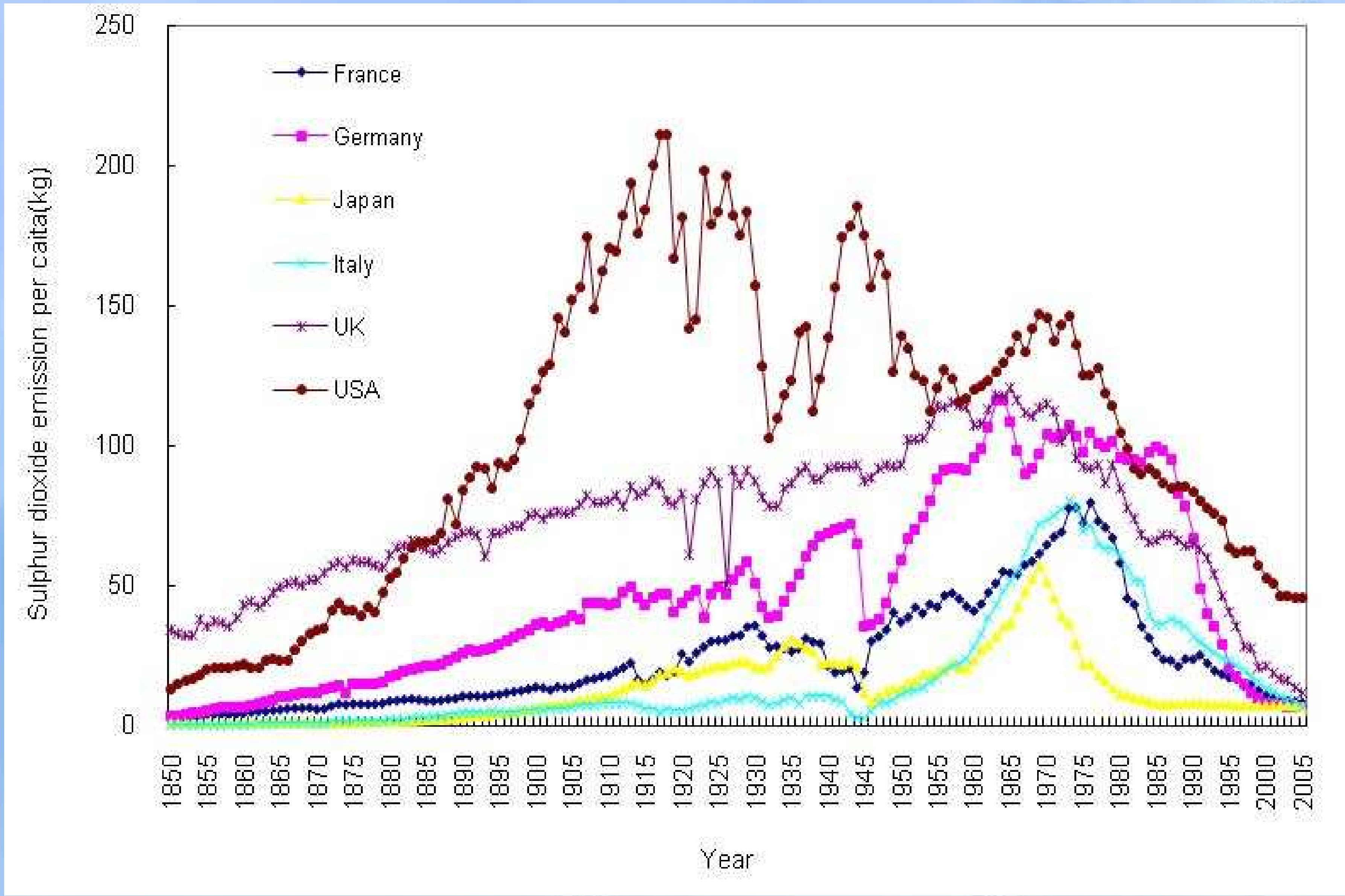


The historical trend of sulphur dioxide emission intensity in 6 developed countries
Data source: Maddison,2010; Smith et al, 2010



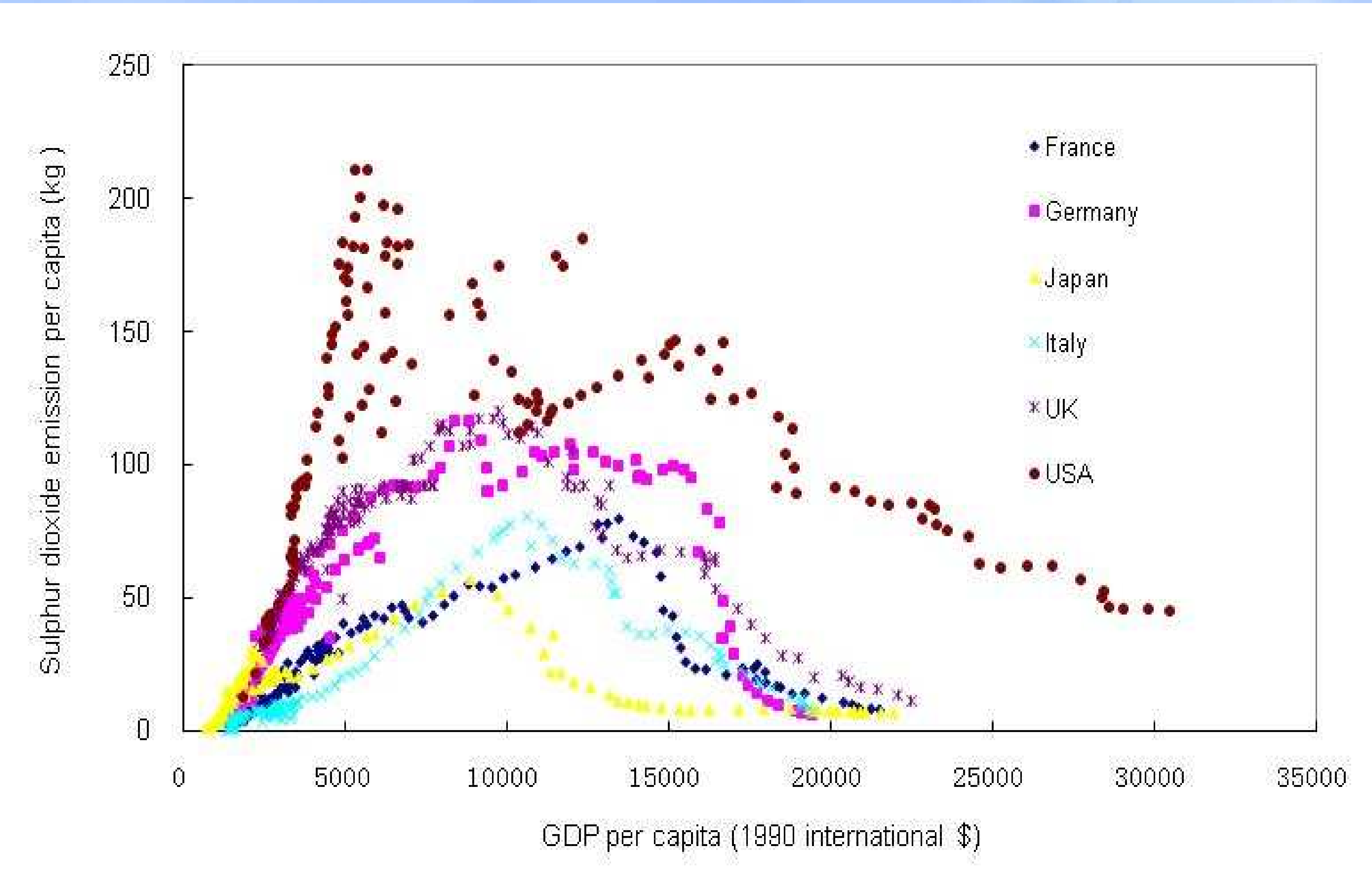
The relationship between sulphur dioxide emission intensity and GDP per capita in 6 developed countries

Data source: Maddison,2010; Smith et al, 2010



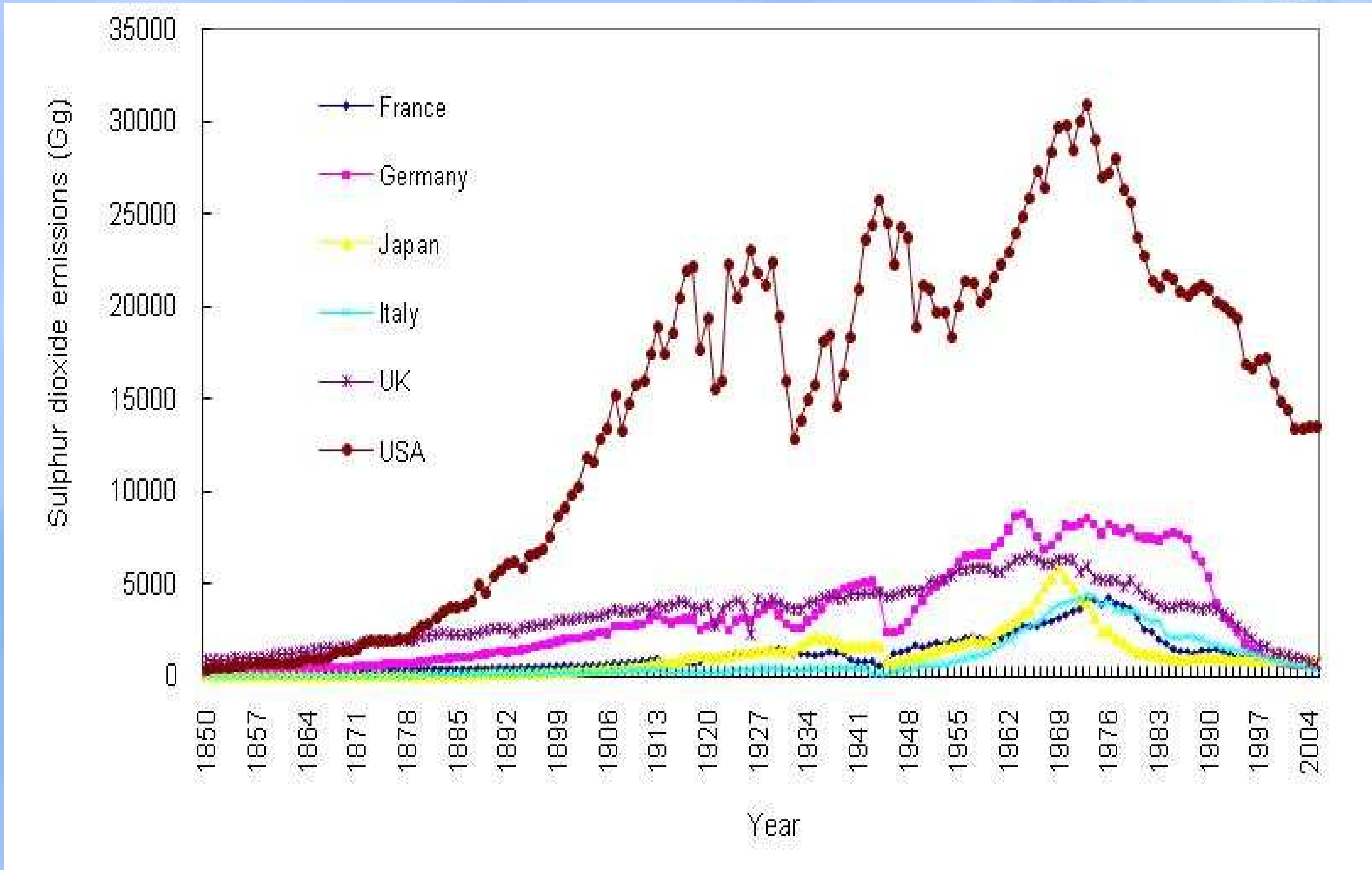
The historical trend of sulphur dioxide emission per capita in 6 developed countries

Data source: Maddison,2010; Smith et al, 2010



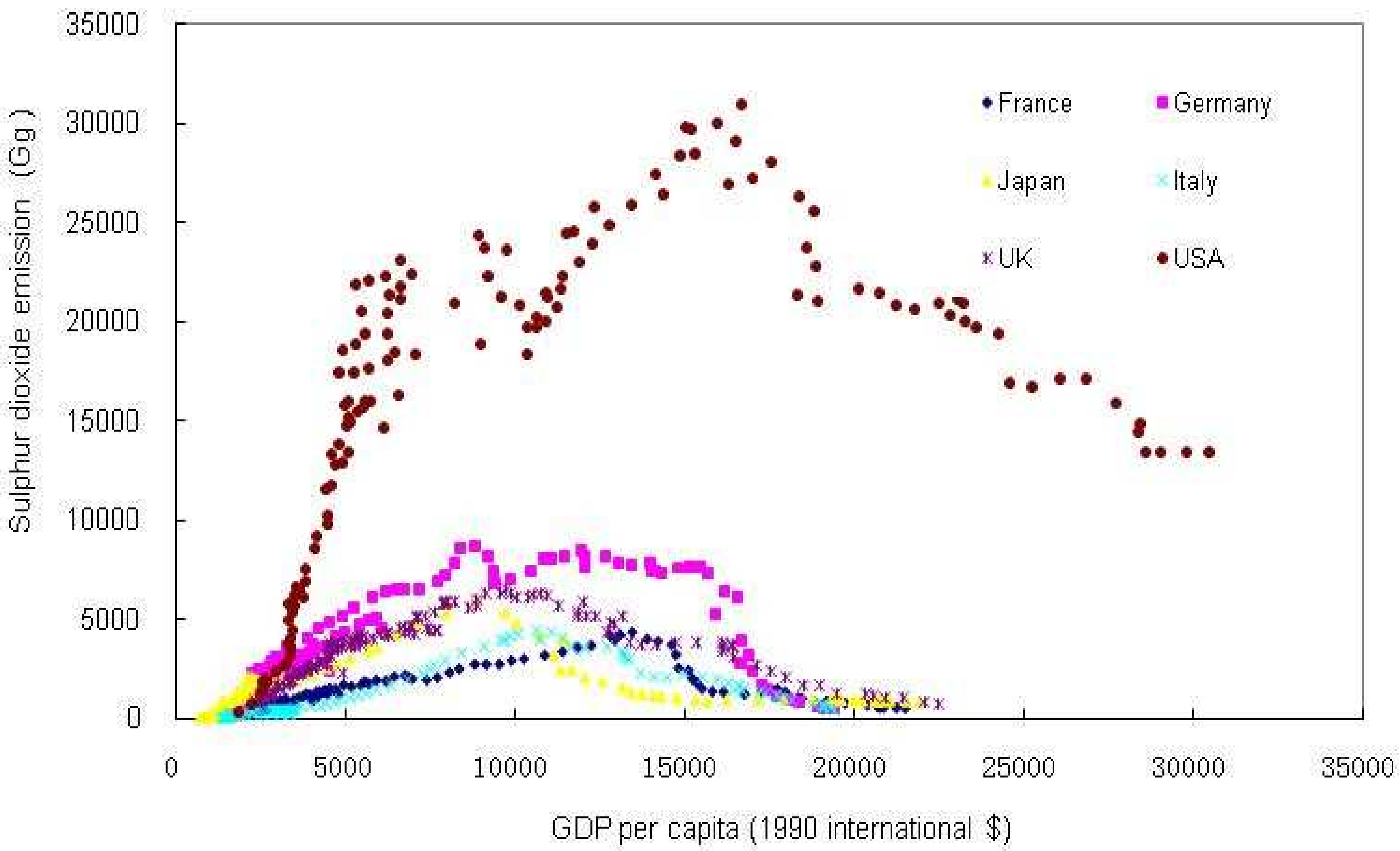
The relationship between sulphur dioxide emission and GDP per capita in 6 developed countries

Data source : Maddison,2010; Smith et al, 2010



The historical trend of total sulphur dioxide emissions in 6 developed countries

Data source: Maddison,2010; Smith et al, 2010



The relationship between total sulphur dioxide emission and GDP per capita in 6 developed countries

Data source: Maddison,2010; Smith et al, 2010

Empirical study on three inverted U shape curves hypothesis- taking China's main resource consumption and pollutant emissions since 1949 as an example

Changing Tendency of the Main Resources Consumption or Pollutants Discharge along Economic Development or Time in China

Categories of resources consumption or pollutants emissions	Periods	Resources consumption or pollutants emissions per unit of GDP		Resources consumption or pollutants emissions per capita		Total resources consumption or pollutants emissions	
		Tendency	Peak time	Tendency	Peak time	Tendency	Peak time
Fertilizer use	1952-2008	Inverted "U"	1991	Rising	None	Rising	None
Plastic membrane for agricultural use	1990-2007	Inverted "U"	2003	Rising	None	Rising	None
Pesticide use	1990-2007	Inverted "U"	1995	Rising	None	Rising	None
Energy consumption	1953-2008	Hump shape	1960/1977	Rising	None	Rising	None
CO_2 emissions from fuel combustions	1952-2006	Hump shape	1960/1976	Rising	None	Rising	None
Consumption of finished steel	1953-2008	Hump shape	1985/2007	Rising	None	Rising	None
Non-ferrous common metals use	1980-2007	"U" curve	1994	Rising	None	Rising	None
Cement consumption	1953-2008	Inverted "U"	2006	Rising	None	Rising	None
Timber consumption	1953-2000	Inverted "U"	1959	Hump shape	1985/1996	Inverted "U"	1996
Paper and paper board consumption	1952-2007	Inverted "U"	1992	Rising	None	Rising	None
Area of land under water and soil loss	1973-2005	Falling	None	Inverted "U"	1996	Inverted "U"	1996
Water consumption	1957-2008	Falling	None	Inverted "U"	1979	Rising	None
Wastewater discharge	1980-2008	Falling	None	Rising	None	Rising	None
Industrial wastewater discharge	1980-2008	Falling	None	"N" shape	1985 (first peak value)	"N" shape	1988 (first peak value)
Industrial waste gas emission	1983-2008	"U" curve	1999	Rising	None	Rising	None
SO_2 emission	1980-2008	Falling	None	Inverted "U"	2006	Inverted "U"	2006
Industrial SO_2 emission	1985-2008	Falling	None	Inverted "U"	2005	Inverted "U"	2006
Regional soot emission	1985-2008	Falling	None	Hump shape	1987/1996	Inverted "U"	1997
Industrial soot emission	1985-2008	Falling	None	Inverted "U"	1987	Inverted "U"	1997
Industrial solid	1980-2008	"U" curve	2000	Rising	None	Rising	None

Policy implications of the three inverted U-shaped curves hypothesis

- Three inverted U-shaped curves cannot be jumped over in general
- The time interval between different peaks or could be shortened and the value of different peak could be lowered
- What we can do are to surpass three peaks at as a lower cost of resource and environment as possible and as soon as possible while promoting economic development and satisfying moderate needs
- Different targets and emphasis of managing resource consumption and protecting environment at different development. At a lower development stage ,intensity or efficiency indicators could be chosen, but per capita or total amount indicator in higher development stage.

Environmental Performance Evaluation in China: Methodology and Applications

Three composite indicators developed

$$REPI_j = \frac{1}{n}\sum_{i}^{n} w_{ij} \frac{x_{ij}/g_j}{X_{i0}/G_0}$$

Resource and Environment Performance Index

$$PCI_j = \frac{1}{n}\sum_{i}^{n} w_{ij} \frac{x_{ij}/p_j}{X_{i0}/P_0}$$

Per capita resource consumption and pollutant discharge index

$$TI_j = \frac{1}{n}\sum_{i}^{n} w_{ij} \frac{x_{ij}}{X_{i0}}$$

Total Amount of Resource Consumption and Pollution Discharge Index

REPI: an eco-efficiency based composite indicator

- Resource and Environment Performance Index (REPI) was developed (CASSDSSG,2006-2012; Chen et al, 2008)
  - To monitor and evaluate resource and environmental performance (REP) of a region or country or levels of green development
  - To reflect the progress toward green development
  - To judge the effectiveness of various policies and measures taken

REPI Definition

$$REPI_j = \frac{1}{n}\sum_{i}^{n} w_{ij}\frac{x_{ij}/g_j}{X_{i0}/G_0}$$

x_{ij}/g_j : the i th resource consumption or pollutant discharge per unit of GDP of the j th country, region , sectors or firms;

X_{i0}/G_0: the i th resource consumption or pollutant discharge per unit GDP of the world , j th country or total sectors

REPI$_j$, in essence**,** is the weighted average value of the ratio of selected resources consumption and pollutants discharge performance / intensity

REPI significance

- The smaller the REPI value, the higher the resource productivity or eco-efficiency
- If REPI =1, Which indicates that *i* th resource and environmental performance of *j* th country or region or sector equals to that of the world or *j* th country or total sector ;
- If REPI >1, Which indicates that *i* th resource and environmental performance of *j* th country or region or sector is lower than that of the world or *j* th country or total sector;
- If REPI <1, Which indicates that *i* th resource and environmental performance of *j* th country or region or sector is higher than that of the world or *j* th country or total sector;

REPI significance

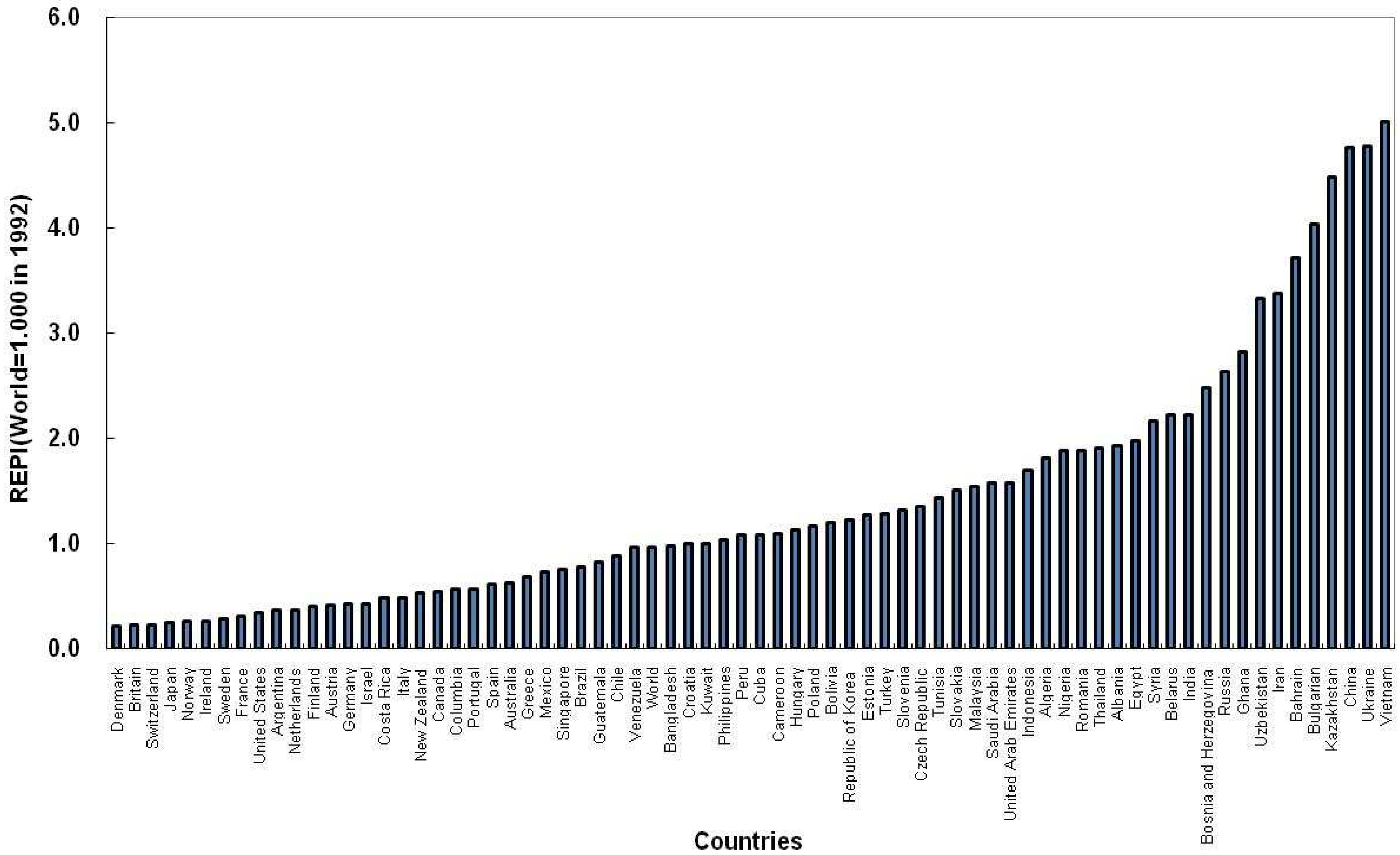
- The characteristics of REPI
  - indicators can be selected flexibly based on data availability
  - Applicable to different levels or scales including global, country, region, sectors, firm levels
  - Capable to conduct horizontal or vertical comparisons easily
  - Determining weight of each indicator is a challenge
  - The same weight given to each resource and pollutant performance indicator for simplicity in empirical study in general

REPI-based evaluation of resource and environmental performance or green development in 73 countries from 1990-2009

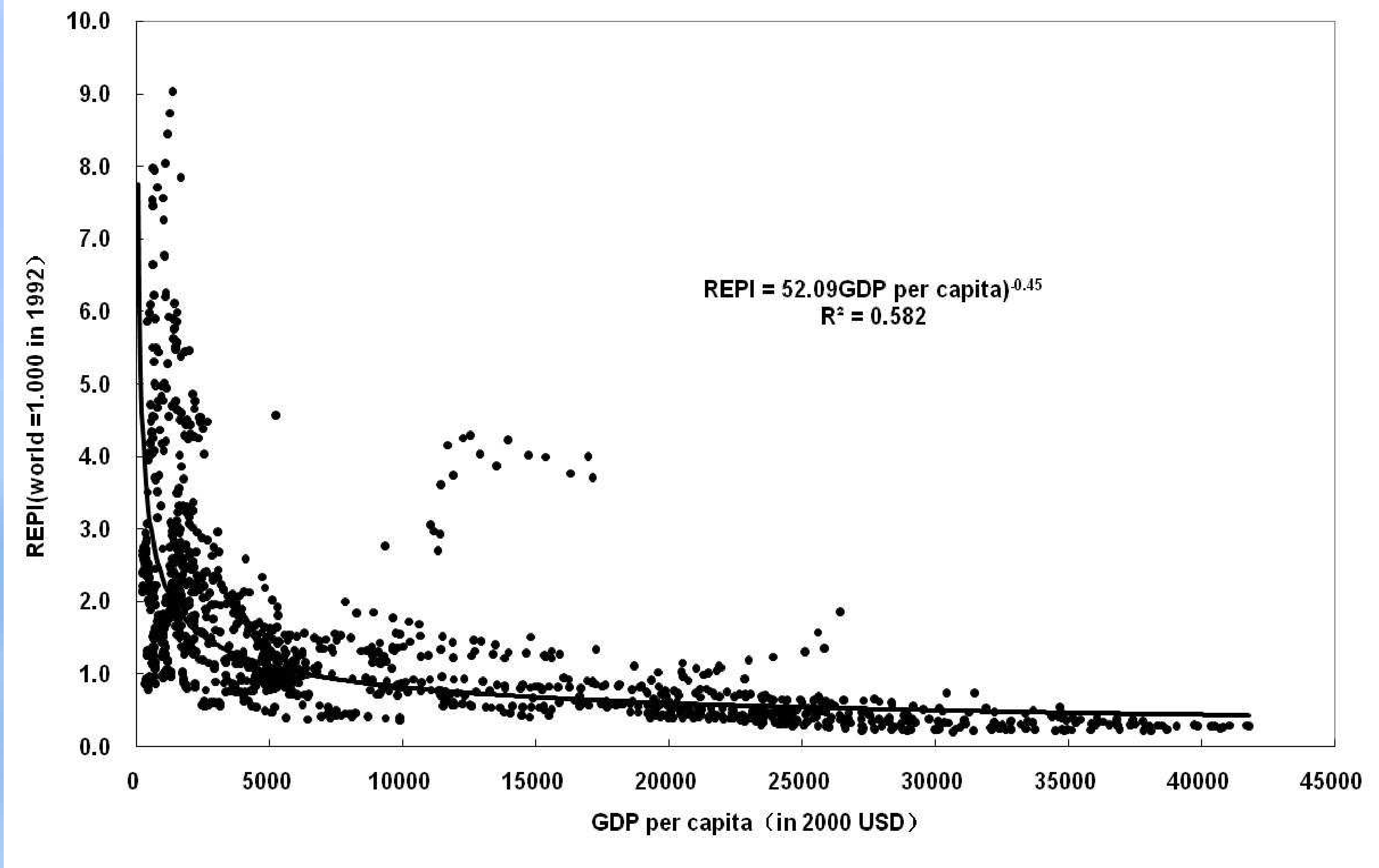
REPI-based evaluation of resource and environmental performance in 73 countries

- **7 resources and pollutants emissions chosen for REPI calculation:**
  - Primary energy;
  - Cement consumption;
  - Finished steel;
  - Non-ferrous common metals including copper, aluminum, zinc, lead, nickel, tin, cadmium;
  - CO_2 emissions from fossil fuels combustion
  - ODS consumption
  - SO_2 emissions
- **73 countries selected**

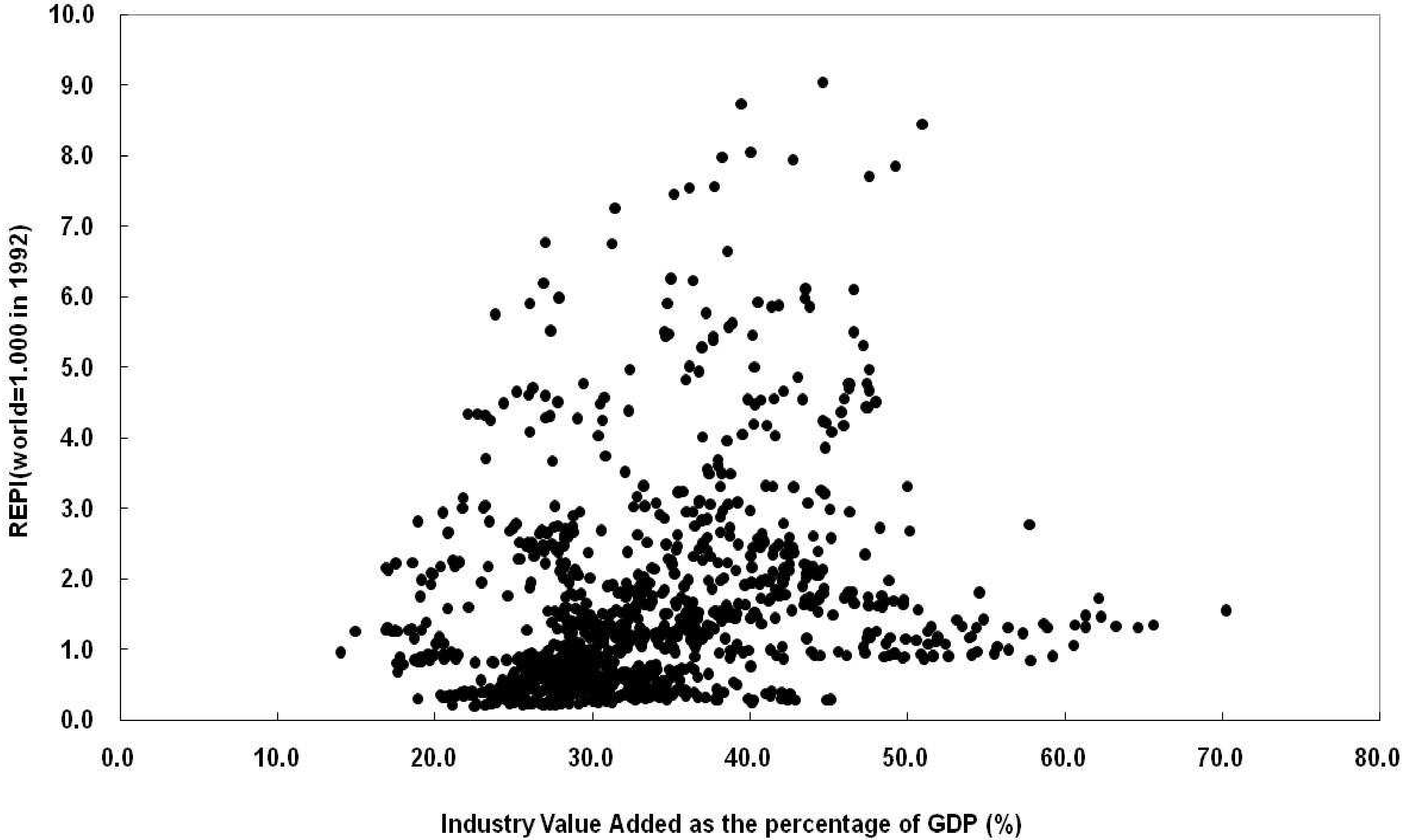
GDP (in 2000 US$) as 96.7% of the world total



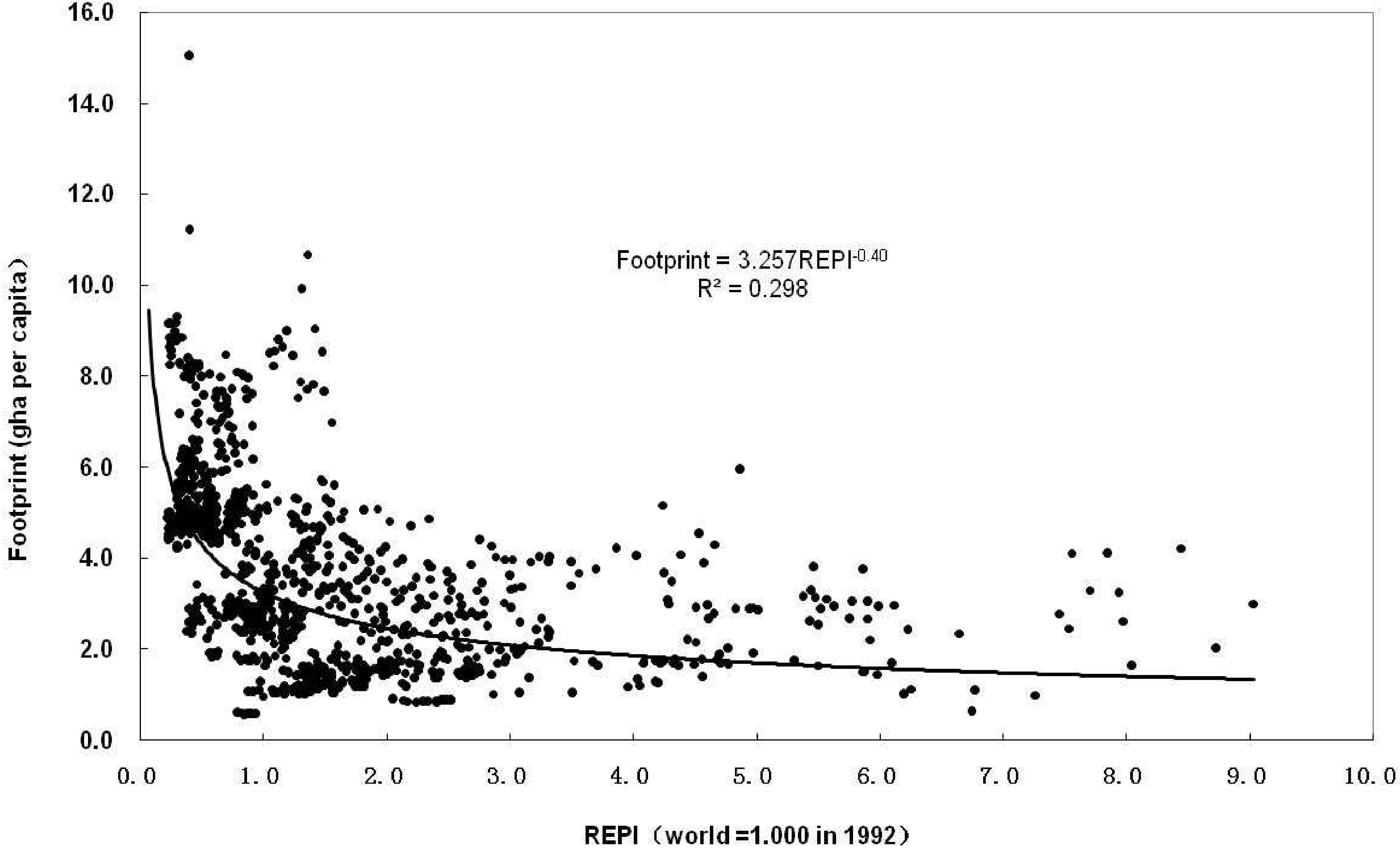
The ranking of REPI in the main countries in 2009
Data source: CSDR,2012



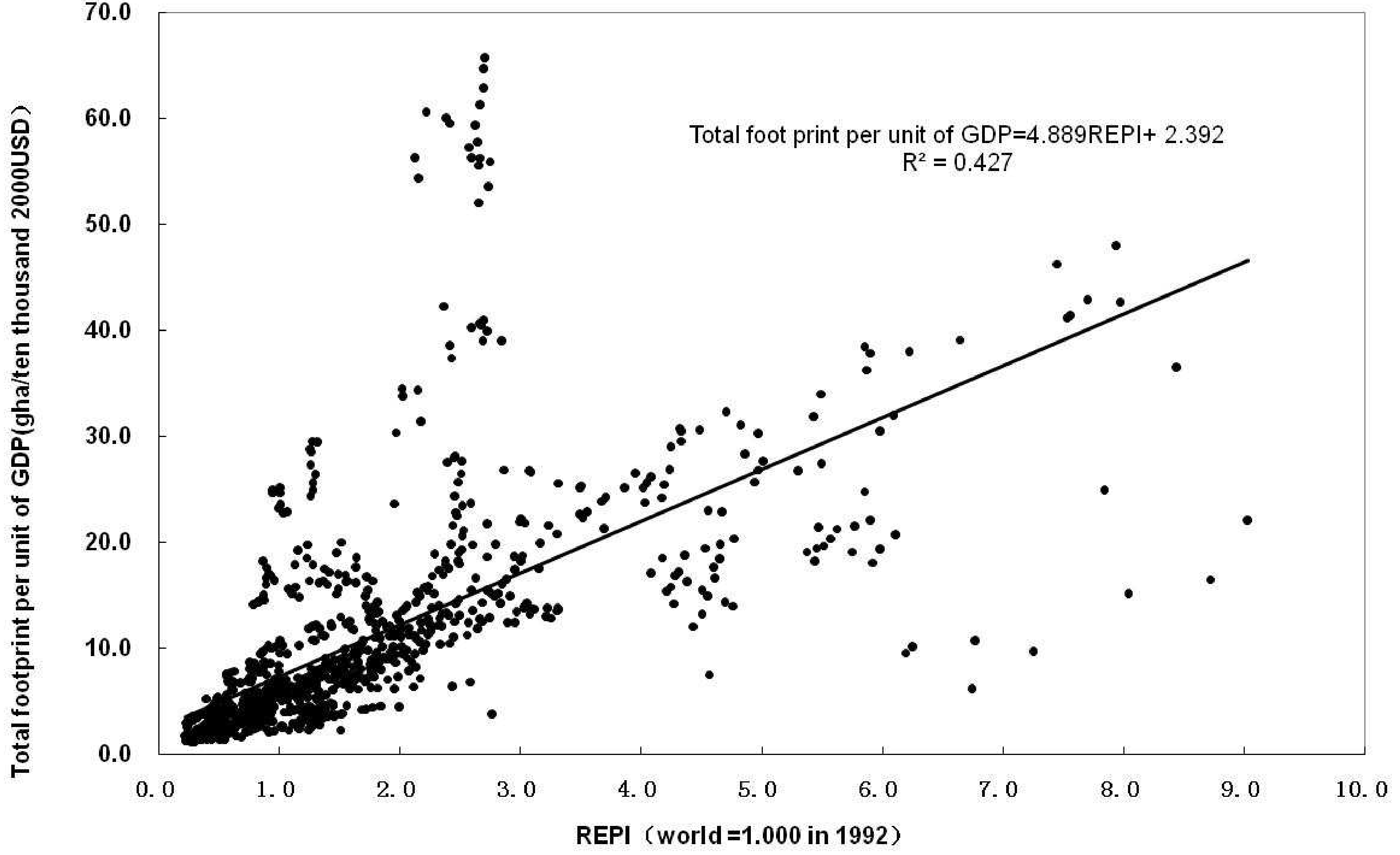
The relationship between REPI and GDP per capita in the main countries from 1990-2009
Data source: UNEP,2011; CSDR,2012



The relationship between REPI and percentage of industrial value added in GDP of the main countries from 1990-2009
Data source: UNEP,2011; CSDR,2012

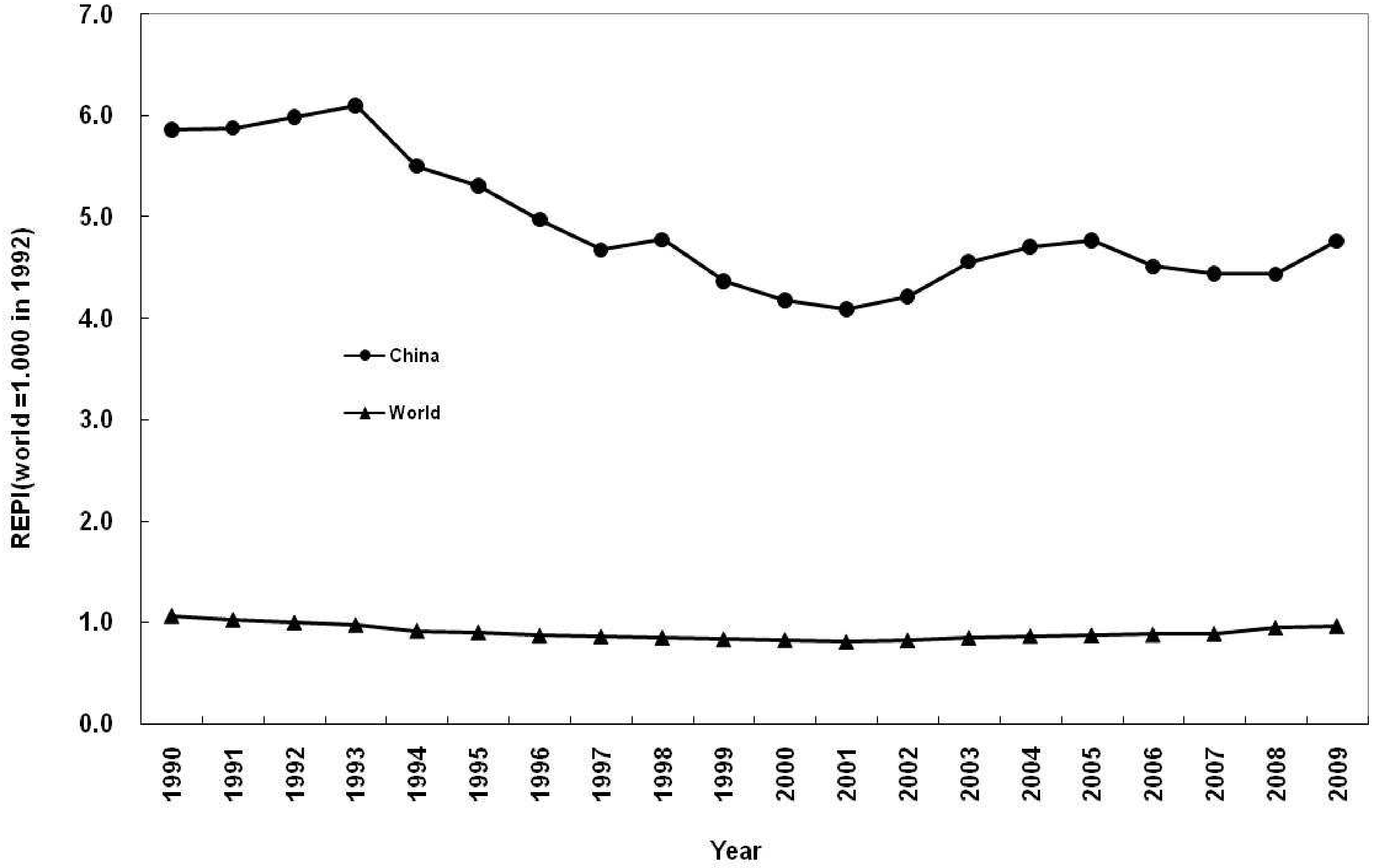


The relationship between REPI and Footprint in the main countries from 1990-2009
Data source: Global Footprint Network,2010; CSDR,2012



The relationship between REPI and Total footprint per unit of GDP in the main countries from 1990-2009

Data source: Global Footprint Network,2010; CSDR,2012



The variation tendency in REPI between China and World from 1990-2009
Data source: Global Footprint Network,2010; CSDR,2012

REPI-based evaluation of resource and environmental performance or green development in 31 provinces of China from 2000-2005

REPI-based evaluation for resource and environmental performance in 31 provinces of China

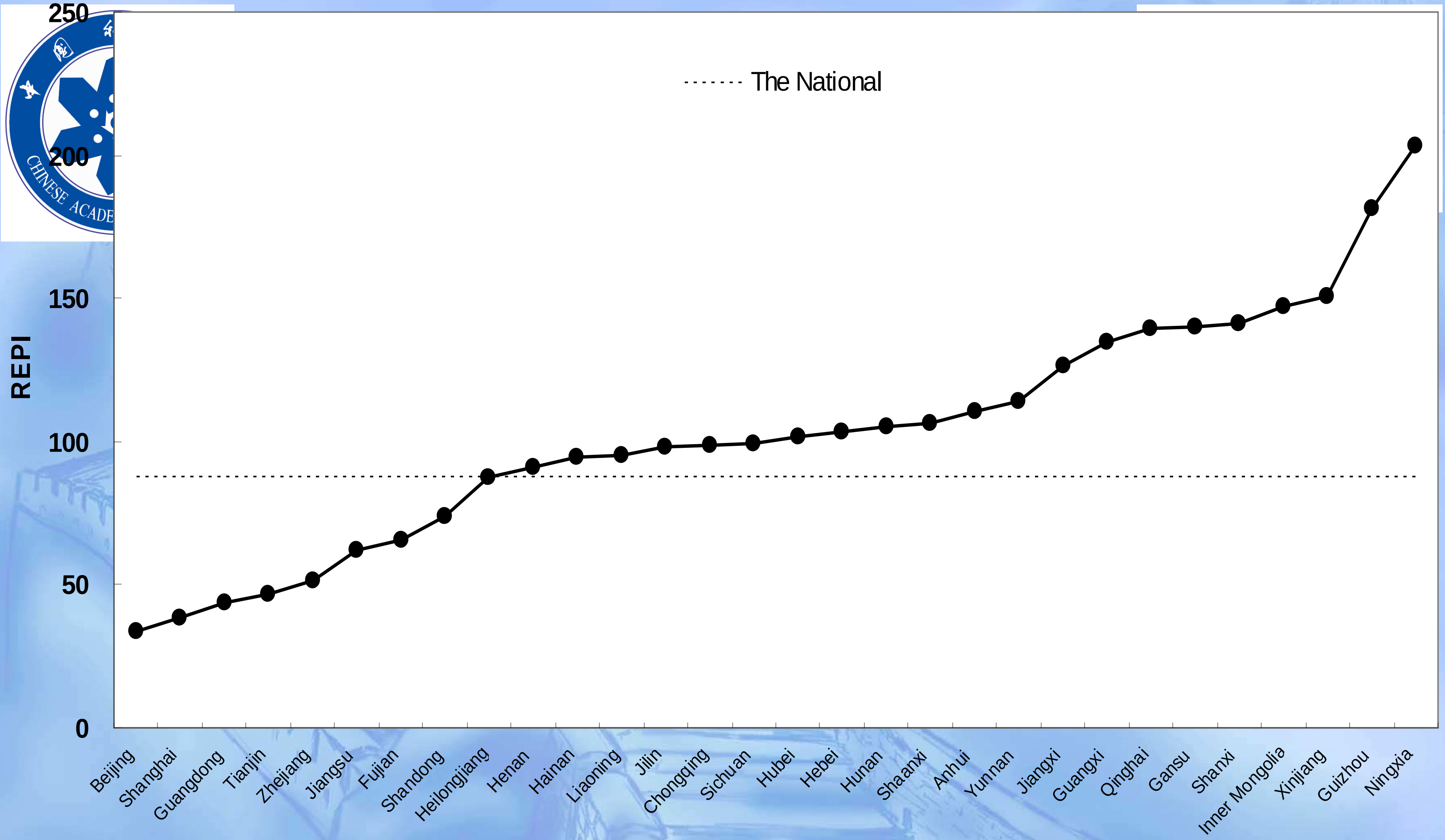
- 7 kinds of resources and pollutants chosen for REPI calculation :
  - primary energy
  - water use
  - land area for construction
  - total investment in fixed assets(which indirectly represents the demand for raw materials)
  - COD discharge
  - SO_2 emission
  - volume of industrial solid wastes produced

The REPI of China's provinces in 2000~2005 (1)

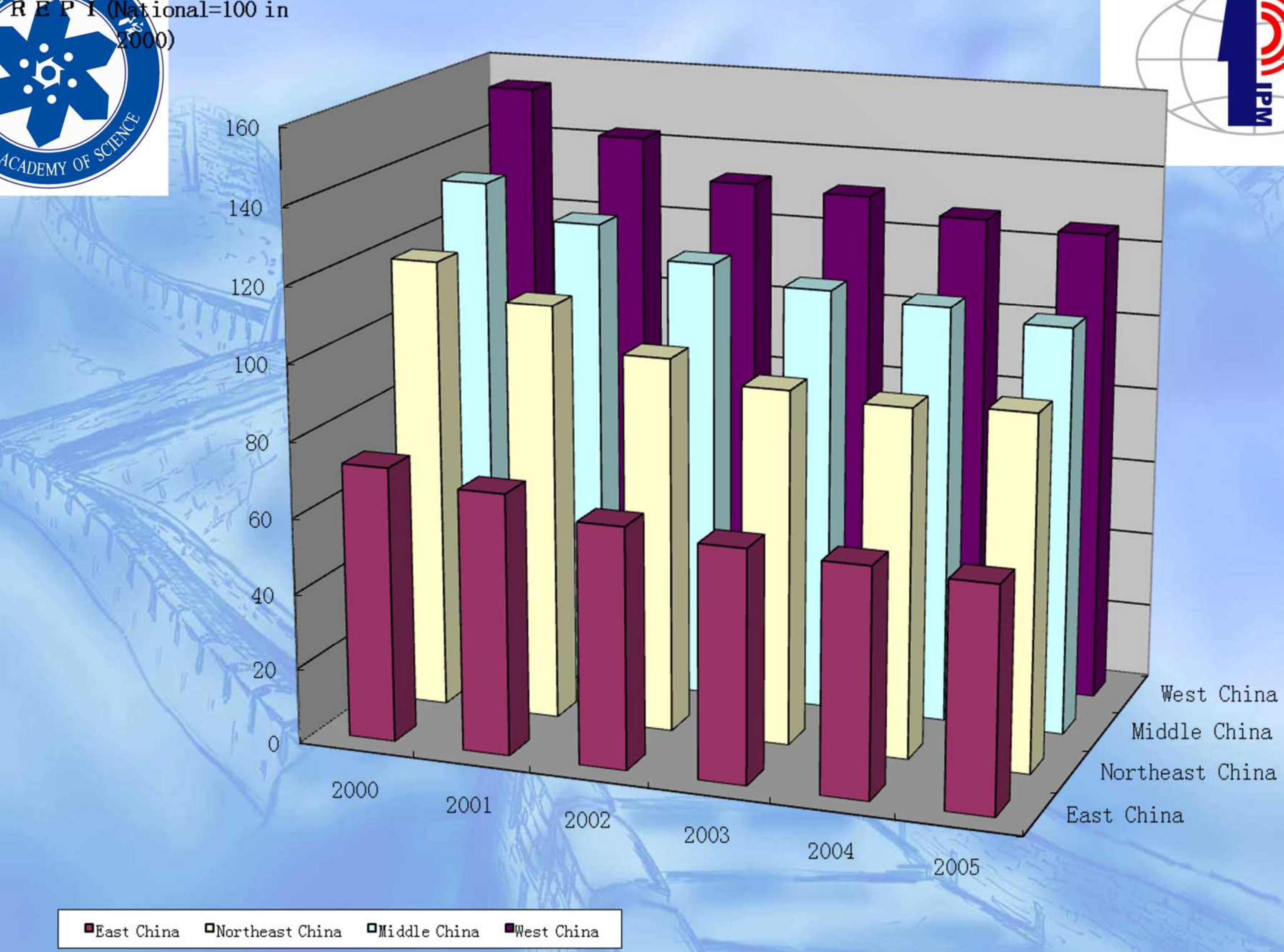
Region	2000	2001	2002	2003	2004	2005
National	100.0	94.8	88.4	86.4	87.1	87.4
Beijing	42.9	40.0	37.5	37.0	35.9	33.9
Tianjin	64.8	54.3	48.7	47.9	46.4	46.8
Hebei	118.8	114.3	103.7	99.5	108.1	103.4
Shanxi	178.9	166.0	158.4	154.1	145.6	141.5
Inner Mongolia	161.1	152.9	141.9	151.3	143.3	147.4
Liaoning	116.1	106.8	96.6	91.1	89.6	95.1
Jilin	123.1	113.2	104.6	99.9	98.2	98.4
Heilongjiang	121.7	113.5	99.1	93.1	91.2	87.6
Shanghai	49.0	46.1	43.0	40.7	39.0	38.6
Jiangsu	75.4	72.0	64.7	62.8	62.6	62.3
Zhejiang	60.2	57.0	55.7	55.1	53.7	51.7
Anhui	139.9	134.3	121.1	116.2	112.0	110.4
Fujian	77.1	81.8	72.6	66.7	64.4	65.8
Jiangxi	152.1	134.6	135.1	128.2	129.2	126.6
Shandong	93.1	85.3	81.7	79.4	74.6	73.8

The REPI of China's provinces in 2000~2005 (2)

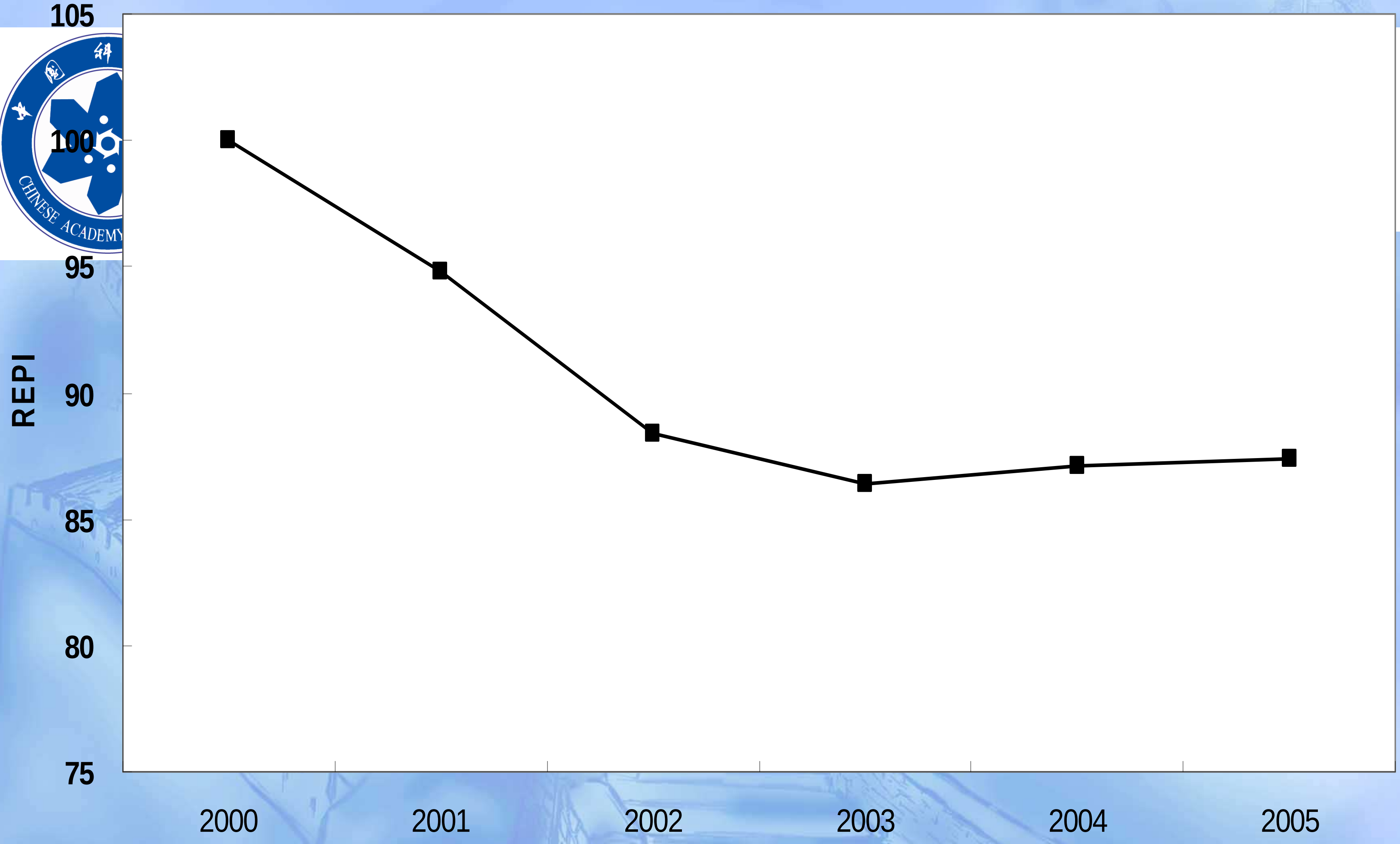
Region	2000	2001	2002	2003	2004	2005
Henan	110.3	105.1	97.8	92.3	91.3	90.9
Hubei	141.5	128.3	117.0	110.5	108.5	101.9
Hunan	123.5	117.3	108.7	108.0	107.7	105.1
Guangdong	56.5	55.2	50.0	47.8	45.6	43.9
Guangxi	172.1	155.5	144.8	143.7	139.2	135.0
Hainan	114.0	100.9	100.6	97.6	99.4	94.6
Chongqing	119.0	110.7	101.7	99.2	98.8	98.9
Sichuan	136.5	124.7	113.9	110.5	105.2	99.1
Guizhou	226.0	209.6	198.6	200.2	193.5	181.7
Yunnan	126.9	120.2	114.4	111.0	111.0	114.0
Shaanxi	124.4	116.2	109.7	107.4	106.4	106.2
Gansu	178.4	158.5	153.1	150.3	142.5	140.0
Qinghai	147.1	139.7	129.7	124.9	128.6	139.3
Ningxia	256.0	237.6	202.9	202.7	194.2	203.6
Xinjiang	192.1	181.4	163.9	159.7	155.9	150.9



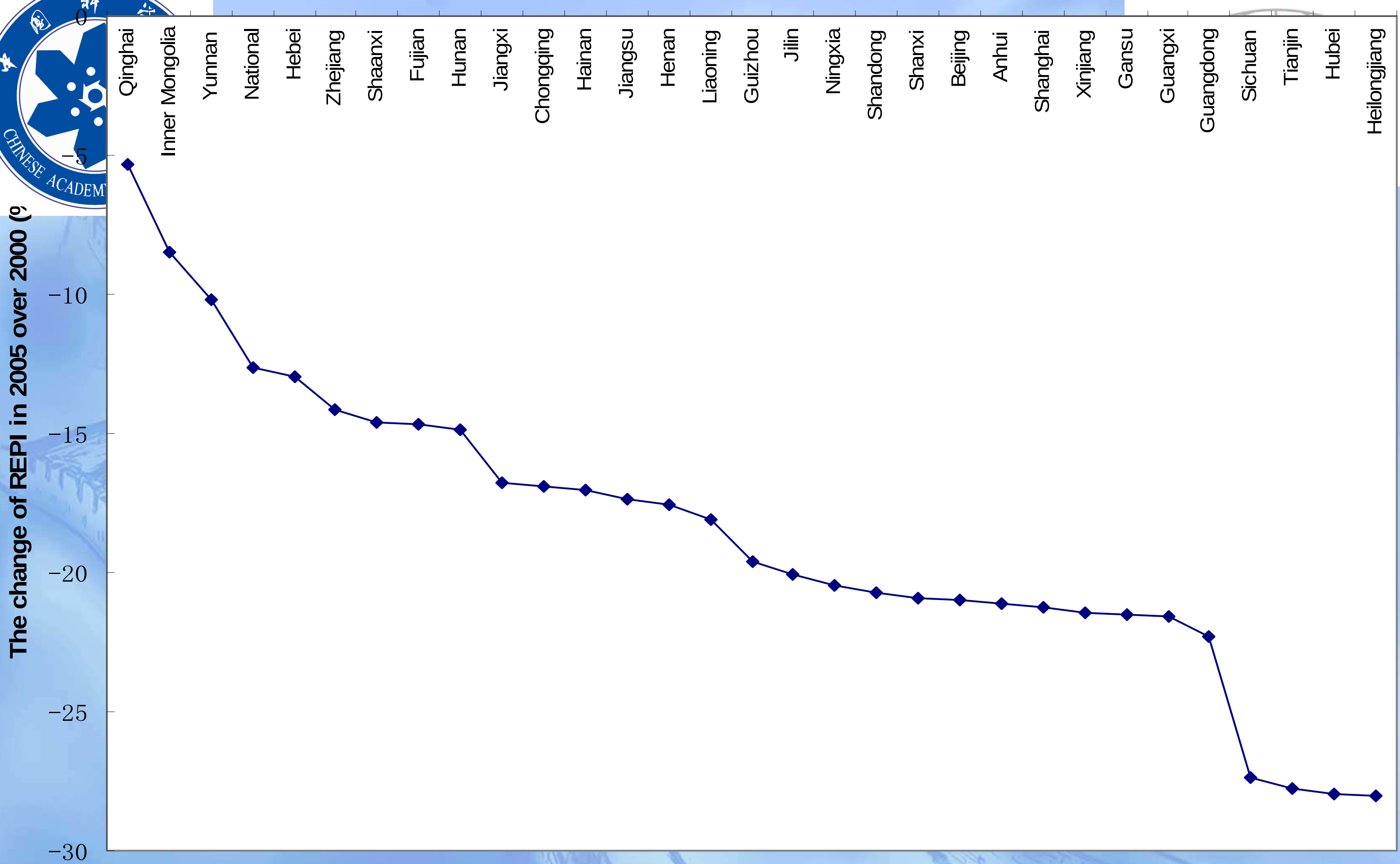
The Provincial REPI Ranking in 2005



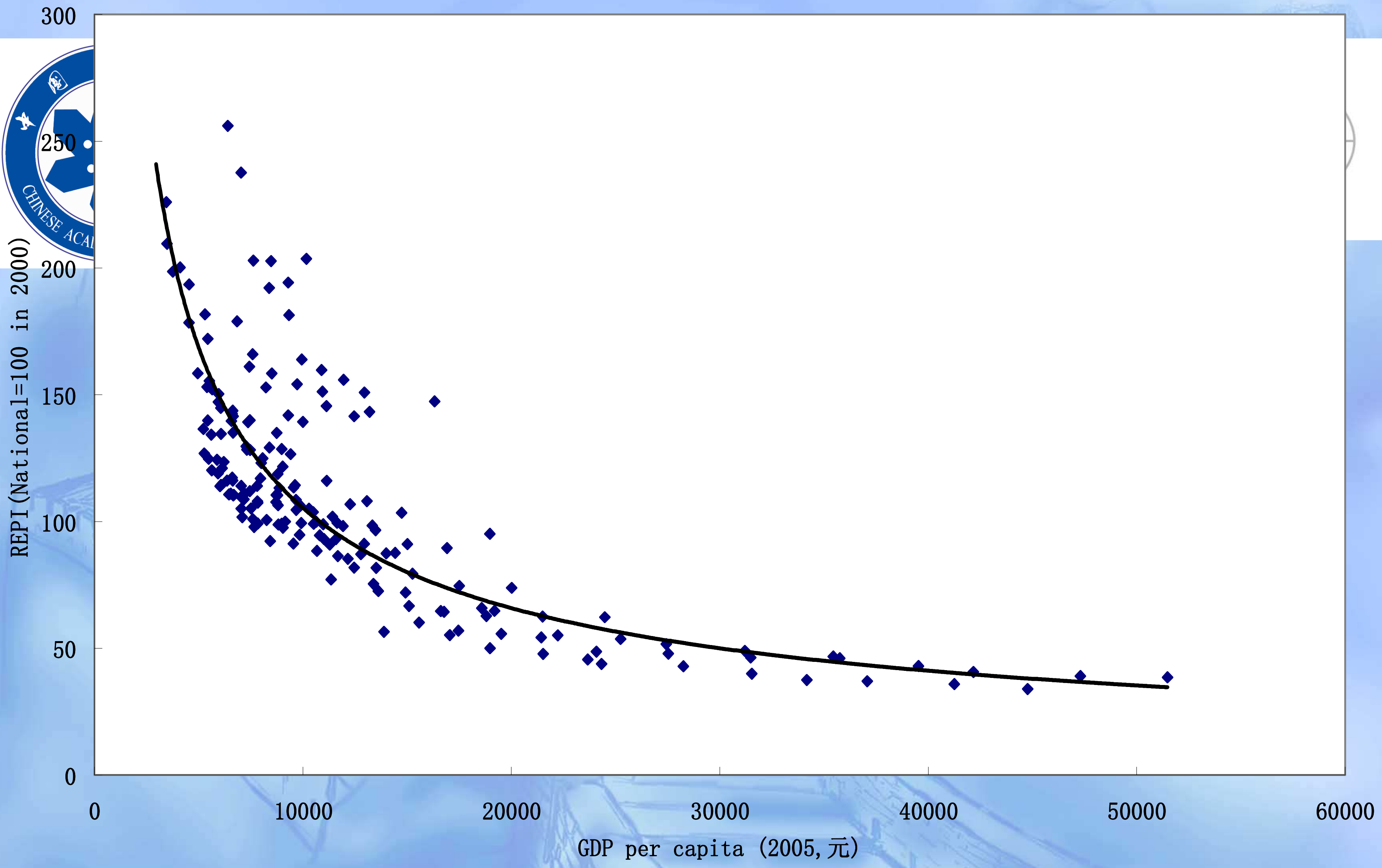
REPI of East China, Middle China, West China, and Northeast China in 2000~2005



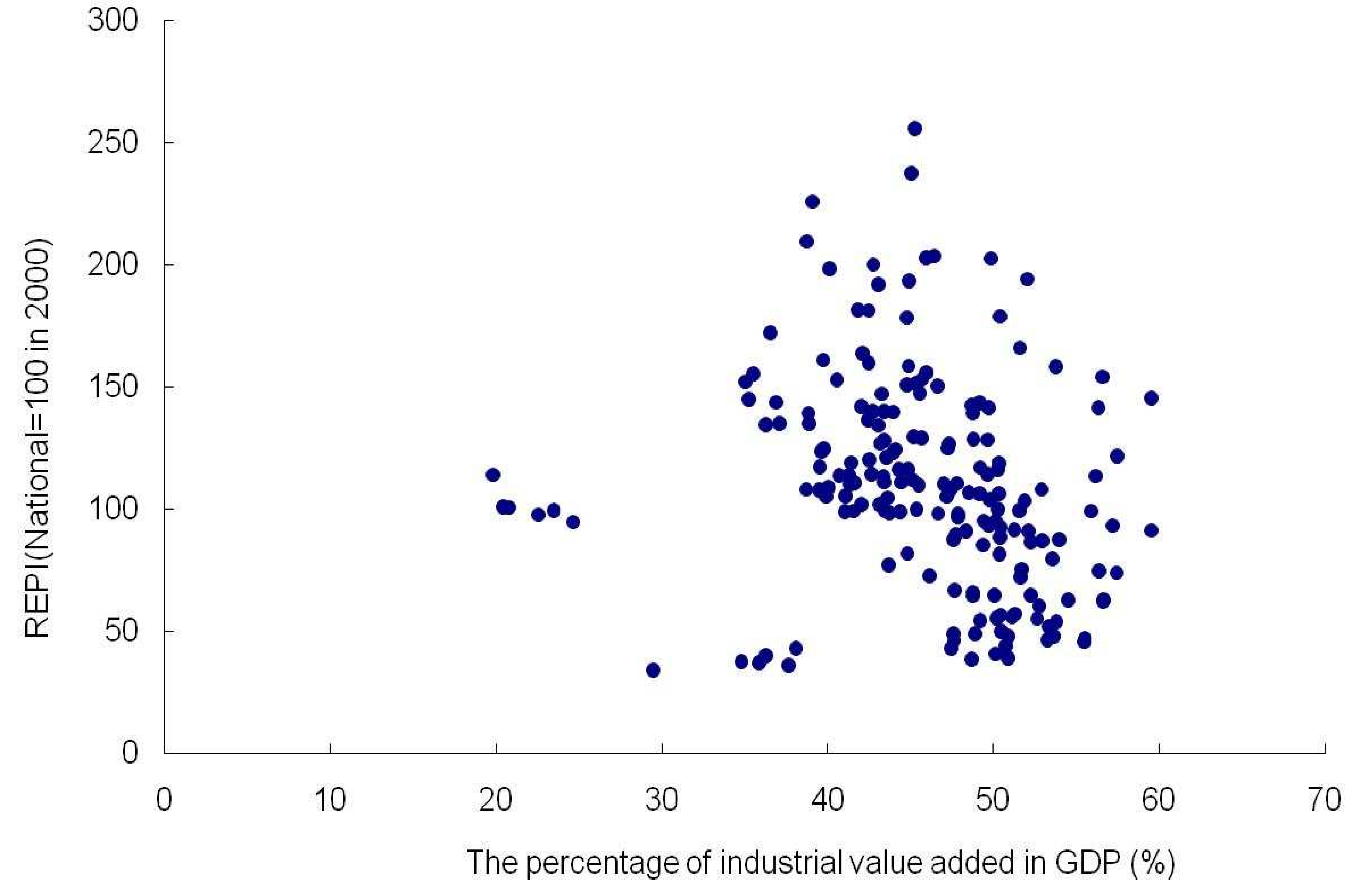
The tendency of the variation of National REPI



The change of REPI of each province in 2005 over 2000



Relationship between REPI and per capita GDP in each provinces in 2000~2005



Relationship between REPI and the percentage of industrial value added in GDP in each provinces in 2000~2005

REPI-based evaluation of industrial resource and environmental performance or green development in 31 provinces of China from 2005-2010

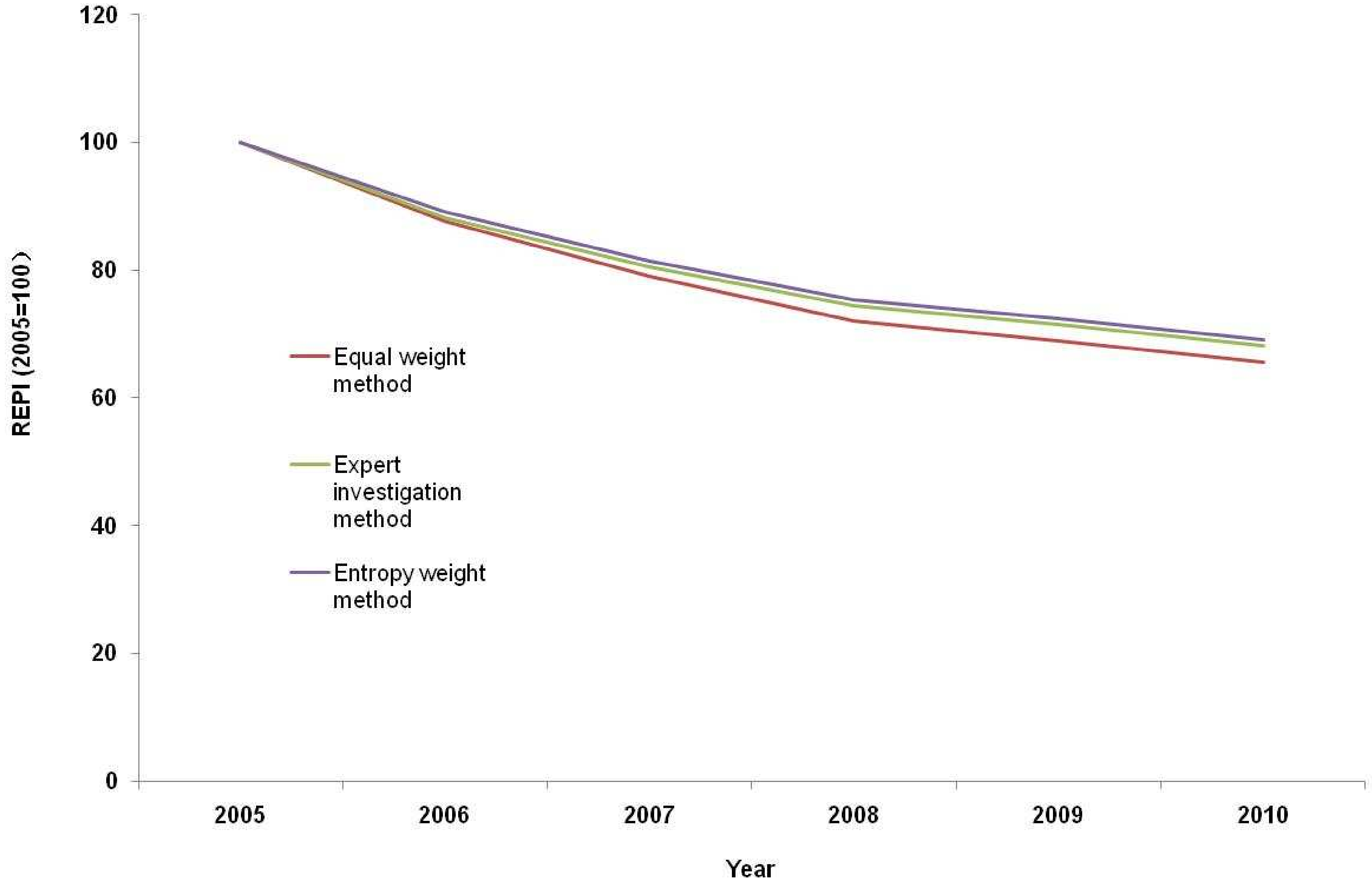
Green development of China's industry

- REPI has been used for evaluating and monitoring industrial green development in China and it 31 provinces

  - Economic indicator selected: Industrial value added
  - 10 kinds of resources and pollutants chosen for industrial REPI calculation : primary energy consumption, water use, land use area, raw materials consumption, COD discharge, Ammonia nitrogen discharge, SO_2 emission, Nitrogen oxides emission, Smoke and dust emission, industrial solid wastes.
  - Determination of weight for each resource or pollutant emission by 3 methods adopted

Solution for determining weight of each indicator

Topics	Sub topics	indicators	Weight approach		
			Equal weight method	Expert investigation method	Entropy weight method
Resource consumption		Primary energy	0.10	0.15	0.10
		Water use	0.10	0.14	0.13
		Land use	0.10	0.13	0.10
		Raw materials	0.10	0.08	0.15
Pollutant emissions	Waste water	COD	0.10	0.10	0.08
		Ammonia nitrogen	0.10	0.10	0.06
	Waste gas	SO2	0.10	0.08	0.10
		Nitrogen oxides	0.10	0.08	0.06
		Smoke and dust	0.10	0.04	0.09
	Waste solid	solid wastes	0.10	0.10	0.13



Three results of REPI for China from 2000-2010 based on three weight approaches

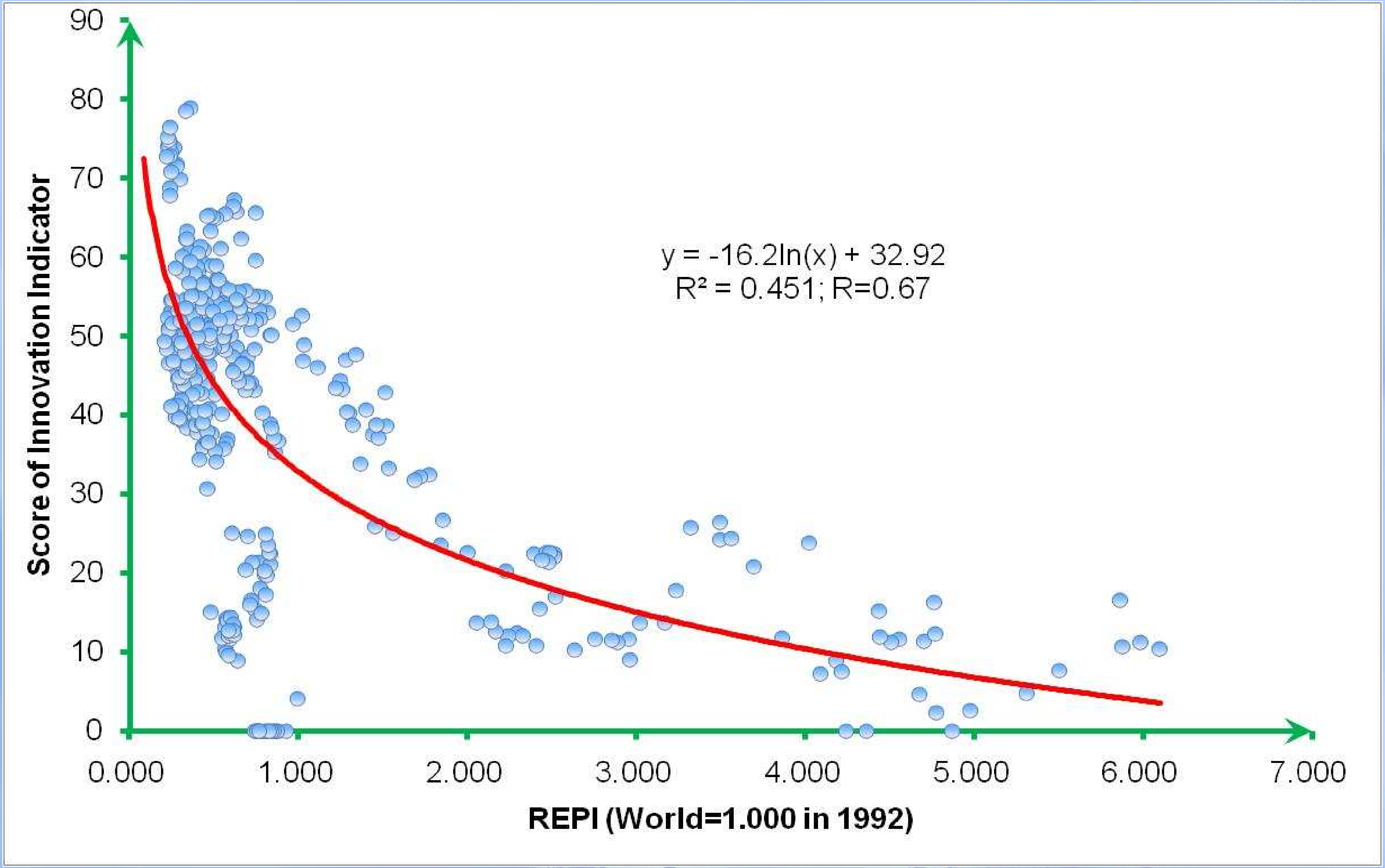
Annual growth rates of industrial REPI for 31 provinces between 2005 and 2010 based on three weight approaches and their rankings

Provinces	equal weight method	Ranking	expert investigation method	Ranking	entropy weight method	Ranking
Beijing	-5.33	29	-5.30	29	-5.28	28
Tianjin	-12.67	11	-12.14	9	-12.1	9
Hebei	-8.76	22	-8.25	22	-6.98	25
Shanxi	-10.9	16	-10.04	16	-10.92	13
Inner Mongolia	-11.7	13	-11.16	13	-9.65	18
Liaoning	-12.61	12	-11.72	11	-11.26	12
Jilin	-14.15	5	-13.58	5	-13.56	5
Heilongjiang	-10.3	17	-9.65	18	-9.96	17
Shanghai	-6.73	27	-6.18	28	-6.5	26
Jiangsu	-10.91	15	-10.26	15	-10.76	14
Zhejiang	-10.09	18	-9.36	19	-9.6	19
Anhui	-13.39	8	-12.38	8	-12.13	8
Fujian	-8.6	23	-7.92	23	-8.2	22
Jiangxi	-14.99	4	-14.23	4	-14.95	4
Shandong	-9.9	20	-9.03	20	-9.42	20
Henan	-13.87	6	-12.63	7	-12.86	6
Hubei	-12.71	10	-11.37	12	-11.54	11
Hunan	-18.38	3	-17.15	3	-17.16	3
Guangdong	-7.79	24	-6.74	24	-7.71	23
Guangxi	-20.31	1	-19.12	1	-18.74	1
Hainan	-10.05	19	-9.84	17	-10.29	16
Chongqing	-18.85	2	-17.19	2	-18.08	2
Sichuan	-12.87	9	-11.93	10	-11.97	10
Guizhou	-6.98	26	-6.35	27	-6.42	27
Yunnan	-7.49	25	-6.57	25	-7.48	24
Shaanxi	-11.13	14	-11.07	14	-10.44	15
Gansu	-13.5	7	-13.03	6	-12.3	7
Qinghai	-9.1	21	-8.82	21	-8.91	21
Ningxia	-5.84	28	-6.40	26	-4.56	29
Xinjiang	-1.6	30	-1.44	30	-0.72	30

Eco-efficiency & eco-innovation

Eco-efficiency & eco-innovation

- To improve eco-efficiency need eco-innovation
  - Eco-efficiency affected by many factors such as technologies, policies or institutions
  - The variation in eco-efficiency as the result of changes of various factors reflects to a certain degree the technological progress in broad sense
  - Eco-innovation : key to improve eco-efficiency and realizing green development or environmentally sustainable development



The relationship between REPI and the score of innovation indicator in the period from 1990-2009

Data source: CSDR 2012; Innovation indicator 2011

Conclusions and Discussions

- "Three inverted U shaped curves hypothesis" makes it possible to integrate such concepts and hypotheses as EKC Hypothesis, Decoupling and Dematerialization theory
- Eco-efficiency can be regarded as the premise , basic approach or foundation to realize green development or environmentally sustainable development
- It is possible for REPI to become a composite indicator to measure and monitor environmental performance, green development or the effects and speeds of eco-innovations

Conclusions and Discussions

- **Open room left for improvement including:**
  - **Elaboration of “Three inverted U shaped curves hypothesis” and empirical study,**
  - **Some problems on the indicator selection, weight and driving forces of REPI**
  - **Case studies strengthened**

Thank you for your attention!

sfchen@casipm.ac.cn

CAS Sustainable Development Strategy Study Group

http://www.china-sds.org

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