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Taguchi, Hiroyuki

Saitama University, MLIT, Government of Japan

2002

Latecomers' Advantages in Environmental Management of Middle Income Economies

Hiroyuki TAGUCHI*

Middle-income economies in the world are under pressure to deal with a variety of environmental problems, such as industrial pollution, urban environmental issues, the deterioration of ecosystems, and global warming, while they are expected to simultaneously achieve high economic growth. In this context, they urgently need to leapfrog over environmental difficulties through progressive environmental management by utilizing their "latecomers' advantages" to the maximum extent possible.

By utilizing the analytical framework of the environmental Kuznets curve (EK curve), this study examines whether or not middle-income economies actually enjoy latecomers' advantages in environmental management, depending on their stages of development. The study's main findings are as follows: (1) the outcomes of comparative analysis of the EK curves are generally consistent with the hypothesis that middle-income economies do enjoy latecomers' advantages; and (2) a regression analysis using cross-sectional data provides significant confirmation of the existence of latecomers' advantages for addressing the well known environmental problem of sulfur emissions in lower-middle-income economies.

1. Introduction

Our economies presently face two kinds of policy challenges: economic development and environmental conservation. In particular, middle-income economies[1], most of which are in the process of industrializing, are under pressure to deal simultaneously with a variety of environmental problems, including industrial pollution, urban environmental issues, the deterioration of ecosystems, and global warming, while at the same time they are expected to achieve further economic development. In this context, they urgently need to leapfrog over environmental difficulties with progressive environmental management by utilizing their "latecomers' advantages" — latecomers' availability of the capital, skills, and technology of more advanced countries[2], to the maximum extent possible.

This study is aimed at examining whether or not middle-income economies actually do enjoy latecomers' advantages in environmental management by utilizing the analytical framework of the environmental Kuznets curve. The reason why we focus on middle-income economies is that they most seriously face environmental policy challenges in the process of industrialization, while high-income economies, which already attained industrialization, can afford to allocate their resources to environment issues and while low-income

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* Director of National and Regional Planning Bureau, Ministry of Land, Infrastructure and transport, Government of Japan

[1] The middle-income economies are those with a GNP per capita of more than U.S. $760 but less than U.S. $9,360, according to the World Bank's classification of economies. See World Bank [18] (2000).

[2] The hypothesis of "latecomers' advantages" was advanced by Alexander Gerschenkron. See Gerschenkron [2] (1962).

economies put a first priority on their poverty alleviation.

In the following sections, we will first outline the hypothesis behind the environmental Kuznets curve (Section 2), review previous studies on that topic (Section 3), conduct our own empirical study of latecomers' advantages (Section 4), and end with concluding remarks (Section 5).

2. EK curve hypothesis

The environmental Kuznets curve (EK curve) provides an analytical framework to examine how economies deal with environmental issues. The EK curve hypothesis suggests that in the course of economic development, the environment gets worse before it gets better. In this section, we outline the theoretical background for the EK curve, then show its policy implications, by summarizing the explanations of Panayotou [12] (1995).

2.1 Theoretical background

We first concentrate on the reason why environmental degradation rises at first and then falls in the course of economic development.

First, the state of natural resources and the environment in a country depends on the structure of its economy. There are fairly close relationships between the level of development and the share of the industrial sector in GDP. In the low-income stage, the share of industry in GDP is small (less than that of agriculture) — dominated by agroprocessing and light manufacturing. In the middle-income stage, industry's share approaches or exceeds one-third of GDP; the relationships, however, are not linear ones. In the higher-income stage, the share of industry stabilizes or declines somewhat, dominated by more sophisticated technology industries. Industrial emissions vary with the size of industrial sector. In the later development stage, the share of the industrial sector within the total GDP levels off and begins to decline gradually. These structural changes alone may explain the inverted relationship between emissions and the level of economic development.

Second, as incomes grow, people can afford to become more environmentally-conscious; environmental regulations are tightened and more strictly enforced. Environmental quality is an income-elastic "commodity" that does not constitute a significant part of the consumer's budget until fairly high levels of income have been attained. Only after the higher levels of income and wealth are consolidated economically does the demand for environmental quality (being income-elastic) rise. As a result, economic, social, and political pressures are built up to institute and enforce environmental regulations and to increase budgetary allocations for environmental protection. Thus, in the later stages of development, environmental quality improves.

2.2 Policy implications of the EK curve hypothesis

The EK curve hypothesis has important policy implications. First, it implies a certain inevitability of environmental degradation along a country's development path. Second, it suggests that as the development process picks up, when a certain level of income per capita is reached, economic growth turns from an enemy of the environment into an ally. This would tend to suggest that resources can best be focused on achieving rapid economic growth to move quickly through the environmentally- unfavorable stage to the environmentally-favorable range of the EK curve.

However, there are several reasons why this growth-oriented policy may not be optimal. First, the positively-sloping part of the curve, where growth worsens the environment, may take several decades to peak, in which case the present value of higher future growth and a cleaner future environment may be more than offset by high current rates of environmental damage. Second, it may be less costly today than in the future to prevent or abate certain forms of environmental degradation, such as with the problem of hazardous waste. Third, certain types of environmental degradation may be physically irreversible. Tropical deforestation and the loss of biological diversity, for example, are either physically irreversible or prohibitively costly to reverse. The fourth reason, more important in economic terms, is that certain forms of environmental degradation-such as soil erosion, watershed destruction, and damage to human health and productivity-constrain economic growth. Therefore, the policy implication is that in the presence of ecological thresholds, a sharply rising EK curve (implying high rates of resource depletion) should be flattened out through better management.

2.3 Implications in global context

Low- and middle-income economies often appear on the positively- sloping part of their EK curve, and some of them may reach ecological thresholds. Since environmental resources are valuable for high-income countries today and for lower income economies in the future, a case could be made for providing assistance to lower income economies to help them to flatten their EK curve so as to avoid, or at least to limit, irreversible environmental damage. In addition, the idea of assistance derives from the observation that cleaner production technologies and pollution abatement technologies are available in high-income economies. Since most lower income economies lack the financial resources to import these technologies at commercially-viable costs, the case has been made that high-income economies should transfer these technologies to lower income economies on concessionary terms. The implications of the EK curve hypothesis in global context are, therefore, significant in terms of international assistance in environment technology and management areas, to help lower income economies benefit from latecomers' advantages.

There are various forms of international assistance to materialize latecomers' advantages[3]. The first example is the assistance for formalizing legal and institutional framework such as laws, standards, and agencies for environmental protection. The second is the transfer of technologies such as monitoring system, energy supply management, and anti-pollution facilities, at various levels of central and local government and private companies. The third is the assistance for capacity building to enforce environmental laws and standards, and to disseminate advanced technologies nationwide.

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[3] For more deteils, see Japanese Environment Agency [8] (1998) and Japanese Ministry of the Environment [9] (2001).

3. Previous studies

Next is a summary of previous studies on the EK curve, followed by a discussion on the frontiers of studies on the topic.

3.1 Previous empirical studies

The issue of the EK curve was first discussed in the World Bank's 1992 World Development Report (World Bank [17] 1992). The report showed that past patterns of environmental degradation are not inevitable; individual countries can choose policies and technologies that lead to much better (or worse) environmental conditions than those in other countries at similar income levels. In this context, the report illustrates the downward shift of the cross-sectional EK curve, which shows that concentrations of sulfur dioxide are lower today than in the past.

Since the World Bank's report, there have been numerous theoretical debates and empirical tests on the EK curve. Empirical evidence has grown supporting the EK curve for some regions and some environmental problems. Grossman and Krueger [3] (1995) found an EK curve relationship between per capita GDP and urban air quality (suspended particulate matter (SPM) and sulfur dioxide (SO_2)), while Selden and Son [14] (1994) identified the relation for the aggregate emissions of SPA, SO_2, oxides of nitrogen and carbon monoxide. A similar relationship was found for fecal coliform and arsenic in rivers (Islam [7] 1996). Stokey [15] (1998) made a theoretical contribution to explain the EK curve relationship by using dynamic growth models. Suri and Chapman [16] (1998) examined the linkage between the EK curve and international trade of industrial goods. Despite these results, it is prudent to resist the temptation to elevate the EK curve hypothesis to a universal law of development. There is a substantial body of empirical work that rejects the EK curve hypothesis (Ecological Economics 1998; Rothman [13] 1998). In addition, research is limited to the class of environmental problems for which data exist, such as the concentration of pollutants in urban areas. We are not aware of empirical analyses of the relationship between income and the degradation of key ecological services.

3.1 Frontiers of EK curve studies

Most of the empirical studies so far have concentrated on validating the EK curve hypothesis and its requirements by using cross-sectional data from developed countries. Other issues that have not been addressed as much include comparing the EK curves of specific countries in terms of the height and timing of their peaks, shapes, and so on; and investigating the causes of different patterns of EK curves, especially external impacts, such as policy changes and technological innovation and transfer. To address these issues, the EK curve should be validated in specific countries with the use of time-series data.

Irie [6] (2000) tested the empirical proof on the EK curves of individual countries for SO_2 by using time-series data from 30 developed countries (OECD countries and the former Soviet Union). The main findings were that (1) the EK curves were verified on SO_2 emissions in 17 countries; (2) the EK curves varied in the shape of their trajectories and the height and timing of their peaks; and (3) the differences in the height can be explained by five factors (a country's available technology, scale of economy, fuel quality, leading industries, and political system). Matusoka et al. [11] (2000) compared the EK curves of Asian countries and explained the differences in the height of the EK curves by the latecomers' advantages as arising from the dissemination of environmental monitoring systems in Asian countries.

4. Empirical studies

Now, by utilizing the analytical framework of the environmental Kuznets curve, we examine whether middle-income economies enjoy latecomers' advantages in environmental management. We first conduct comparative analysis of the EK curves by using both cross-sectional and time-series data. We next carry out a regression analysis to identify the latecomers' advantage by using cross-sectional data from selected countries in the world with normalized levels of per capita GDP of U.S. \$2,000, U.S. \$4,000, U.S. \$6,000 and U.S. \$8,000. Some outliers in the sample data may sometimes produce biased results of analyses. For examples, it is not rare for outliers to dominate estimated coefficients in regression analyses. It is significant, therefore, to conduct here both comparative analyses using cross-sectional and time-series data and a regression analysis to identify the existence of latecomers' advantages. Throughout these analyses we focus on sulfur and carbon emissions as indexes of the environment, because they are often used to represent environmental quality, and data are generally available.

4.1 Comparative analysis of the EK curves

We first examine the existence of the latecomers' advantages in environmental management through the following comparative analysis of the EK curves.

4.1.a Methodology

We here conduct two kinds of comparative analysis of the EK curves: the comparison of the EK curves using cross-sectional data and the comparison of the EK curves using time-series data. The former is the same method as the World Bank [17] (1992) adopted in its report; the downward shift of the cross-sectional EK curve is examined. We first create the scattering diagram to plot income-emission relationship in each of 152 countries in the world in 1950, 1970 and 1990 respectively. Then we estimate quadratic curve from the cross-sectional data in each year and verify the existence of its downward sift in the middle-income area. In the latter analysis, we examine the time-series income-emission relationship of the second half of the past century (1950-1992) for each of 50 countries with middle-income[4]. Then we analyze the relationship between peak emission timings and levels in the selected 31 countries, in which the time-series EK curves are identified.

For an index of income, we use per capita real GDP. For indexes of environment, we use two kinds of indicators: sulfur and carbon emissions per capita, and those per U.S. \$1,000 real GDP. The former is for seeing the change of the absolute level of emission per capita accompanied with the growth of income per capita, while the latter is for seeing the speed of

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[4] These fifty countries were chosen as those countries with real GDP per capita (in Version 5.6 of the Penn World Tables) of more than U.S. \$760 but less than U.S. \$9,360 (the World Bank's classification) in 1992 and with the data availability of sulfur and carbon emissions.

the growth of emission relative to the growth of income.[5] Therefore, the latter, which corresponds to the slope of the EK curve made by the former, has usually its peak earlier than the former does in the ordinary EK curve.

4.1.b Data

For sulfur emissions, we use the data estimated by Center for Air Pollution Impact and Trend Analysis (CAPITA) from Washington University in St. Louis, Missouri (ASL & Associates [1] 1996). This database was developed for estimating the global emissions of sulfur from 1850 to 1990, with a common methodology applied across all years and countries. In all cases, the emissions estimates for each country are based on the production, percent sulfur, and sulfur retention information associated with that country's activities.

For carbon emissions, we use the data estimated by Carbon Dioxide Information Analysis Center (CDIAC) at the Oak Ridge National Laboratory of the U.S. Department of Energy (Marland et al. [10] 2000). The database, named "Global, Regional, and National Fossil Fuel CO_2 Emissions," covers data from 1751 to 1997. The emissions estimates are based on a specific methodology using statistics on gas fuels, liquid fuels, solid fuels, gas flaring, cement manufacturing, estimated parameters of carbon coefficients and oxidation rates.

For population figures and per capita real GDP, we use Version 5.6 of the Penn World Tables (Heston and Summers [5] 1995). As per capita real GDP, we use the data of "Real GDP per capita" (Laspeyres Index) in 1985 international prices.

4.1.c Main findings

Figure 1 reports the cross-sectional relationships between emissions (sulfur and carbon emissions per capita and per U.S.$1,000 real GDP), and per capita real GDP for 1950, 1970 and 1990. We here verified the cross-sectional EK curves except the case of carbon emission per capita (y-1). We then found the downward sift of the EK curves, which shows that the emissions are lower today than in the past at similar middle-income levels.

Table 1 describes the time-series relationships between the emissions and per capita real GDP in 50 countries with middle-income for 1950-1992. We here identified the following as those countries with the EK curve (increase, then decrease as income per capita grows): 19 countries in the case of sulfur emission per capita (a-1), 21 countries in sulfur emission per U.S. $1,000 real GDP (a-2), 12 countries in carbon emission per capita (b-1) and 16 countries in carbon emission per U.S. $1,000 real GDP (b-2). Table 2 and Figure 2 describes the relationships between peak emission timings and levels in those countries identified as having the EK curve. We found negative correlations between peak emission timings and levels especially in the cases of sulfur and carbon emissions per capita. It means at least that the later a country has its peak in sulfur and carbon emissions per capita, the lower level of their emissions it has at the peak. These outcomes above are generally consistent with the hypothesis that middle-income economies do enjoy latecomers' advantages.

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[5] Hayami [4] (1997) used the latter indicator in his EK-curve analysis of carbon emission while most of other studies use the former indicator.

4.2 Regression analysis of latecomers' advantages

Now we conduct a regression analysis to identify the latecomers' advantage. We have already recognized the possibility of the existence of the latecomers' advantage through the comparative analysis of the EK curves in Section 4.1. It seems, however, that the differences in the EK curves may be produced by other factors, like industrial structure and the structure of energy sources, rather than the latecomers' advantage. Therefore, the comprehensive relationships must be analyzed between the differences in EK curves and related factors at normalized levels of per capita GDP, and then the significance of the latecomers' advantage can be validated.

4.2.a Methodology

We first focus on the four groups of middle-income countries in the world that have attained U.S $2,000, U.S. $4,000, U.S. $6,000 and U.S. $8,000 of real GDP per capita (1985 international prices) since 1950. In each group with 46, 44, 38 and 31 sets of cross-sectional data respectively, we conduct a regression analysis.

We now specify the modality of regression. We use ordinary least squares. For the dependent variables, we use sulfur and carbon emissions per capita (even if we use those emissions per U.S. $1,000 GDP, the estimation result would be just the same, because real GDP per capita is normalized at the same level). The independent variables are as follows: the year when a sample country attained U.S $2,000, U.S. $4,000, U.S. $6,000 and U.S. $8,000 of real GDP per capita respectively (YEAR); the share of coal as a source for electricity production in a sample country in the YEAR (COAL); and the share of "industry" value-added in GDP of a given country in that YEAR (INDS). "Industry" comprises mining, manufacturing, construction, electricity, water, and gas. The data on SO_2, CO_2, real GDP, and population come from the same sources as those in Section 4.1.a. The data on COAL and INDS come from World Bank [18] (2000).

The crucial variable for this study is the YEAR: If the coefficient of the YEAR is significantly negative, we can assume the existence of latecomers' advantages. This is because a negative YEAR coefficient means that the later a sample country attained U.S $2,000, U.S. $4,000, U.S. $6,000 and U.S. $8,000 of real GDP per capita, the lower are that country's sulfur and carbon emissions per capita. Table 3 reports the results of the regressions.

4.2.b Main findings

In the regressions for SO_2 (equations: A, B, E, F, I, J, M and N), all of the YEARs are negative, but only the YEARs in equations A, B and E (countries with GDP per capita of less than U.S. $4,000) are significantly negative. Equations A and E show INDSs registering significantly positive and Equation B shows both COAL and INDS registering significantly positive.

In the regressions for CO_2 (equations: C, D, G, H, K, L, O and P), most of equations do not perform well in terms of adjusted R-squared values. The crucial variables of the YEARs are not significant in negative degrees in equation C and G and even positive in other equations.

From the above observations, we have confirmed the existence of latecomers' advantages for sulfur emission in the middle-income economies with GDP per capita of less than U.S. $4,000.

We speculate that the reason for this is that high-income economies were early to address the problem of sulfur emissions, which directly affects human health. To respond, they regulated sulfur emissions strictly and developed desulfurization technologies. We may, therefore, state that middle — income economies seem to be in the position in which they can benefit from the transfer of environmental know-how and technologies from the high-income economies that already possess them. Especially, the middle-income economies standing on the positively — sloping part of their EK curves may seriously need to benefit from latecomers' advantages, while those passing through the peaks of their EK curves may have already exploited latecomers' advantages in the process of leapfrogging over environmental difficulties. If we follow the outcomes of Table 2 (a-1), the average peak of the EK curves on sulfur emission per capita appeared at the GDP per capita of U.S. $2,243. One could, therefore, conclude that the middle-income economies with GDP per capita of less than U.S. $4,000 might well enjoy latecomers' advantages for sulfur emission.

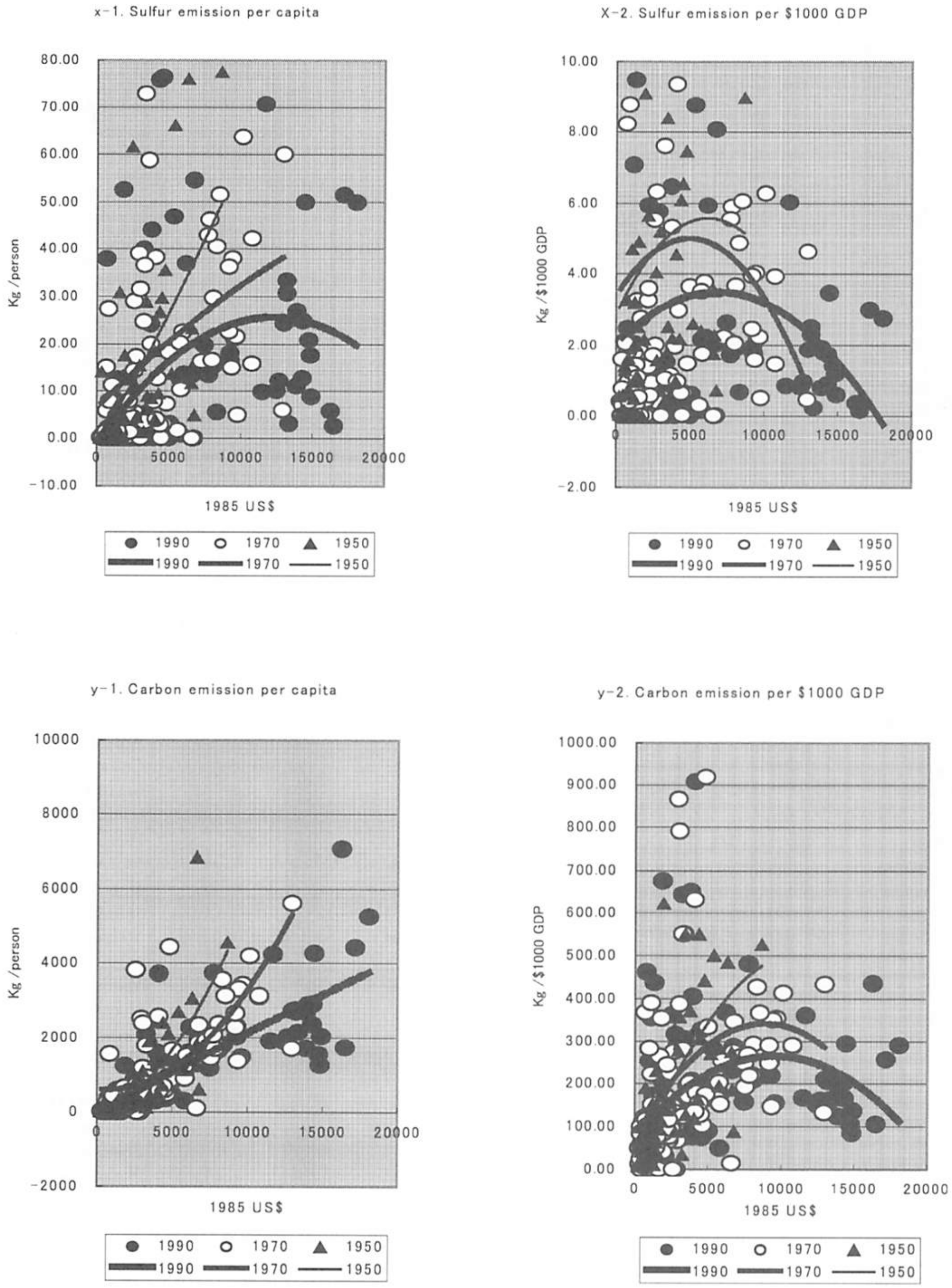
On the other hand, our analysis was not able to verify the existence of latecomers' advantages for carbon emissions. Perhaps this is because many countries have just begun to address the issue of carbon emissions, which is related to global warming. As a result, it may be difficult for lower — income economies to benefit from latecomers' advantages on this more recent environmental issue.

5. Concluding remarks

In this study we set out to examine, using empirical studies (Section 4), whether or not middle-income economies enjoy latecomers' advantages in environmental management.

First, we concentrated on a comparative analysis of the EK curves among middle-income economies. We found that the outcomes are mostly consistent with the hypothesis that middle-income economies benefit from latecomers' advantages in environmental management. Nevertheless, the comparative analysis cannot be considered a direct proof of the existence of latecomers' advantages. Therefore, as a second step we carried out a regression analysis to identify the latecomers' advantages by using cross-sectional data on selected countries in the world. Through this analysis, we verified the existence of latecomers' advantages on the well- known environmental issue of sulfur emissions in lower-middle-income economies.

However, these studies may only be initial steps for analyzing the latecomers' advantages in lower-income economies. Analytical issues still remain that need to be addressed. First, environmental degradation involves a wide variety of pollutants and ecosystems; therefore, empirical tests are needed on emissions and factors other than sulfur and carbon. Second, we can enrich the corroborative information on latecomers' advantages by showing how and in what fields the transfers in technology and know-how to lower-income economies have been carried out. Further studies on the environmental Kuznets curve will provide significant information to enable improved planning and evaluation of environmental assistance to lower-income economies.



Sources:
ASL & Associates (1996); Marland, G., T.A. Boden and R.J. Andres (2000)
Heston, A. and R. Summers (1995).

Fig. 1. The cross-sectional relationships between emissions and GDP per capita

Table 1. The relationship between emissions and GDP per capita in 1950-1992

a-1. Sulfur emission per capita

increase, then decrease	increase constantly	others
Bolivia	Brazil	Algeria ••
Congo ••	Ecuador	Bangladesh •••••
Colombia	India	Cameroon ••
Cyprus	Indonesia ••	Chili
Dominican Rep.	Romania ••	China ••
Fuji ••	Thailand	Costa Rica ••••
Honduras •	Turkey	Egypt
Iran •		El Salvador •••
Kenya		Gabon ••
Morocco		Ghana •
Namibia ••		Guatemela •
Pakistan		Hungary ••••
Panama ••		Malaysia •
Peru		Mauritania ••••
Philippines		Mauritius
Sri Lanka		Mexico
Tunisia ••		Nigeria
Venezuela		Paraguay ••••
Zimbabwe •		Poland ••••
		South Africa
		Uruguay

a-2. Sulfur emission per $1000 GDP

increase, then decrease	increase constantly	others
Bolivia	India	Algeria ••
Brazil	Thailand	Bangladesh •••••
Colombia	Turkey	Cameroon ••
Congo ••		Chili
Cyprus		China ••
Dominican Rep.		Costa Rica ••••
Fuji ••		Ecuador •••
Honduras •		Egypt
Indonesia ••		El Salvador
Iran •		Gabon ••
Kenya		Ghana •
Malaysia •		Guatemala •
Morocco		Hungary ••••
Namibia ••		Mauritania ••••
Pakistan		Mauritius
Peru		Mexico
Philippines		Nigeria
Sri Lanka		Panama •••
Tunisia ••		Paraguay ••••
Venezuela		Poland ••••
Zimbabwe •		Romania ••
		South Africa
		Uruguay

b-1. Carbon emission per capita

increase, then decrease	increase constantly	others
Algeria **	Bangladesh *****	Cameroon **
Brazil	Bolivia	China **
Cape Verde Is.**	Colombia	Congo **
Chili	Costa Rica	Dominican Rep.
Fuji **	Cyprus	Gabon **
Honduras	Ecuador	Ghana *
Hungary ****	Egypt	Iran *
Kenya	El Salvador	Mauritania **
Philippines	Guatemala	Papua N.G.**
Sri Lanka	India	Poland ****
Uruguay	Indonesia **	Zimbabwe ***
Venezuela	Malaysia ****	
	Mauritius	
	Mexico	
	Morocco	
	Nigeria	
	Pakistan *****	
	Paraguay	
	Peru	
	Romania **	
	Rwanda ***	
	South Africa	
	Thailand	
	Tunisia **	
	Turkey	

b-2. Carbon emission per $1000 GDP

increase, then decrease	increase constantly	others
Algeria **	Bangladesh *****	Cameroon **
Brazil	Bolivia	China **
Cape Verde Is.**	Costa Rica	Congo **
Chili	Ecuador	Dominican Rep.
Colombia	El Salvador	Gabon **
Cyprus	India	Ghana *
Egypt	Pakistan *****	Guatemala
Fuji **	Thailand	Hungary ****
Honduras		Iran *
Indonesia **		Malaysia ****
Kenya		Mauritania **
Philippines		Mauritius
Romania **		Mexico
Sri Lanka		Morocco
Turkey		Nigeria
Uruguay		Papua N.G.**
		Paraguay
		Peru
		Poland ****
		Rwanda ***
		South Afric
		Tunisia **
		Venezuela
		Zimbabwe ***

Notes:

*, **, ***, ****, ***** indicate the sample period is 1955-92, 1960-92, 1965-92, 1970-92, and 1975-92 respectively according to their data availability.

Sources:

ASL & Associates (1996) ; Marland, G., T. A. Boden and R. J. Andres (2000) ; Heston, A. and R. Summers (1995).

Table 2. Peak emission timings and levels in the EK curve economies

a-1. Sulfur emission per capita

Country	Year	GDP per capita (1985 US$)	Emission per capita (Kg/person)
Cyprus	1957	2,379	63.82
Venezuela	1957	6,939	55.14
Iran	1960	2,987	9.70
Peru	1961	2,148	22.84
Pakistan	1963	709	1.54
Kenya	1965	609	1.56
Namibia	1965	2,286	49.28
Panama	1969	2,430	14.58
Sri Lanka	1970	1,240	0.89
Bolivia	1970	1,657	2.98
Dominican Rep	1974	2,077	5.40
Zimbabwe	1976	1,206	13.84
Congo	1979	1,726	2.64
Philippines	1980	1,882	5.90
Tunisia	1980	2,530	1.63
Morocco	1982	1,954	3.22
Fuji	1982	3,518	0.45
Colombia	1984	2,949	3.33
Honduras	1985	1,387	2.23

a-2. Sulfur emission per $1000 GDP

Country	Year	GDP per capita (1985 US$)	Emission per capita (Kg/person)
Morocco	1953	854	2.70
Venezuela	1953	5,346	8.92
Brazil	1956	1,499	1.20
Cyprus	1957	2,379	26.83
Iran	1957	2,404	3.64
Colombia	1958	1,613	1.53
Peru	1960	2,031	11.03
Namibia	1962	1,940	23.69
Pakistan	1963	709	2.17
Kenya	1965	609	2.56
Tunisia	1965	1,232	1.24
Bolivia	1966	1,390	1.97
Honduras	1970	1,235	1.79
Sri Lanka	1970	1,240	0.072
Malaysia	1970	2,154	1.39
Philippines	1971	1,432	3.52
Dominican Rep	1974	2,077	2.60
Zimbabwe	1976	1,206	11.48
Congo	1979	1,726	1.53
Indonesia	1980	1,282	0.61
Fuji	1982	3,518	0.13

b-1. Carbon emission per capita

Country	Year	GDP per capita (1985 US$)	Emission per capita (Kg/person)
Venezuela	1957	6,939	2,926.74
Sri Lanka	1669	1,236	96.15
Chili	1971	3,889	798.35
Uruguay	1972	40,034	585.11
Honduras	1977	1,468	165.66
Philippines	1977	1,725	219.87
Algeria	1978	2,590	972.09
Hungary	1978	5,089	2,203.88
Cape Verde Is.	1979	714	238.6
Brazil	1979	4,074	425.37
Kenya	1981	869	102.87
Fuji	1981	3,818	448.92

b-2. Carbon emission per $1000 GDP

Country	Year	GDP per capita (1985 US$)	Emission per capita (Kg/person)
Kenya	1962	580	142.83
Colombia	1963	1,728	188.33
Egypt	1965	1,021	251.40
Uruguay	1965	3,692	151.57
Romania	1969	743	2,047.83
Sri Lanka	1969	1,236	77.79
Brazil	1969	2,233	110.23
Honduras	1972	1,271	113.00
Philippines	1973	1,532	136.64
Chili	1976	2,938	219.00
Cyprus	1976	3,824	288.04
Indonesia	1978	1,124	157.99
Algeria	1978	2,590	375.33
Cape Verde Is.	1979	714	334.17
Fuji	1981	3,818	117.58
Turkey	1986	3,299	205.03

Sources: See Table 1.

Table 3. Results of regressions on sulfur and carbon Emissions

<Countries with GDP per capita of U.S.$2,000>

	Equations	YEAR	COAL	INDS	adj R^{**2}
SO_2	A	−0.013***		1.142***	0.370
	B	−0.010**	0.293**	0.791***	0.414
CO_2	C	−0.008		11.653**	0.089
	D	0.007	5.021*	8.460	0.144

<Countries with GDP per capita of U.S.$4,000>

	Equations	YEAR	COAL	INDS	adj R^{**2}
SO_2	E	−0.014*		1.221***	0.248
	F	−0.011	0.464**	0.904**	0.335
CO_2	G	−0.103		31.301***	0.157
	H	0.148	22.865***	9.353	0.438

<Countries with GDP per capita of U.S. $6,000>

	Equations	YEAR	COAL	INDS	adj R^{**2}
SO_2	I	−0.013		0.748	0.047
	J	−0.003	0.163	0.711	0.006
CO_2	K	0.781***		−2.108	−0.038
	L	0.771***	10.908**	−5.521	0.107

<Countries with GDP per capita of U.S. $8,000>

	Equations	YEAR	COAL	INDS	adj R^{**2}
SO_2	M	−0.001		0.748*	0.078
	N	−0.005	0.237	0.846*	0.124
CO_2	O	0.911***		6.596	−0.044
	P	0.717**	11.112**	10.970	0.118

Notes:

YEAR: Year When a country attains U.S.$2,000, $4,000, $6,000 and $8,000 of GDP per capita

SO_2: Sulfur emissions per capita of a country in the YEAR (kg)

CO_2: Carbon emissions per capita of a country in the YEAR (kg)

COAL: Electricity production from coal sources of a country in the YEAR (% of total).

(When the data is not available in the YEAR, the alternative data in the nearest year is used)

INDS: Industry, value added of a country in the YEAR (% of GDP). "Indusry" comprises value added in mining, manufacturing, construction, electricity, water, and gas (ISIC divisions 10-45). (When the data is not available in the YEAR, the alternative data in the nearest year is used.)

*, **, *** indicate coefficient is significant at 10, 5, and 1 percent levels, respectively.

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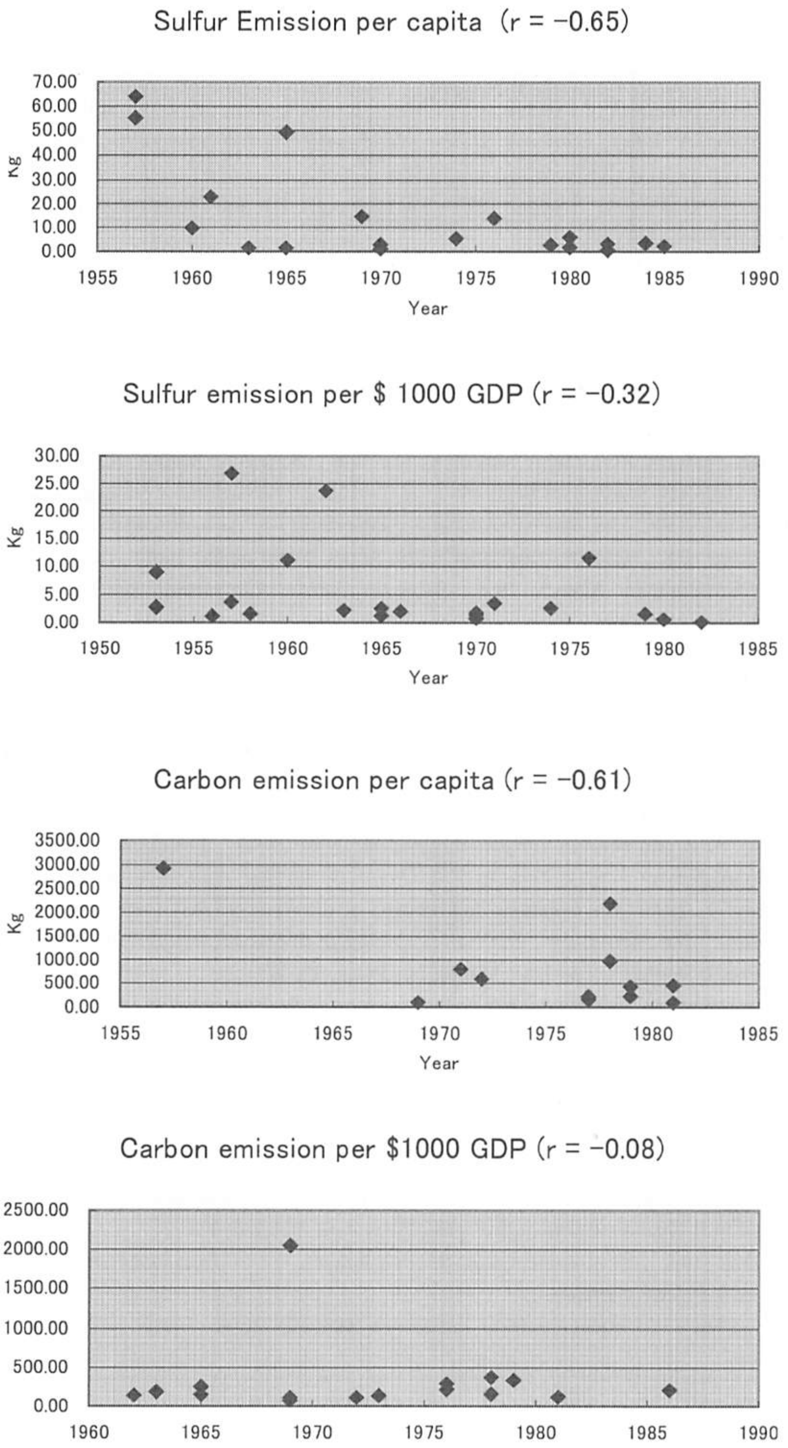

Sources: See Table 1.

Fig. 2. The relationship between peak emission timings and levels

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