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Estimation of Environmental Kuznets Curve for Various Indicators: Evidence from Cross-Section Data Analysis

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Abstract:

COP15 concluded the " Copenhagen Accord " with take note of all participant countries, but failed to reach a broad agreement that binds all of countries. This reluctant result is partly due to objection of many developing countries, including some Asian countries, which regard strong regulation on global environment as interference to their growth and development. This study tries to estimate environmental Kuznets curve (EKC) for various indicators based on cross-section data provided as Environmental Performance Index (EPI) developed by Yale and Colombia Universities. The inverted-U shaped EKC suggests that economic development does not conflict with global environment quality in long-term. The estimation results support inverted-U shaped EKC for some EPI individual indicators but fails for others. The existence of inverted-U shaped EKC, however, does not deny efforts to reduce or mitigate environmental burdens at all. Considering situations of Asian income situation and present global environmental issues, it is absolutely required to take some reducing or mitigating measures against environmental burdens.

Keywords: Environmental Kuznets Curve, Cross-Section Analysis, Economic Development, Environmental Quality, Environmental Performance Index

JEL Classifications: Q56, Q53, O13

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1. Introduction

In December 2009, The 15th United Nations Climate Change Conference (COP15) held in Copenhagen, the capital of Denmark, concluded with the " Copenhagen Accord " drawn up by a limited group of countries and formally accepted by the official session of all participants to " take note " of it. But COP15 failed to reach a broad agreement that binds all participant countries. This reluctant result is partly due to objection of many developing countries that regard strong regulation on global environmental as interference against their growth and development. " Copenhagen Accord, " consisting of 12 paragraphs, can be summarized as follows:

1) Long-Term Objective

We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity.

2) Annex I Parties (Developed Countries)

Annex I Parties that are Party to the Kyoto Protocol commit to implement individually or jointly the quantified economy-wide emissions targets for 2020, to be submitted to the secretariat by 31 January 2010, and will thereby further strengthen the emissions reductions initiated by the Kyoto Protocol. Delivery of reductions and financing by developed countries will be measured, reported and verified in accordance with existing and any further guidelines.

3) Non-Annex I Parties (Developing Countries)

Non-Annex I Parties to the Convention will implement mitigation actions, including those to be submitted to the secretariat in the context of sustainable development. Least developed countries and small island developing States may undertake actions voluntarily and on the basis of support. Mitigation actions taken by Non-Annex I Parties will be subject to their domestic measurement, reporting and verification the result of which will be reported through their national communications every two years. Nationally appropriate mitigation actions seeking international support will be subject to international measurement, reporting and verification.

4) Market Approach

We decide to pursue various approaches, including opportunities to use markets, to enhance the cost-effectiveness of, and to promote mitigation actions. Developing countries, especially those with low emitting economies should be provided incentives to continue to develop on a low emission pathway.

5) Fund Access to Developing Countries

The collective commitment by developed countries is to provide new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010-2012 with balanced allocation between adaptation and mitigation. Funding for adaptation will be prioritized for the most vulnerable developing countries, such as the least developed countries, small island developing States and Africa. In the context of meaningful mitigation actions and transparency on implementation, developed countries commit to a goal of mobilizing jointly USD 100 billion dollars a year by 2020 to address the needs of developing countries. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance.

6) Assessment

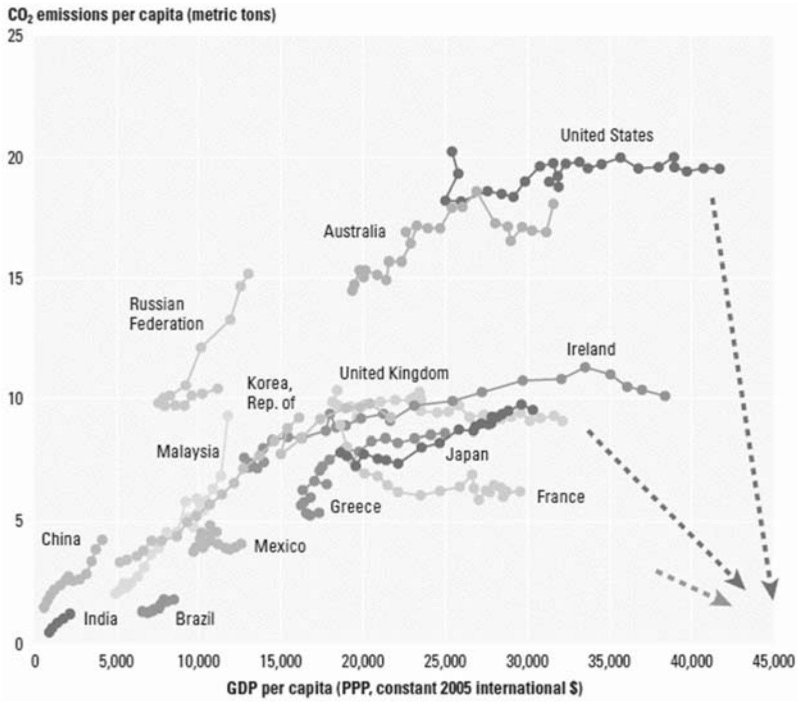
We call for an assessment of the implementation of this Accord to be completed by 2015.

From the view point of Asian development strategies, a deep attention must be paid whether economic development raises global environmental burdens or not because many developing countries increase emission matter according to their growth, for instance, carbon dioxide (hereafter, CO2), sulfur dioxide (hereafter, SO2), nitrogen oxide (hereafter, NOX), and suspended particulate matter (hereafter, SPM), etc. However, World Bank (2009) insists that the inverted-U shaped environmental Kuznets curve (hereafter, EKC) for CO2 emissions may hold as Figure 1.

As well-known among economists, the original Kuznets curve was postulated by Kuznets (1955). This curve depicts the relationship between income inequality and economic development as inverted-U shape. According to Dinda (2004), Panayotou (1993) for the first time names this relationship between environmental burdens and economic development as EKC. If EKC hypothesis holds, per capita environmental burdens will automatically decrease after the turning point of EKC. Arrow et al (1995), however, present an opposite view and strongly insist that these curves do not imply that growth by itself can solve the problem of environmental degradation.

This study employs per capita PPP GDP and Environmental Performance Index (here-

Figure 1: Energy-related CO2 emissions per capita



Note: CO2 Emissions and GDP per capita are from 1980 to 2005.
Source: World Bank (2009) Figure 4.6 p.197

after, EPI) to estimate EKC for various indicators based on cross-section data. A quadratic inverted-U shaped EKC that depicts the relationship between environmental burden and income is assumed. EPI is estimated and provided as results of a collaboration of Yale and Colombia Universities on its web site *http://epi.yale.edu/*. The EPI 2006 data includes 238 countries and areas[1] and consists of 6 policy categories and 16 indicators.[2] Although EPI 2008 data are already published, this study employs EPI 2006 data because of the data availability of GDP, which are taken from Penn World Table 6.3,[3] where Real GDP per capita (Constant Prices: Chain series)[4] is available until 2007.

Apart from this introduction section, this study consists of three sections: the second section surveys some existing literatures related to EKC; the third section reports estimation

1 Among these 238 countries and areas, 133 are selected for estimation. See section 3.

2 Section 3 reports more detailed EPI contents.

3 Further information on Penn World Table and its latest version 6.3 is provided at its web site: *http://pwt.econ.upenn.edu/*

4 The code name is " rgdpch. "

results; and, the final section briefly concludes the paper. STATA V11 is employed for estimation.

2. Concepts of Environmental Kuznets Curve and Empirical Results

Originally, there are two contradictory hypotheses for the relationship between economic development and environmental disruption, such as pessimistic and optimistic scenarios. The former insists that economic development inevitably brings environmental destruction and collapse of ecosystems, which shift substantially against economic development in a long-term. The latter stresses that ecological system is destroyed during the prior period of economic development, but further growth results in a more ecological society according to a technology progress. In particular, Meadows et al. (1972) strongly suggest the pessimistic future and the necessity of steady-state economy that means zero growth. Against this opinion of the Club of Rome, some counterarguments, including Malenbaum (1978),[5] are expressed from technological viewpoints.

Among these counterarguments, EKC hypothesis is empirically estimated by many economists and ecologist. Some dynamic analyses, including John and Pecchenino (1994), Selden and Song (1995), and Stokey (1998),[6] suggest the possibility of the economic equilibrium shift, i.e., in early stage of development with small capital accumulation, the economic equilibrium is located at the corner solution without any pollution mitigation or introduction of ecological technology, but according to capital accumulation, the equilibrium sifts to the inner solution with implementation of ecological technologies, which implies inverted-U shaped EKC. According to Andreoni and Levinson (2001), this shift is due to the change of production and/or consumption structure, environmental preference,[7] institutional change to internalize external diseconomy like pollution, and increasing return to scale on ecological activities. On the other hand, Lieb (2002) insists that the satiation of consumption is the necessary condition for inverted-U shaped EKC under the condition that environmental quality is normal goods. Hauer and Runge (2000) discuss environmental quality as a sort of public goods, named "Global Commons," from a view point of the game theory.

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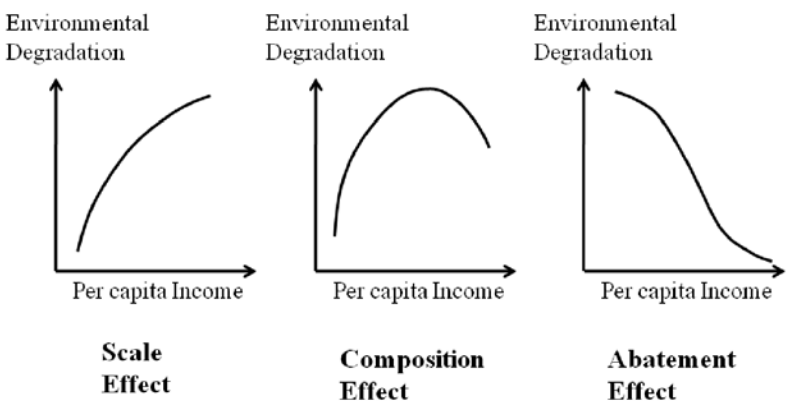
5 Malenbaum (1978) indicates that the ratio of raw materials to income in developed countries is decreasing during 1970s.

6 For dynamic analyses, John and Pecchenino (1994) employ an overlapping generation model, while Selden and Song (1995) and Stokey (1998) adopt a neoclassical Ramsey/Cass-Koopmans model, based on Ramsey (1928), Cass (1965), and Koopmans (1965).

7 Some textbooks, including Bardhan and Udry (1999), regard environment as superior goods.

Focusing on the shift of the economic equilibrium by the change of production structure, Islam et al. (1999) identify three distinct structural forces that affect the environment: i) the scale of economic activity; ii) the composition or structure of economic activities; and, iii) the effect of income on the demand and supply of pollution abatement efforts. The respective effects on the environment are named: the scale or level effect, the structure or composition effect, and the pure income or abatement effect. The scale effect on environmental degradation, controlling for the other two effects, is expected to be a monotonically increasing function of economic activities because the larger the scale of economic activity per unit of area the higher the ecological burden, ceteris paribus. The structural change that accompanies economic growth affects environmental quality by changing the composition of economic activities toward sectors of higher or lower environmental burden intensity. At lower levels of per capita income, the dominant shift is from agriculture to manufacturing with a consequent increase of pollution intensity. At higher income, the dominant shift is from manufacturing to services with a consequent decrease in environmental burden intensity. Hence, the changing share of manufacturing in economic activities may be taken to represent structural change. The composition effect is then likely to be a inverted-U or non-monotonic function of economic activities or per capita income, i.e., as the share of manufacturing first rises and later falls, environmental burden will first rise and later fall according to income growth, controlling for all other influences transmitted through income. Islam (2003) too insists that these three distinct effects are applicable to Asian developing countries. Panayotou (2003) presents some figures related to these effects, which is reported in Figure 2.

Figure 2: Decomposition of Income Effects on Environment



Source: Panayotou (2003) Chart 2.5.1 p.53

In 1990s, based on these theoretical backgrounds, many economists proceed to empirical studies because sizable environmental data became available. Three entities such as National Bureau of Economic Research (NBER), the World Bank, and International Labor Organization (ILO) started empirical studies in EKC hypothesis. These study results are Grossman and Krueger(1991),[8] World Bank (1992),[9] and Panayotou (1993), respectively. After these pioneering studies, some important studies are completed.

Surveying empirical studies in income-environment, some employ cross-section data and others adopt panel data in various areas. Among these, many literatures successfully estimate EKC and calculate the value of its turning point for various environmental burdens, including CO2, SO2, NOX, SPM, and smoke, etc. Table 1 summarizes some typically successful estimation results of inverted-U shaped EKC hypothesis, using an assumption of the quadratic inverted-U shaped relationship between income and environmental burden.[10] After the adoption of Kyoto Protocol proposed at COP3 in 1997, global interests in environmental issues appears to shift from general pollution to global warming and CO2 emission as well-known. It seems that empirical studies also shift to estimation of EKC between income and CO2 emission. It should be stressed that income values of turning point among developed countries, including OECD members, have some tendency to be calculated lower than those of all or developing countries, which is partly due to sample bias including countries under turning points.

Table 1: Summary of Empirical EKC Studies[11]

Source	Income	Environmental Burden	Turning Point (per capita income)
Shafik (1994)	1985 per capita PPP GDP	Ambient SPM	3280
		Ambient SO2	3670
Cropper and Griffiths (1994)	1985 per capita PPP GDP, Wood Prices, and Density of Rural Population	Deforestation Rate	Africa 4760
			Latin America 5420
Holts-Eakin and Selden (1995)	1985 per capita PPP GDP	CO2	35428

8 This working paper is published as a chapter of Garber (1994). Furthermore, Grossman and Krueger (1995) provide more comprehensive results, not concentrated in the trade.

9 Shafik and Bandyopadhyay (1992) contribute to its background research.

10 Some researchers also try to find out EKC using an assumption of cubic normal-N shape. See Panayotou (2000) for more detail.

11 Other than reported in Table 1, Shafik and Bandyopadhyay (1992) and Hattige et al (1992) successfully estimate inverted-U shaped EKC, but value of turning point is not explicitly mentioned.

Cole et al. (1997)	Current per capita US $	NOX	15100
		SO2	5700
		SPM	8100
		CO	10100
		NOX of Transport Sector	15100
		SO2 of Transport Sector	9400
		SPM of Transport Sector	15000
		Nitrates	15600
		CO2	25100
		Energy Consumption	22500
Kaufmann et al. (1998)	1985 per capita PPP GDP	SO2	Cross-Section 11577
			Fixed Effect 12500
			Random Effect 12175
Kahn (1998)	Current per capita US $	Vehicle Hydrocarbon Emissions	35000
Agras and Chapman (1999)	1985 per capita PPP GDP	CO2	13630
Sachs et al. (1999)	1985 per capita PPP GDP	CO2	12000
Stern and Common (2001)		SO2	OECD 9239
			non-OECD 101166
Cole (2003)	1985 per capita PPP GDP	CO2	20352
Dijkgraaf and Vollebergh (2005)	1990 per capita PPP GDP	CO2	20647
Galeotti et al (2006)	1990 per capita PPP GDP	CO2	OECD 16587
			non-OECD 21186
Richmond and Kaufmann (2006)	1996 per capita PPP GDP	CO2	29687

Note: (1) Cropper and Griffiths (1994) include wood prices and density of rural population as explanatory variables other than income.

(2) Agras and Chapman (1999) include trade indicator and energy prices as explanatory variables other than income.

(3) Cole (2003) includes trade factor as an explanatory variable other than income.

(4) Dijkgraaf and Vollebergh (2005) accept heterogeneity of parameters across the countries for a panel data analysis.

(5) Richmond and Kaufmann (2006) includes fuel shares based on final energy consumption as an explanatory variable other than income.

3. Estimation of Environmental Kuznets Curve Using Environmental Performance Index

The main purpose of this study is to estimate environmental Kuznets curve (EKC) under the assumption of quadratic inverted-U shape employing Environmental Performance Index (EPI). For this purpose, this study takes a following basic model:

(EQ-1) Basic Model[12]

$$EPI = const. + \alpha_1 Y + \alpha_2 Y^2 + error$$

where EPI Environmental Performance Index

Y Per capita income (PPP 2005 chain index)

α_i Parameters ($i=1,\ 2$)

When inverted-U shaped EKC holds, the parameter for Y is negative, and that for Y^2 is positive, i.e., $\alpha_1<0$ and $\alpha_2>0$. This sign condition is reverse compared with taking environmental burden as an explained variable. This is due to the fact that the larger EPI[13] is, the better the environmental performance is or the less the environmental burden is. Hence, against EPI, a normal-U shaped EKC is observed. If a quadratic inverted-U shaped EKC in a normal sense is successfully estimated, the value of the turning point is calculated from the first-order condition as follow:

(EQ-2) Turning Point

$$TP = -\frac{\alpha_1}{2\alpha_2}$$

where TP Value of turning point

Here, the signs for the parameters are not the necessary and sufficient condition for the quadratic inverted-U shaped EKC, because the value of turning point must be plausible and in-sample. A turning point of one million dollar per capita GDP, for example, should not seem plausible.

According to recent existing literatures, including Neumayer (2002), Cole (2003), and Richmond and Kaufmann (2006), this study takes income data from Penn World Table Version 6.3 as an explanatory variable and EPI 2006 as an explained variable. Hence, other explanatory variables than income are not taken, because Agras and Chapman (1999) sur-

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12 For estimating cubic normal-N shape EKC, the cubic term of Y, i.e., $\alpha_3 Y^3$, must be added.

13 Individual indicators of EPI are estimated as proximity-to-target that are stretched 1-100 with 100 representing the target.

veys various explanatory variables and conclude that income shows the most explanatory, which is too supported by Stern (1998) and Neumayer (2002). Penn World Table seems famous among economists and there is no need to explain in detail, but for further information, see Deaton and Heston (2009) and Feenstra et al. (2007). EPI is already mentioned in this study as a collaboration of Yale and Colombia Universities presented on its web site *http://epi.yale.edu/*. The EPI 2006 data includes 238 countries and areas and consists of 6 policy categories, and 16 indicators, which are reported in detail in Table 2 with summary of data descriptions. Esty et al. (2006) provide further information on EPI 2006. Among these 238, overall EPI is estimated only for 133 countries and areas. A country that is Myanmar, however, misses per capita GDP data at Penn World Table V6.3 among them. After dropping some countries and areas from view point of data availability, this study includes 132 countries and areas, which are reported at Appendix.

Table **2 (1)**: Contents of EPI

Index	Policy Categories	Indicators
EPI	Environmental Health	Urban Particulates
		Indoor Air Pollution
		Child Mortality
		Drinking Water
		Adequate Sanitation
	Biodiversity & Habitat	Water Consumption
		Timber Harvest Rate
		Wilderness Protection
		Ecoregion Protection
	Sustainable Energy	Energy Efficiency
		CO_2 per GDP
		Renewable Energy
	Water Resources	Nitrogen Loading
		Water Consumption
	Air Quality	Regional Ozone
		Urban Particulates
	Productive Natural Resources	Timber Harvest Rate
		Agricultural Subsidies
		Overfishing

Note: Some indicators are redundantly categorized.

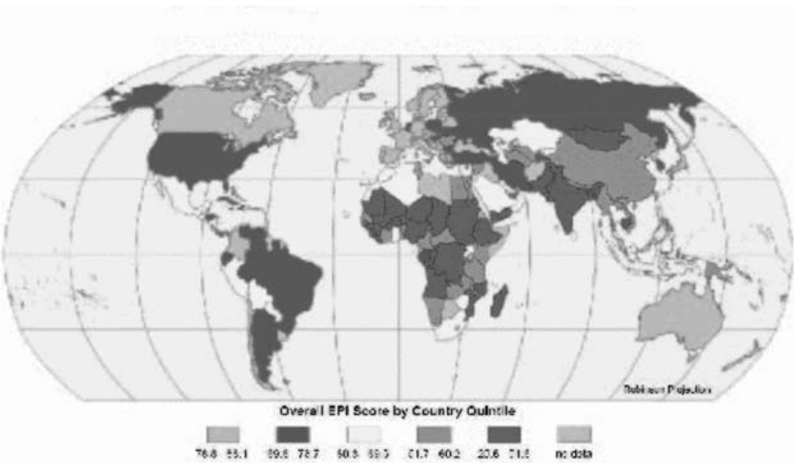
Source: Esty et al. (2006)

Table 2 (2): Data Description of EPI, Policy Categories, and Individual Indicators

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
GDP	132	11520.4	12090.8	370.2	49794.7
EPI	132	64.511	14.207	25.7	88.0
Environmental Health	132	63.511	29.477	0.0	99.4
Biodiversity and Habitat	132	50.758	19.008	5.1	88.1
Sustainable Energy	132	66.357	22.778	0.0	92.4
Water Resources	132	81.791	21.806	6.5	100.0
Air Quality	132	54.580	18.885	6.9	98.0
Productive Resource Management	132	74.053	19.156	33.3	100.0
Regional Ozone	132	44.231	28.088	0.0	100.0
Urban Particulates	132	64.930	24.822	0.0	96.2
Indoor Air Pollution	132	52.909	40.030	0.0	100.0
Nitrogen Loading	132	89.615	24.218	0.0	100.0
Water Consumption	132	73.961	30.457	0.0	100.0
Timber Harvest Rate	132	89.773	25.708	0.0	100.0
Agricultural Subsidies	132	82.787	32.727	0.0	100.0
Child Mortality	132	73.152	33.034	0.0	99.6
Energy Efficiency	132	72.326	27.106	0.0	100.0
CO2 per GDP	132	71.775	26.106	0.0	98.1
Renewable Energy	132	16.823	21.064	0.0	100.0
Overfishing	101	37.793	22.221	0.0	83.3
Drinking Water	132	66.339	32.139	0.0	100.0
Adequate Sanitation	132	60.895	33.968	0.0	100.0
Wilderness Protection	132	19.765	17.766	0.0	72.5
Ecoregion Protection	132	62.995	31.520	0.0	100.0

Source: Author

Figure 3: Map of Overall EPI Country Scores by Quintile

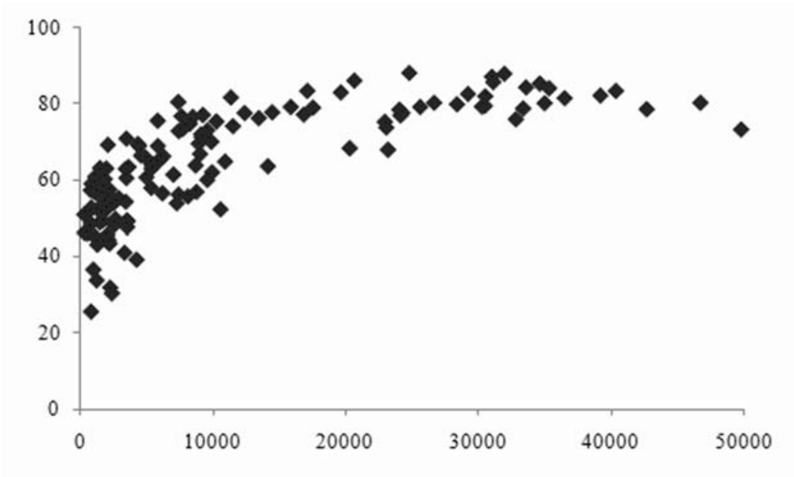


Source: Esty et al. (2006) Figure 1 p.4

Figure 3 depicts a map of overall EPI country scores by quintile. At a glance, this map strongly indicate that low income developing countries, including those in Sub-Sahara Africa and South Asia, show poor EPI, while developed countries, including those of Japan, Australia, and Western Europe, show relatively high EPI score. The US, Russia, Brazil, and Argentina, etc. are located in a midway from view point of EPI score.

Figure 4 reports a scatter chart which depicts relationship between per capita GDP and EPI for employed 132 countries and areas.

Figure 4: Relationship between per capita GDP and EPI



Note: The vertical axis represent EPI, while the horizontal does per capita GDP.
Source: Penn World Table and EPI 2006

Based on a quadratic inverted-U shaped EKC described in (EQ-1) and turning point shown in (EQ-2), estimation results for overall EPI, policy categories, and individual indicators are reported in Table 3.

According to the estimation results, an inverted-U shaped EKC is not necessarily observed for overall EPI.[14] Among 6 policy categories, only "Sustainable Energy" shows an inverted-U EKC with 5% statistical significance. "Environmental Health" contains normal-U shaped EKC, while "Biodiversity & Habitat" follows a monotonic decreasing EKC. Although other 3 policy categories, such as "Water Resources," "Air Quality," and "Productive Natural Resources" shows inverted-U shaped EKC, estimated parameters are not statistically significant. Among these three, the turning point of "Productive Natural Resources" appears too high. Viewing individual indicators, some result in inverted-U

14 Some alternative estimation targeted for relatively higher income countries and areas, such as those over $1000, $5000, and $10000 are also completed, but there is not much difference.

Table 3: Estimation results

		α_1	α_2	const.	Turning Point
EPI		0.0022927***	-3.75E-08***	48.50806***	n.a.
	Environmental Health	0.0051134***	-8.56E-08***	28.38855***	n.a.
	Biodiversity & Habitat	-0.0000356	-3.19E-09	52.05357***	n.a.
	Sustainable Energy	-0.0013916**	3.55E-08**	72.51443***	19600
	Water Resources	-0.0001818	8.09E-09	81.63854***	11236
	Air Quality	-0.0002896	7.8E-09	55.75054***	18564
	Productive Natural Resources	-0.0007342	5.04E-09	81.11081***	72837
EPI Individual Indicators					
		α_1	α_2	const.	TP
	Regional Ozone	-0.002453***	4.08E-08**	61.1458***	30061
	Urban Particulates	0.0018731***	-2.52E-08*	50.3571***	n.a.
	Indoor Air Pollution	0.0066979***	-1.09E-07***	6.100248*	n.a.
	Nitrogen Loading	0.0004995	-4.08E-09	84.99367***	n.a.
	Water Consumption	-0.0008626	2.02E-08	78.27839***	21351
	Timber Harvest Rate	0.0017348***	-3.05E-08**	78.2599***	n.a.
	Agricultural Subsidies	-0.0028982***	3.65E-08**	106.0301***	39701
	Child Mortality	0.0053234***	-9.86E-08***	39.20536***	n.a.
	Energy Efficiency	-0.0015503**	2.82E-08*	82.34217***	27488
	CO_2 per GDP	-0.0012073*	4.24E-08***	73.89291***	14237
	Renewable Energy	-0.0015726***	3.53E-08***	25.12857***	22275
	Overfishing	-0.0000678	-6.17E-09	40.65766***	n.a.
	Drinking Water	0.0047383***	-7.86E-08***	33.59991***	n.a.
	Adequate Sanitation	0.0056337***	-9.23E-08***	21.63937***	n.a.
	Wilderness Protection	-0.0001312	-3.92E-09	22.36583***	n.a.
	Ecoregion Protection	-4.93E-04	4.28E-09	67.4868***	57593

Note: *** Significantly different from zero at 0.01 level.
** Significantly different from zero at 0.05 level.
* Significantly different from zero at 0.10 level.
Source: Author's estimation

shaped EKC with plausible value of turning points, such as " Water Consumption, " " Energy Efficiency, "" CO_2 per GDP, " and " Renewable Energy. " However, estimated results of " Water Consumption " are not statistically significant. While " Regional Ozone, " " Agricultural Subsidies, " and " Ecoregion Protection " shows inverted-U shaped EKC, their per capita income of turning points are sizably high, which exceed $30000. 7 individual indicators among 16, such as " Urban Particulates, "" Indoor Air Pollution, "" Nitrogen

Loading," "Timber Harvest Rate," "Child Mortality," "Drinking Water," and "Adequate Sanitation," follow normal-U shaped EKC. On contrary, the curves of "Overfishing" and "Wilderness Protection" are monotonic decreasing without statistical significance. In short, it should be stressed that environmental burdens related to energy and CO2 may have possibility to follow inverted-U shaped EKC.

Considering aforementioned corner solution at early stage of development stressed by John and Pecchenino (1994), Selden and Song (1995), and Stokey (1998), the income level that brings shift from the corner solution may differ from each environmental burden since each rate of return to pollution mitigation and/or introduction of ecological technology. The estimated results shown in Table 3 may report this sort of differences.

4. Conclusion and Remaining Issues

This study successfully estimates inverted-U shaped environmental Kuznets curves (EKC) for a policy category and some individual indicators of EPI. Utilization of EPI is one of the most remarkable features of this study. However, for other various EPI indicators than energy-related ones, inverted-U shaped EKC is not necessarily observed.

On contrary, the existence of inverted-U shaped EKC does not deny efforts to reduce or mitigate environmental burdens at all. The significantly estimated values of turning points in the range of PPP US$14000-30000 seem relatively high, compared with income of typical Asian developing countries, which are $7447 of China, $5036 of Indonesia, $3579 of India, $17140 of Malaysia, $4391 of the Philippines, and $9069 of Thailand. Considering situations of Asian income and present global environmental issues, it is absolutely required to take some reducing or mitigating measures against environmental burdens before waiting for their further growth.

Some critical views against EKC, stressed in Arrow et al. (1995), should be mentioned here. First, EKC does not consider interactive relationship between environment and production/income because the latter is treated as exogenous. Meadows et al (1972) insist of counter effects that the environmental degradation will depress economic activities, which implies the possibility that growth in developing countries may stop before the turning point. Second, inverted-U shaped EKC may originate in pollution-exporting. According to upgrading industrial structure, developed countries do reduce environmental burdens, but as its result, developing countries may accept environmental-burden-intensive industries. Hence, some studies, including Dijkgraaf and Vollebergh (2005), insist that homogeneity of panel analysis parameters across the countries does not hold.

Finally, considering a rather technical point, EPI includes “ CO_2 per GDP ” as an individual indicator, but world-wide concern is now shifting from overall environmental quality to CO_2 emission that causes global warming after Kyoto Protocol in 1997. Recent COP15, for instance, is concentrated on agreement on CO_2 emissions, but regrettably failed to reach a binding strong agreement. Further investigation, focusing on CO_2 emission and global warming, may be required, at which panel data analysis instead of cross-section research may be more efficient.

Appendix: EPI **2006** Countries and Areas Employed for Estimation

Angola, Albania, United Arab Empire, Argentina, Armenia, Australia, Austria, Azerbaijan, Burundi, Belgium, Benin, Burkina Faso, Bangladesh, Bulgaria, Bolivia, Brazil, Central Afr. Rep., Canada, Switzerland, Chile, China, Cote d’Ivoire, Cameroon, Dem. Rep. Congo, Congo, Colombia, Costa Rica, Cuba, Cyprus, Czech Rep., Germany, Denmark, Dominican Rep., Algeria, Ecuador, Egypt, Spain, Ethiopia, Finland, France, Gabon, United Kingdom, Georgia, Ghana, Guinea, Gambia, Guinea-Bissau, Greece, Guatemala, Honduras, Haiti, Hungary, Indonesia, India, Ireland, Iran, Iceland, Israel, Italy, Jamaica, Jordan, Japan, Kazakhstan, Kenya, Kyrgyzstan, Cambodia, South Korea, Laos, Lebanon, Liberia, Sri Lanka, Morocco, Moldova, Madagascar, Mexico, Mali, Mongolia, Mozambique, Mauritania, Malawi, Malaysia, Namibia, Niger, Nigeria, Nicaragua, Netherlands, Norway, Nepal, New Zealand, Oman, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Poland, Portugal, Paraguay, Romania, Russia, Rwanda, Saudi Arabia, Sudan, Senegal, Sierra Leone, El Salvador, Suriname, Slovakia, Slovenia, Sweden, Swaziland, Syria, Chad, Togo, Thailand, Tajikistan, Turkmenistan, Trinidad & Tobago, Tunisia, Turkey, Taiwan, Tanzania, Uganda, Ukraine, United States, Uzbekistan, Venezuela, Viet Nam, Yemen, South Africa, Zambia, Zimbabwe

Note: All indicators as of EPI component are not necessarily estimated for all countries and areas. Some indicators of EPI components are missing for certain countries and areas.

Source: Esty et al (2006) and author

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