Economic growth and Environmental Quality in Developing Countries: A Verification of "Environmental Kuznets Curve"

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Abstract

This article examines the Environmental Kuznets Curve, which has been the leading hypothesis for explaining the relationship between economic growth and environmental degradation. First, we examine previous studies and point out their analytical shortcomings. Then, we show our research which attempts to overcome these shortcomings. The environmental indicators we used were; per capita emission of sulfur oxide (SOx), nitrogen oxide (NOx) and carbon dioxide (CO2), ratio of population with access to safe water and sanitation equipment, and forest degradation ratio. In our analysis we use two starting point dates (1980 and 1990) and data for 29 countries. We did an elastic analysis in order to determine the environmental trend of each country. In our results, we found that it was only SOx that can reasonably be regressed by quadratic equation (inverted U). NOx, CO2, safe water and sanitation should be regressed by linear equation, and the deforestation ratio seems to have no relation to economic indicators. The result tells us that the Environmental Kuznets Curve can not be adapted to every case of environmental degradation, and that there are some types of environmental degradation, such as forest degradation, that have no relation to economic conditions.

1. Introduction

The World Development Report 1992 reports that environmental degradation and increase of per capita income have an inverted U-shaped relation trend. This means that environmental damage increases at early stages of development, then declines when the economic level reaches a certain point (World Bank, 1992). This inverted U-shaped relation is the so called "Environmental Kuznets Curve" (hereafter EKC), named after Kuznets who hypothesized an inverted U pattern in the relation between inequality of income distribution and a nation's economic level. Nowadays, EKC is the leading hypothesis concerning economic growth and environmental quality.

Figure 1 illustrates EKC. This hypothesis indicates the following 4 points.

First, environmental degradation is an inevitable outcome of economic growth because there is a trade-off between economic growth and environmental degradation until a turning point is reached.

Second, environmental degradation is restrained as the economy grows, because environmental resources become more scarce. Investment into pollution removal devices also increases. Consequently, economic growth and environmental preservation may occur at the same time.

Third, developing countries have late-comer advantages such as access to, and opportunity to use cheaper and more efficient pollution removal devices introduced through technical innovation, and economic development with comparatively low polluting industrial activities. Therefore, EKC shifts towards the origin (left and down).

Finally, environmental policy in developing countries is not always effective, and must be compatible with their economic level. Furthermore, technical transfer by Official Development Assistance (ODA) or Foreign Direct Investment (FDI) from developed countries could be much more effective.

The EKC hypothesis can be used to rationalize the position that ″pollution can not be avoided during economic growth″. This ″Polluted and Clean″ hypothesis can cause irreversible environmental destruction.

To begin with, we must mention that EKC is still an open question. Thus, in this paper, we empirically examine the concepts of EKC. We verify EKC with per capita emission of SOx, NOx and CO2, which is based on per capita Gross Domestic Product (GDP) and purchasing power parity (PPP), ratio of population with access to safe water and urban sanitation, and deforestation, by elasticity and regression analysis with cross-country data. In addition, adding the social factor of population growth as an explanatory, we determine the relation between economic growth and environmental degradation in a more structured manner. Finally, we conclude that EKC should not be widely assumed and that it is necessary to refer to various and more flexible considerations. In other words, not only economic factors but also social and natural ones should be taken into account.

2. Review of empirical studies of the EKC hypothesis

As mentioned above, the World Bank's World Development Report 1992 (World Bank, 1992), subtitled ″Development and the Environment″ and presented at Earth Summit 1992, was a leading paper which discussed the concept of the EKC. This report asserted that there were three types of cases related to environmental degradation and economic growth.

Type 1 is the case in which, while income increases, some environmental conditions, such as the ratio of population without access to safe water, and urban population without access to adequate sanitation, declines. This occurs because increases in income improves access to public services such as sanitation and rural electricity.

Type 2 is the case where pollution is initially worsened but then improves as income increases. Such examples are air pollution such as SOx and suspended particular matter (SPM), water pollution and some types of deforestation. Thus, environmental preservation can be achieved only when countries deliberately introduce policies to ensure that additional resources are devoted to dealing with environmental problems as income increases.

Type 3 is the case where income growth worsens some aspects of the environment such as the emission of CO2, NOx and municipal waste. In this case, it is difficult to reduce emissions because abatement is more expensive than the social cost produced by emission.

Type 2 has become the main hypothesis for explaining the relation between environment and development in developing countries, probably because this idea has been easier to adapt by economists.

Shafik(1994) is one of the leading researchers, who developed the background report of the World Bank Report 1992. Also, previous studies by Grossman (Grossman & Kruger 1995, Grossman 1995), Selden & Song (1994) and Hayami (1995) are important.

The environmental indicators used in previous studies are shown in Table 1. Shafik analyzed indicators such as, air and water pollution, deforestation, municipal waste, lack of access to safe water, lack of access to urban sanitation, and emission of carbon dioxide. Grossman & Kruger analyzed two groups, air pollutants (SOx, SPM, and dark matter (fine smoke)) and water pollutants in detail. Also Selden & Song analyzed 4 air pollutants in their study, and Hayami analyzed CO2 in his research.

It is important to determine which kind of indicator is to be chosen for analysis, because it directly relates to the treatment of environmental problems. Most previous studies used air and water pollution indicators taken from the Global Environmental Monitoring System (GEMS).(1) This data is limited to urban areas for air pollution and rivers for water quality. Even though the data can not show the full picture of a country's environmental state, it is a crucial environmental indicator when dealing with pollution concentration.

Some previous studies do not use GEMS data, but instead use indicators such as ″amount of emission per capita″ or ″amount of emission per GDP″ (only Hayami uses the latter). This ″amount of emission per capita″ is not appropriate for estimating EKC because it indicates energy efficiency rather than environmental damage.

As shown in Table 2, all previous studies used cross country data and dummy variables. Their analysis show that the reverse U shape can be seen if analysis is based on SOx, SPM, biological oxygen demand (BOD) and chemical oxygen demand (COD)(see Table 3).

Originally, the Kuznets Curve was to be analyzed using time series data for each country. Unfortunately, it is difficult to acquire environmental data in time series especially in developing countries. Thus, we can not help but use cross country data to analyze EKC as has been done in previous studies. A problem of previous studies was that they used each country's dummy variables to conduct regression analysis. But this can be misleading in terms of the actual trend because it may lead to the assumption that there are environmental data for 3 points in time and each data set in the time series worsens. But if the data from a country with a higher average income is relatively less than data from a lower average income country, then an ostensibly inverted U or steadily decreasing function form would be realized from regression analysis using dummy variables.

3. Estimation Result

The flow-chart of our study is shown in Figure 2, and data sources are shown in Table 4. Country names and nominal and PPP·GDP are shown in Table 5.

The environmental indicators we examined are SOx, NOx, CO2, ratio of population with access to safe water, the ratio of population with access to urban sanitation, and deforestation in 1980 and 1990. The SOx, NOx and CO2 measures are based on aggregate emission per capita but we also analyzed aggregate emission per GDP.

As mentioned above, in order to treat a variety of countries data as one country data, we must examine the data trend for each country. Therefore, we applied elasticity analysis, which is a regression analysis with the rate of change of environmental indicators divided by per capita GDP growth rate in 1980 and 1990 as the objective variable, and per capita GDP in 1980 as the explanatory variable. This elasticity analysis makes it possible to determine the function form based on the actual trend of each country.

3.1 Elasticity analysis and Regression analysis

The elasticity analysis result is shown in Table 6. In the case of using nominal GDP, the equation concerning only deforestation has little explanatory meaning ($R2=0.382$). In the case where PPP・GDP is used, the equations about NOx, ratio of population with access to urban sanitation, and deforestation, also have little explanatory meaning.

The indicators that have sufficient explanatory meaning due to elasticity analysis are further analyzed, and the trend of each country's data near the X segment will determine the function form. In the case where the regression curve has the X segment, thereafter, that indicator will be applied to quadratic form. In the case where the regression curve does not have the X segment, thereafter, the indicator will be applied to linear form. The X segment which has sufficient explanatory meaning indicates whether the trend of environmental indicators change from increasing to decreasing at some GDP level or not. For example, SOx has enough data to exceed the value on the X segment ($4,421US in nominal GDP, $3,412US in PPP・GDP) with a 95% confidence interval (see Fig.3, Fig.4). This means regression has explanatory meaning for the X segment, thus it is proper to regress this indicator to quadratic form.

But, NOx, CO_2, ratio of population with access to safe water and ratio of population with access to sanitation equipment are properly regressed to linear form because their values of the X segment are so large and the trend of each county's data near the X segment is diverse. For example, in the case of NOx, there are few data that exceed the value on the X segment ($11,431US) with a 95% confidence interval. This means regression has little explanatory meaning for the X segment (shown in Figure 5).

The regression result based on Table 6 is shown in Table 7. The environmental indicator, log scale per capita SOx in both nominal GDP and PPP・GDP has sufficient explanatory meaning to be regressed to quadratic form. This form, an inverted U shaped curve, suggests that EKC can be explained in the case of SOx. The value of per capita GDP at the peak of SOx emission is $8,747US in nominal GDP (shown in Figure 6) and $17,359US in PPP・GDP. However, the peak value derived from elasticity analysis, $4,421US in nominal GDP and $3,412US in PPP・GDP, is more important. NOx, CO_2, ratio of population with access to safe water and ratio of population with access to urban sanitation have sufficient explanatory meaning to regress by linear form, which means these indicators increase steadily with economic growth (shown in Figure 7).

3.2 Additional examination : the case of environmental indicators per GDP

The above analysis uses per capita emission of SOx, NOx and CO_2. Furthermore, we conducted the same analysis using different indicators; the amount of emission of SOx, NOx and CO_2 per GDP. The results are shown in Table 8 and Table 9. With nominal GDP, log scale NOx and CO_2 have inverted U curves but there is little explanatory meaning with PPP・GDP. NOx and CO_2, in the nominal GDP case do not have enough explanatory meaning because R2 is rather smaller than that of per capita NOx and CO_2. As we mentioned already, indicators such as the amount of NOx emission per GDP or the amount of CO_2 emission per GDP are similar to energy consumption per GDP. Thus, it should be discussed as an indicator of energy efficiency (inverse) not an indicator of the environment, and we can not claim the EKC with per capita indicators .

3.3 Deforestation ratio, economic growth and population growth

Since the deforestation ratio could not be explained only by economic indicators (per capita GDP), we add population growth as an explanatory value. The result in Table 10 shows population growth's contribution to deforestation ratio. That is, there is no relation between the rate of deforestation and the degree of economic growth.

4. Concluding Remarks

Our findings strongly suggest that it is not appropriate to generalize the emergence of EKC for all sources of environmental destruction. First, among the following environmental indicators, SOx, NOx,

CO_2, ratio of population with access to safe water, and the ratio of population with access to urban sanitation, it is only SOx that forms EKC based on cross country data. This result is examined by an original method using elasticity analysis that can reflect the trend of environmental indicators in each country. Therefore, this result has high reliability.

But as we already mentioned, EKC should be considered as being based on time series data in one country. Therefore, we proceed to the analysis of Tokyo and Yokohama based on 1960's time series data. Figure 8 and Figure 9 show the realization of EKC, both of which have a turning point in around the mid-1960s. As far as the amount of SOx emission in the case of Japan as a whole is concerned, the curve is at its peak in the mid-1960s and then the figures are flat. After the mid-1970s, the curve shows a drastic decline. This sudden change was the result of efforts mainly by local residents, the local government, and private companies. In large cities, anti-pollution agreements had been concluded between local government or local residents, and private companies since early 1960. To reduce SOx emissions, private companies took measures such as heavy oil desulfurization and the selective use of fossil fuels low in sulfur content. Thereafter, the amount of SOx emission was abruptly reduced by the oil crisis and the spread of fuel-gas desulfurization technology. Second, social factors, such as population growth, could have more of an explanatory meaning than economic factors such as deforestation.

We believe that to hold that there is a relation between economic growth and environmental degradation, we must explain the mechanisms of environmental problems. These mechanisms are not only economic factors but also social, natural, and physiographical factors as well as mechanisms of environmental restriction developed by local resident's environmental activities, freedom of information and environmental education.

Acknowledgement

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Note

(1) Global Environmental Monitoring System (GEMS) is a project to collect worldwide environmental data conducted by WHO and UNEP. Air quality data (GEMS /AIR) has been collected since1975 and Water quality data since 1976. Air quality data contains ambient air quality in urban areas and water quality data contains river quality data. This database includes data from 20 to 60 countries.

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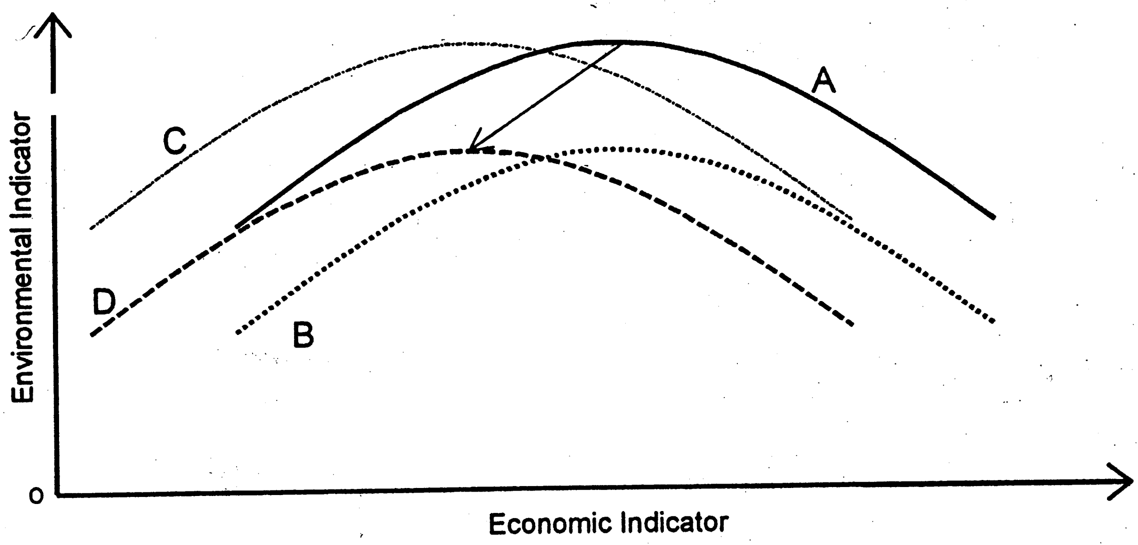


Fig. 1 Environmental Kuznets Curve (EKC)

Table 1 Environmental Indicators in previous studies

	SOx	NOx	CO_2	safe water	sanitation	deforestation	SPM	smoke	DO	BOD	COD	Coliform	heavy metal	municipal waste	CO
Shafik(1994)	a	—	b	d	d	e	a	—	a	—	—	a	—	b	—
Grossman and Krueger(1995)	a	—	—	—	—	—	a	a	a	a	a	a	a	—	—
Selden and Song(1994)	b	b	—	—	—	—	b	—	—	—	—	—	—	—	b
Hayami (1995)	—	—	c	—	—	—	—	—	—	—	—	—	—	—	—

Note: Marks in the table are the denomination of each environmental indicator. a: concentration, b: per capita, c: per GDP, d: Maintaining ratio to population, e: Deforestation ratio. Heavy metals in Grossman and Krueger (1995) are Lead, Cadmium, Arsenic, Mercury and Nickel in rivers.

Table 2 Analysis Method in previous studies

	Function form			Explaining variables				Dummy variable
	liner	quadratic	cubic	GDP/capita	log(GDP/capita)	log(PPP·GDP/capita)	GDP/capita term average	
Shafik (1994)	Y	Y	Y	—	—	Y	—	Y
Grossman and Krueger(1995)	—	—	Y	Y	—	—	Y	Y
Selden and Song(1994)	—	Y	Y	—	Y	—	—	Y
Hayami (1995)	—	Y	—	—	Y	—	—	Y

Note: Y means that the method was applied in each study.

Table 3 Analysis Result of previous studies

	SOx	NOx	CO_2	Safe water	sanitation	deforestation	SPM	smoke	DO	BOD	COD	Coliform	heavy metal	municipal waste	CO
Shafik (1994)	Y	—	N	N	N	Y	Y	—	N	—	—	Y	—	N	—
Grossman and Krueger(1995)	Y	—	—	—	—	—	Y	N	Y	Y	Y	Y	Y	—	—
Selden and Song(1994)	Y	Y	—	—	—	—	Y	—	—	—	—	—	—	—	Y
Hayami (1995)	—	—	Y	—	—	—	—	—	—	—	—	—	—	—	—

Note: Y : It has a Peak N : It has no Peak

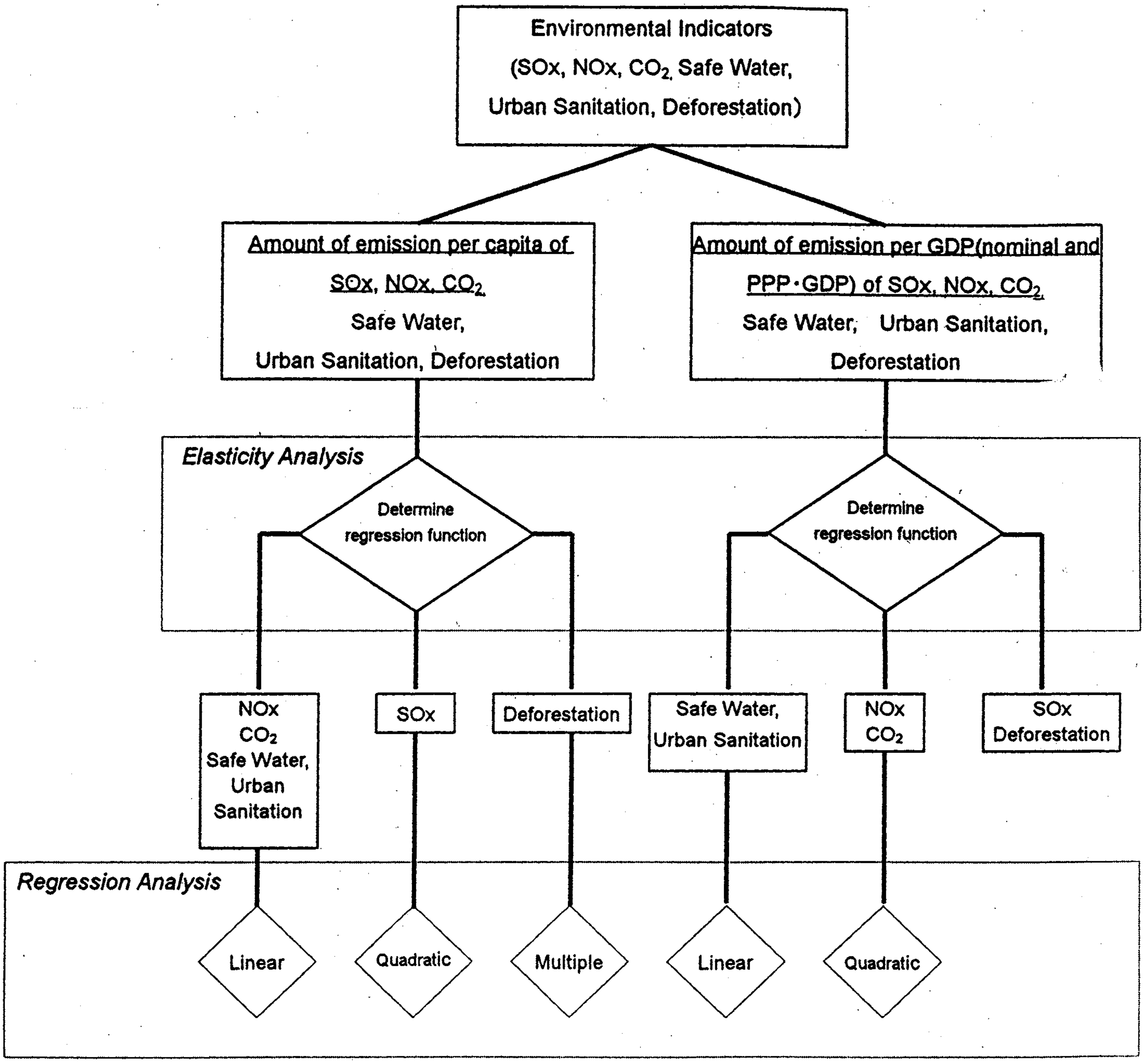


Fig. 2 Research Flow Chart

Table 4 Data Source

	1970' Data	1980' Data	1990' Data
Population	United Nations(1976) Statistical Yearbook 1975. United Nations	United Nations(1986) Statistical Yearbook 1983/84. United Nations	United Nations(1995) Statistical Yearbook 1993. United Nations
Nominal GDP		World Bank(1982) World Development Report 1982. Oxford U. P.	World Bank(1992) World Development Report 1992. Oxford U. P.
PPP·GDP		PWT(Penn-World Tables)(1997) http://www.nber.org/pwt56.html	PWT(Penn-World Tables)(1997) http://www.nber.org/pwt56.html
SOx emission (kg)		STA(1993), Energy Use in Asia and Environmental Forecasting WRI(World Resources Institute) (1994) World Resources 1994-1995. World Resources Institute	STA(1993), Energy Use in Asia and Environmental Forecasting WRI(World Resources Institute) (1994) World Resources 1994-1995. World Resources Institute
NOx emission (kg)		STA(1993), Energy Use in Asia and Environmental Forecasting WRI(World Resources Institute) (1994) World Resources 1994-1995. World Resources Institute	STA(1993), Energy Use in Asia and Environmental Forecasting WRI(World Resources Institute) (1994) World Resources 1994-1995. World Resources Institute
CO_2 emission(t)		World Bank(1996). World Development Report 1996. Oxford U. P.	World Bank(1996). World Development Report 1996. Oxford U. P.
Safe water accessible rate (%)		World Bank(1994) World Development Report 1994. Oxford U. P.	World Bank(1994) World Development Report 1994. Oxford U. P.
Urban sanitation accessible rate (%)		World Bank(1994) World Development Report 1994. Oxford U. P.	World Bank(1994) World Development Report 1994. Oxford U. P.
Deforestation rate (%)		World Bank(1996). World Development Report 1996. Oxford U. P.	

Notes:

1.Taiwan's population and GDP data is from N. Kobayashi(1995), Introduction to Taiwan's Economy (Japanese).

2.Indonesia's 1970 population data is from United Nations(1972) Statistical Yearbook 1971. United Nations.

3.SOx data of 14 Asian countries are from STA(1993) and we used 1975 data for 1980 and 1987 data for 1990. SOx data of 15 European and North America countries are from WRI(1994) 1980 and 1990. The definition of SOx in STA(1993) is as follows: SOx emissions caused by primary energy consumption, and refinery of nonmetal materials. Please refer to the definition of SOx in WRI(1994).

5. NOx data of 14 Asian countries are from STA(1993) and we used 1975 data for 1980 and 1987 data for 1990. SOx data of 15 European and North America countries are from WRI(1994) and we used 1980 and 1990 data. Spain's data in 1990 is unexplained. The definition of NOx in STA(1993) is as follows: NOx emissions caused primarily by energy consumption. Please refer to the definition of SOx in WRI(1994).

6. CO_2 emission is defined as emissions by primary energy consumption. Taiwan's data was unobtainable.

7. Safe water access rate indicates the rate of those people who have access to safe water to the entire population. Safe water is defined as treated water or nonpolluted water.

8. Urban sanitation access rate indicates the rate of those people who have access to urban sanitation to the entire population. Urban sanitation is infrastructure such as sewers.

9. Deforestation rate (%) is the average rate from 1981 to 1990.

Table 5 GDP per Capita

	Nominal GDP per capita(US$)		PPP·GDP per capita(US$)	
	1980	1990	1980	1990
1 Bangladesh	126	212	1,085	1,390
2 China	252	316	972	1,324
3 India	214	308	882	1,264
4 Indonesia	477	597	1,281	1,974
5 Japan	8,903	23,822	10,072	14,331
6 Korea, Rep.	1,528	5,514	3,093	6,673
7 Malaysia	1,702	2,387	3,799	5,124
8 Pakistan	260	317	1,110	1,394
9 Philippines	738	713	1,879	1,763
10 Singapore	4,341	12,791	7,053	11,710
11 Sri Lanka	255	427	1,635	2,096
12 Thailand	720	1,430	2,178	3,580
13 Hong Kong	4,015	10,459	8,719	14,849
14 Taiwan	2,323	7,906	4,459	8,063
15 Belgium	11,829	19,303	11,109	13,232
16 Denmark	12,957	25,479	11,342	13,909
17 Finland	10,439	27,527	10,851	14,059
18 France	12,136	20,988	11,756	13,904
19 Ireland	5,234	12,132	6,823	9,274
20 Italy	6,983	18,917	10,323	12,488
21 Netherlands	11,852	18,670	11,284	13,029
22 Norway	14,004	24,954	12,141	14,902
23 Portugal	2,215	5,758	4,982	7,478
24 Spain	5,298	12,609	7,390	9,583
25 Sweden	14,771	26,651	12,456	14,762
26 Switzerland	15,892	33,500	14,301	16,505
27 United Kingdom	9,346	16,941	10,167	13,217
28 Canada	10,537	21,447	14,133	17,173
29 United States	11,360	21,575	15,295	18,054

Sources: UN 1986&1996, World Bank 1982&1992, Penn-World Tables 1997

Table 6 Elasticity Analysis:
GDP and Environmental Indicators per Capita

In Nominal GDP

Environmental Indicators	Regression Result	Adjusted R^2	Intercept (GDP*US$)	Explanatory meaning	Assumable Function	Number of observations
SOx emission per capita	E=5.048-0.601ln(GDP*) t= (-5.264)	0.497	4,421	Y	quadratic	28
NOx emission per capita	E=3.895-0.417ln(GDP*) t= (-5.315)	0.512	11,431	Y	linear	27
CO2 emission per capita	E=4.504-0.490ln(GDP*) t= (-6.659)	0.625	9,899	Y	linear	27
Safe water accessible rate	E=3.869-0.421ln(GDP*) t= (-7.277)	0.712	9,771	Y	linear	22
Urban sanitation accessible rate	E=6.521-0.697ln(GDP*) t= (-4.914)	0.563	11,609	Y	linear	19
Deforestation rate	E=14.897-1.655ln(GDP*) t= (-3.899)	0.382	8,104	N	—	24

*GDP per capita

In PPP·GDP

Environmental Indicators	Regression Result	Adjusted R^2	Intercept (GDP*US$)	Explanatory meaning	Assumable Function	Number of observations
SOx emission per capita	E=13.353-1.641ln(GDP*) t= (-7.101)	0.647	3,412	Y	quadratic	28
NOx emission per capita	E=7.099-0.749ln(GDP*) t= (-3.848)	0.347	13,122	Y	—	27
CO2 emission per capita	E=9.002-0.979ln(GDP*) t= (-5.510)	0.530	9,891	Y	linear	27
Safe water accessible rate	E=7.883-0.828ln(GDP*) t= (-4.364)	0.462	13,699	Y	linear	22
Urban sanitation accessible rate	E=13.108-1.368ln(GDP*) t= (-2.743)	0.266	14,451	N	—	19
Deforestation rate	E=32.461-3.593ln(GDP*) t= (-4.211)	0.421	8,385	N	—	24

*GDP per capita

Notes: 1. Rate of Environmental Indicators elasticity - GDP effect is the rate of change of environmental indicators divided by per capita GDP growth rate from 1980 to 1990.
2. Deforestation is the rate of forest degradation ratio from 1981 to 1990 divided by per capita GDP growth rate from 1980 to 1990.
3. The Philippines is excluded because of it's minus growth rate of GDP per capita.

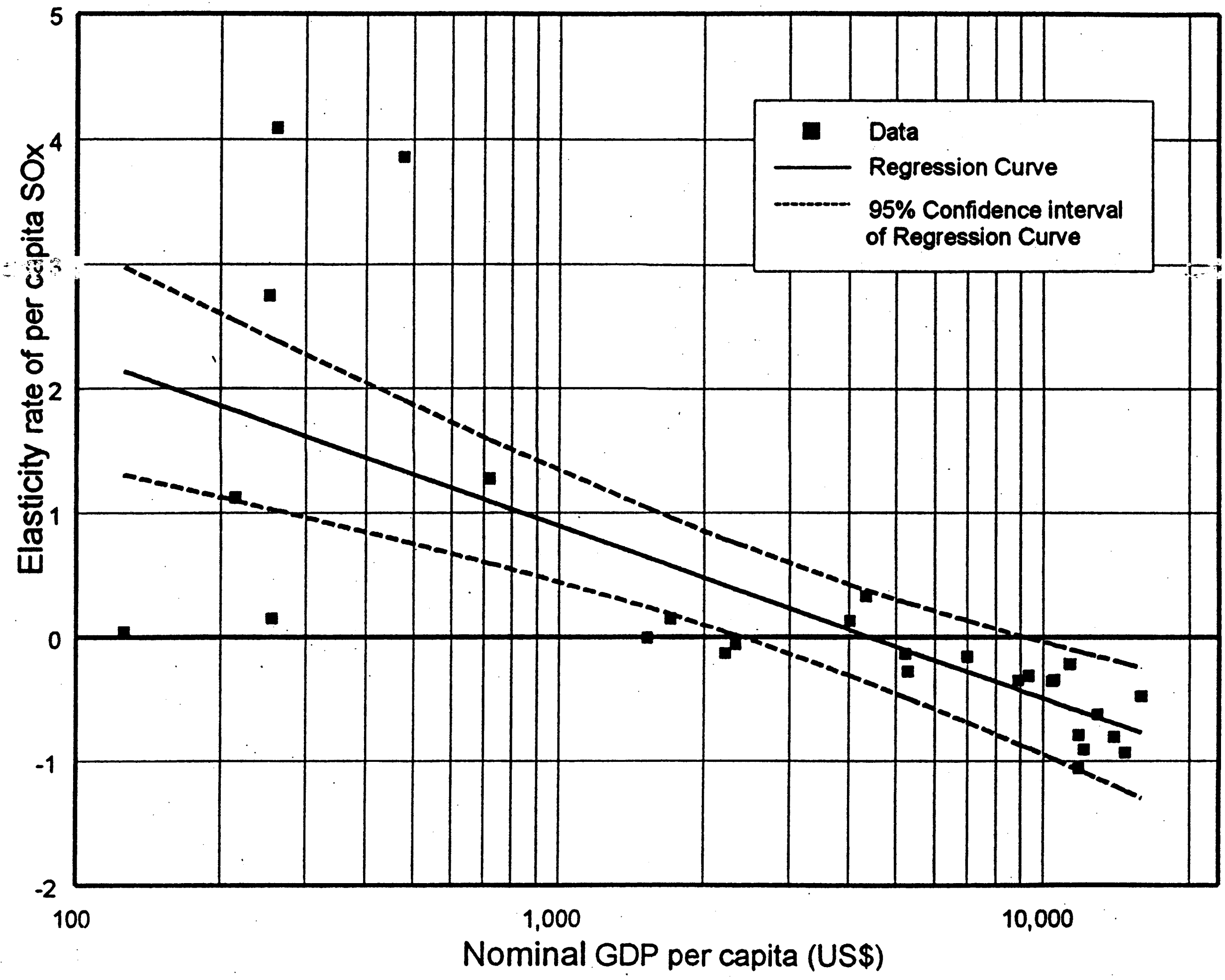


Fig. 3 Elasticity Analysis: SOx Emisson and Nominal GDP

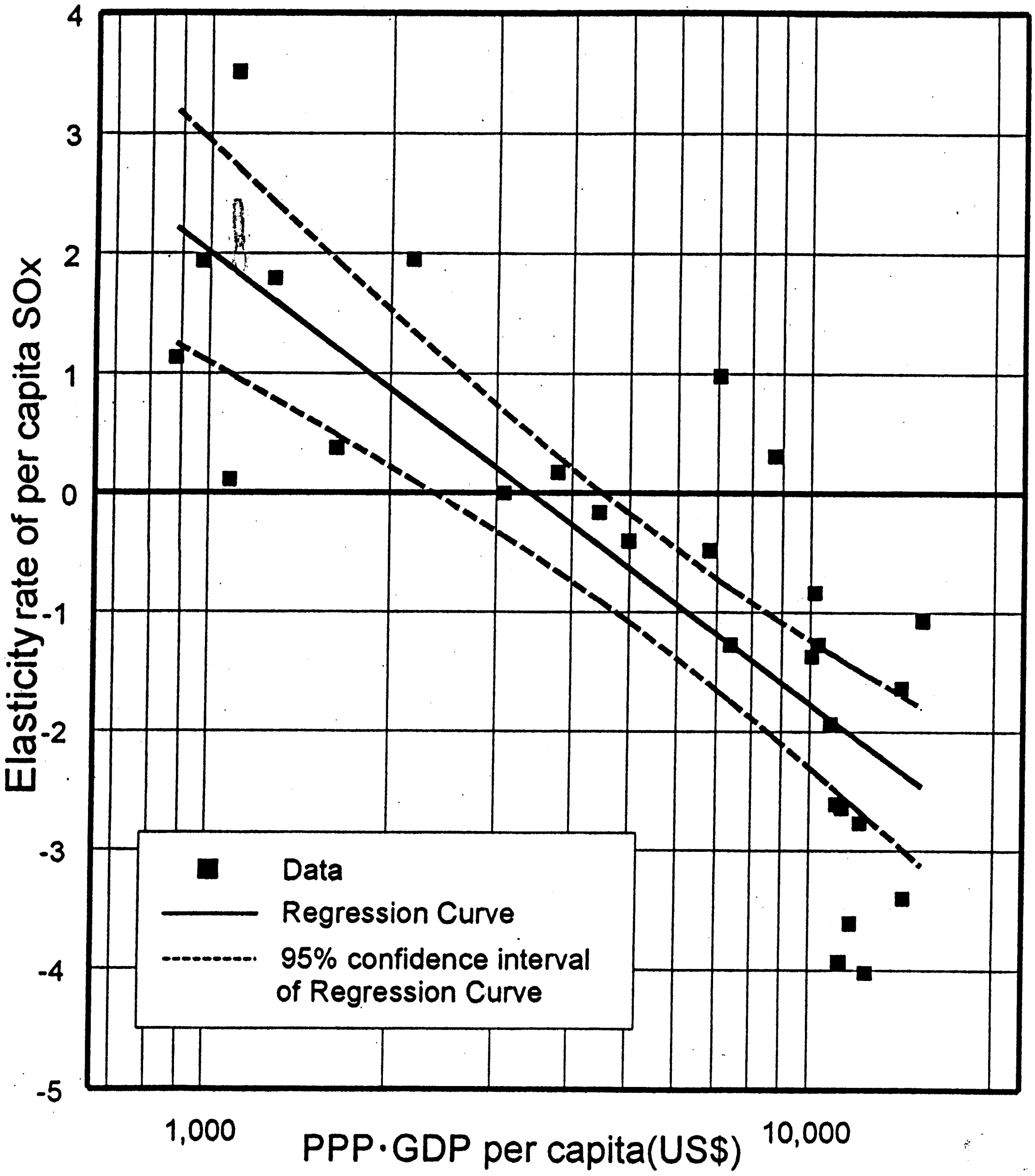


Fig. 4 Elasticity Analysis: SOx Emission and PPP・GDP

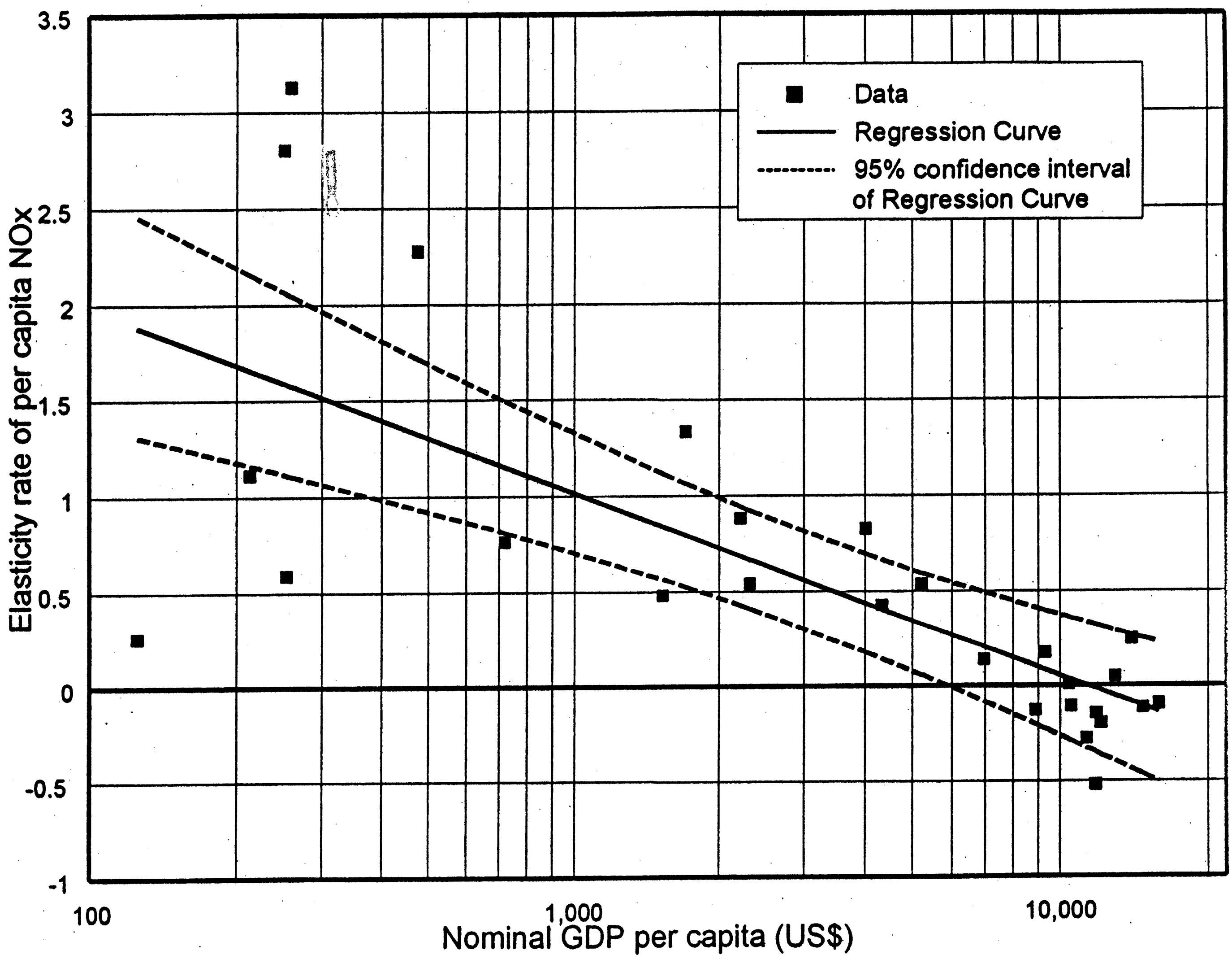


Fig. 5 Elasticity Analysis: NOx Emission and Nominal GDP

Table 7 Regression Results: Environmental Indicators per capita and GDP

In Nominal GDP

Dependent Variables	Regression formula	Adjusted R^2	Number of observations
SOx emission per capita	y=-236.716+59.407ln(GDP/人)-3.056ln(GDP*)² t= (1.796) (-1.442)	0.266	58
log-scale SOx emission per capita	y=-17.050+4.592ln(GDP*)-0.253ln(GDP*)² t= (5.981) (-5.143)	0.713	58
NOx emission per capita	y=-62.598+10.790ln(GDP*) t= (8.429)	0.556	57
log-scale NOx emission per capita	y=-3.565+0.752ln(GDP*) t= (19.450)	0.871	57
CO2 emission per capita	y=-13.741+2.470ln(GDP*) t= (8.808)	0.582	56
log-scale CO2 emission per capita	y=-4.746+0.733ln(GDP*) t= (16.387)	0.829	56
Safe water accessible rate	y=-13.856+11.625ln(GDP*) t= (11.511)	0.725	51
Urban sanitation accessible rate	y=-50.829+15.417ln(GDP*) t= (11.675)	0.750	46

In PPP・GDP

Dependent Variables	Regression formula	Adjusted R^2	Number of observations
SOx emission per capita	y=6.987-17.620ln(GDP/人)+2.401ln(GDP/人)² t= (-0.152) (0.346)	0.292	58
log-scale SOx emission per capita	y=-35.449+8.038ln(GDP/人)-0.412ln(GDP/人)² t= (2.549) (-2.184)	0.620	58
CO2 emission per capita	y=-31.826+4.435ln(GDP/人) t= (9.524)	0.620	56
log-scale CO2 emission per capita	y=-9.654+1.263ln(GDP/人) t= (15.467)	0.812	56
Safe water accessible rate	y=-98.228+20.798ln(GDP/人) t= (12.233)	0.748	51

*GDP per capita

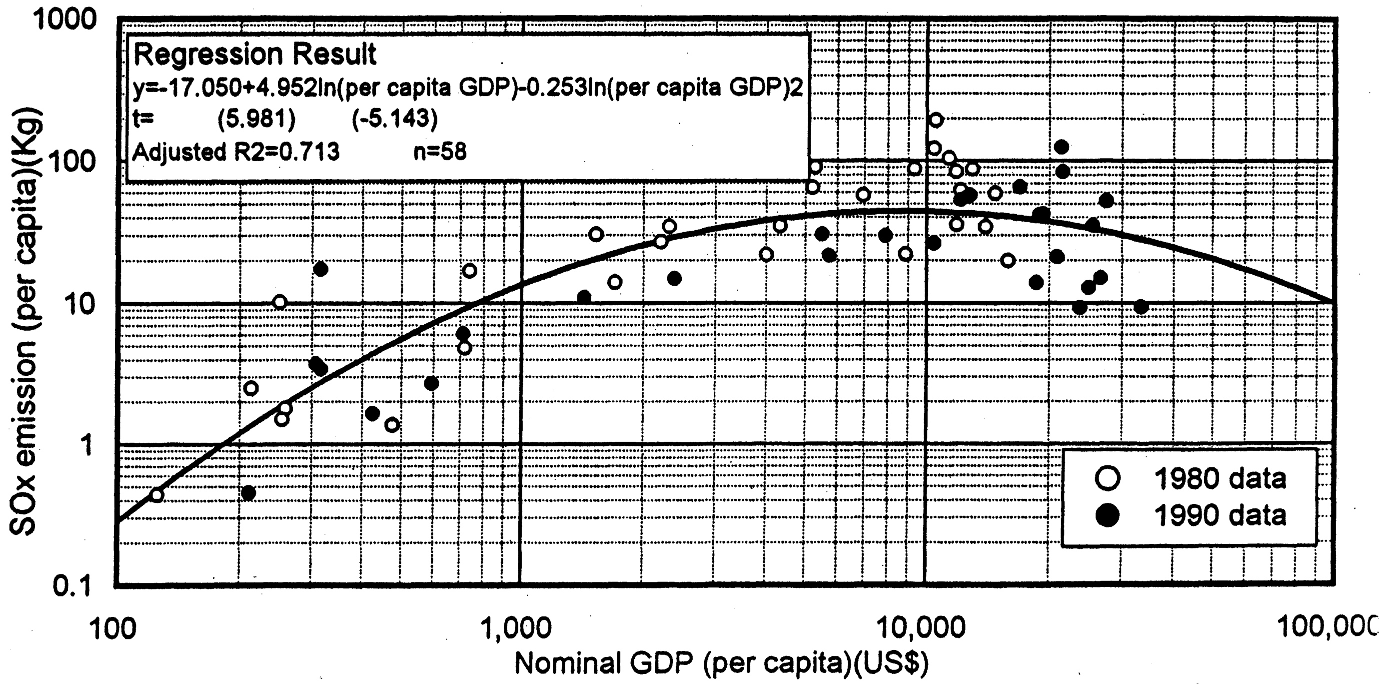


Fig. 6 Economic Growth and SOx Emission: Nominal GDP

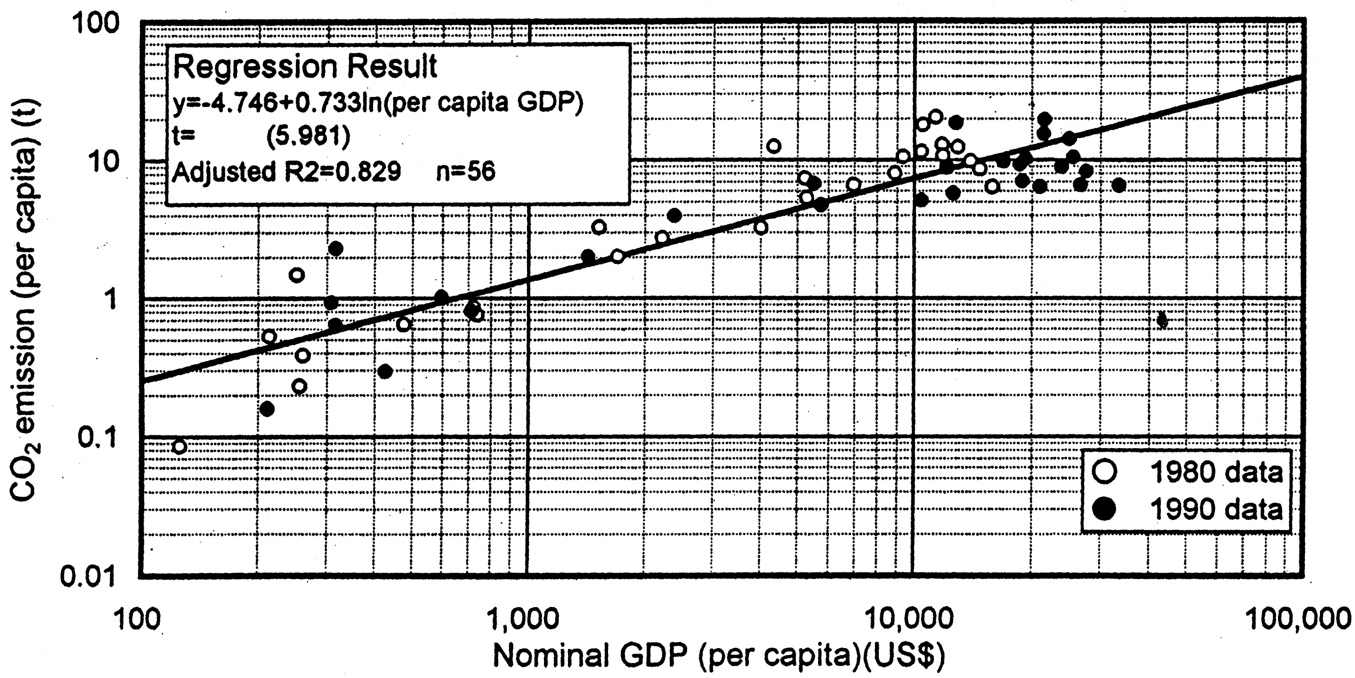


Fig. 7 Economic Growth and CO_2 Emission

Table 8 Elasticity Analysis: GDP and Environmental Indicators per GDP

In Nominal GDP

Environmental Indicators	Regression Result	Adjusted R^2	Intercept (GDP*US$)	Explanatory meaning	Assumable Function	Number of observations
SOx emission per GDP	E=1.218-0.208ln(GDP/人) t= (-2.798)	0.196	349	N	-	29
NOx emission per GDP	E=1.123-0.169ln(GDP/人) t= (-4.986)	0.469	759	Y	linear	28
CO2 emission per GDP	E=1.519-0.214ln(GDP/人) t= (-7.349)	0.663	1,216	Y	linear	28

In PPP·GDP

Environmental Indicators	Regression Result	Adjusted R^2	Intercept (GDP*US$)	Explanatory meaning	Assumable Function	Number of observations
SOx emission per GDP	E=6.366-0.888ln(GDP*) t= (-4.781)	0.438	1,296	N	-	29
NOx emission per GDP	E=3.087-0.393ln(GDP*) t= (-3.318)	0.270	2,583	N	-	28
CO2 emission per GDP	E=4.298-0.539ln(GDP*) t= (-5.090)	0.480	2,886	Y	linear	28

*GDP per capita

Notes: Rate of Environmental Indicators elasticity - GDP effect is the rate of change of environmental indicators divided by per capita GDP growth rate from 1980 to 1990.

Table 9 Regression Results: Environmental Indicators(per GDP) and GDP

In Nominal GDP

Dependent Variables	Regression formula	Adjusted R^2	Number of observations
NOx emission per GDP	y=0.013-0.001ln(GDP*)-0.000ln(GDP*)^2 t= (-0.289) (-0.120)	0.306	57
log-scale NOx emission per GDP	y=-7.385+0.785ln(GDP*)-0.066ln(GDP*)^2 t= (1.663) (-2.194)	0.454	57
CO2 emission GDP per GDP	y=0.002+0.000ln(GDP*)-0.000ln(GDP*)^2 t= (0.241) (-0.587)	0.249	56
log-scale CO2 emission GDP per GDP	y=-11.993+1.696ln(GDP*)-0.126ln(GDP*)^2 t= (3.270) (-3.797)	0.509	56

In PPP·GDP

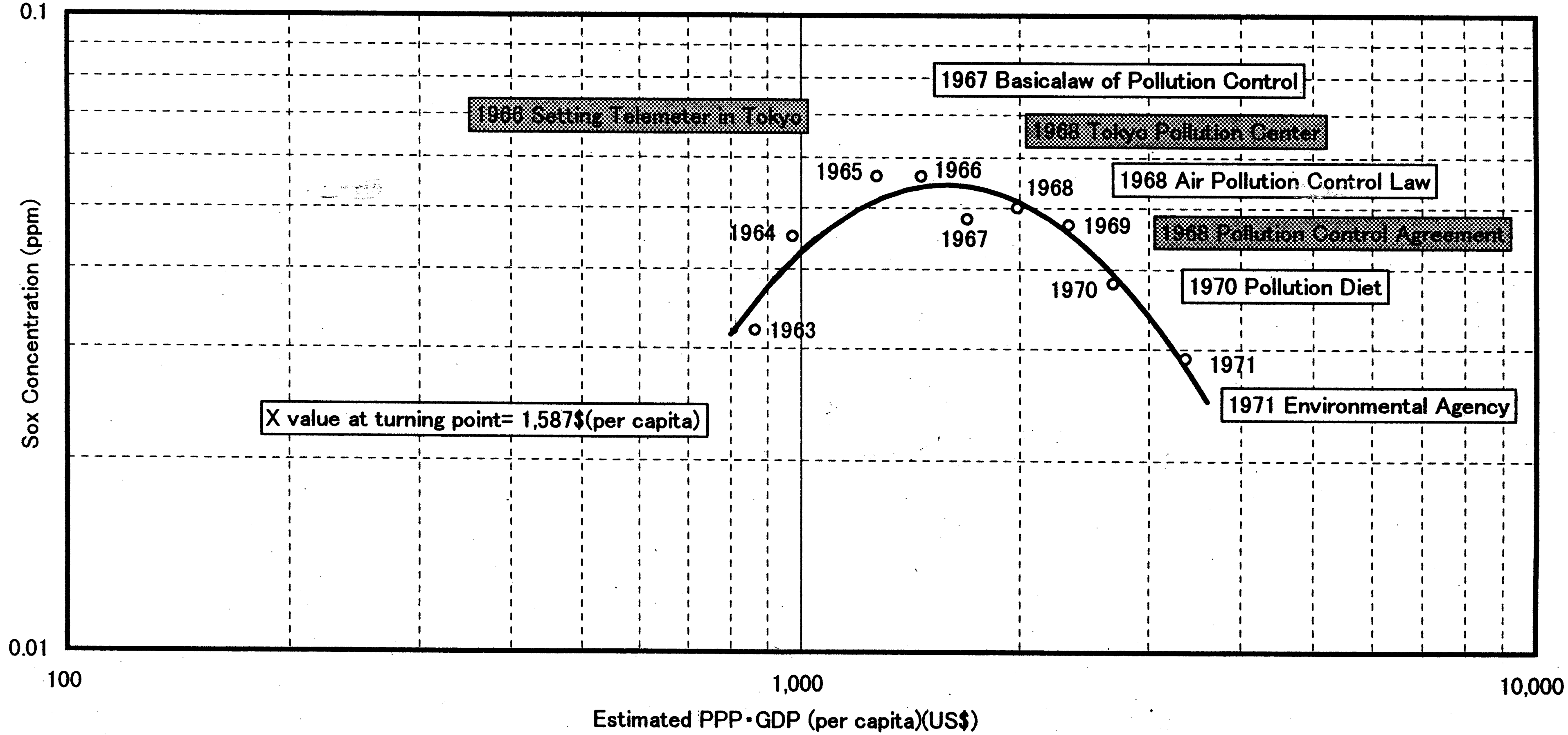
Dependent Variables	Regression formula	Adjusted R^2	Number of observation
CO2 emission GDP per GDP	y=-0.001+0.000ln(GDP/人)-0.000ln(GDP*)^2 t= (0.183) (-0.115)	0.024	56
log-scale CO2 emission GDP per GDP	y=-14.596+1.463ln(GDP/人)-0.072ln(GDP*^2 t= (0.663) (-0.543)	0.135	56

*GDP per capita

Table 10 Deforestation Ratio and Multiple Regression Results

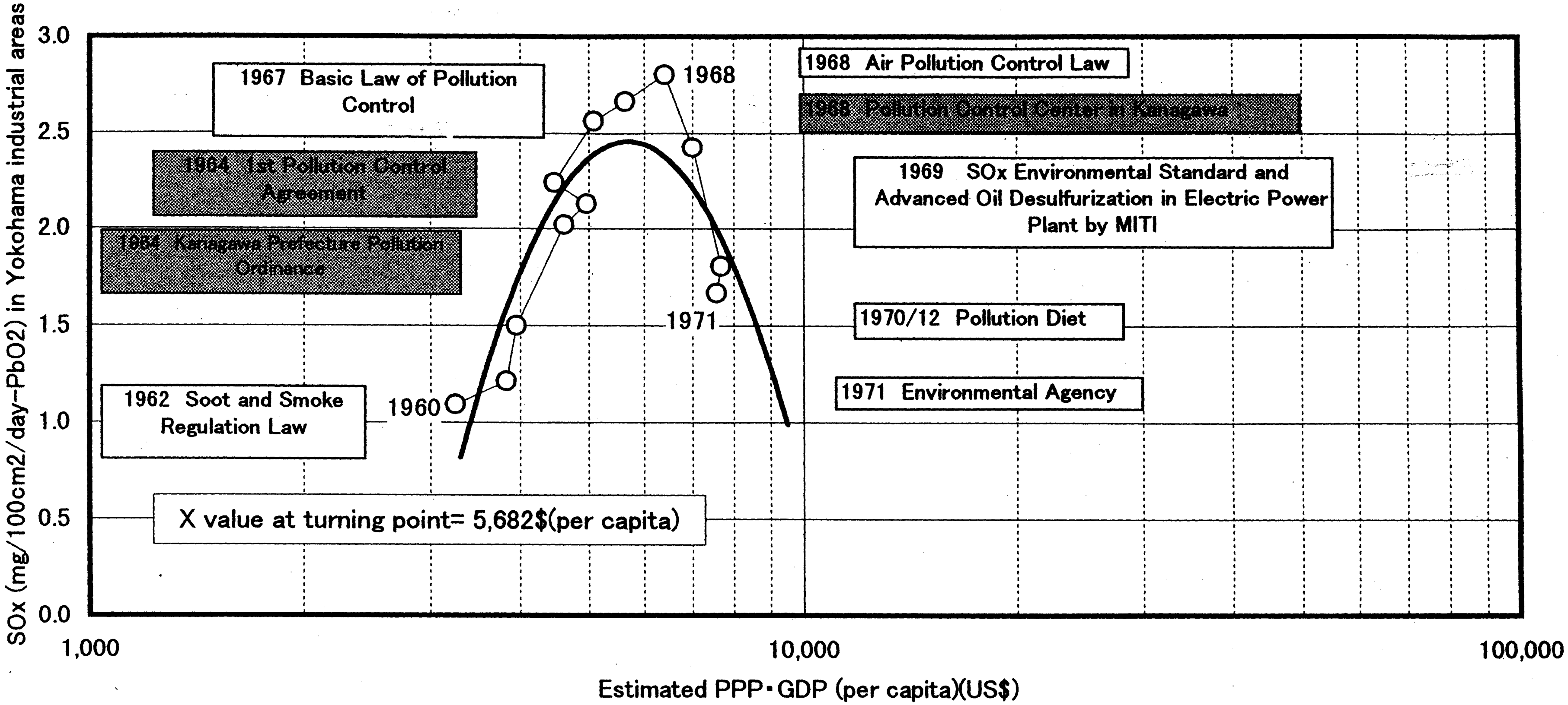
Dependent Variables	Regression formula	Adjusted R^2	Number of observations
Growth rate of GDP(nominal) per capita and Population	y=-7.522-0.005(GDP)+1.452(Population) SC= (-0.017) (0.742) t= (-0.121) (5.198)	0.524	28
Growth rate of GDP(PPP) per capita and Population	y=-5.574-0.085(GDP)+1.521(Population) SC= (-0.110) (0.776) t= (-0.807) (5.720)	0.536	28
Population growth rate	y=-8.753+1.561(Population) t= (6.430)	0.590	29

Notes: 1. The Philippines is excluded because of its negative growth rate of GDP per capita.
2. SC is Standardized regression coefficient.



SOURCE: Hanya・Matsuda(1977), Introduction to Urban Environment, Tokai University (Japanese)
Economic Planning Agency In Japan(1974), Provincial Income Stastics, Shiseidou
Tokyo(1994), 50 Year History of Tokyo, Gyousei

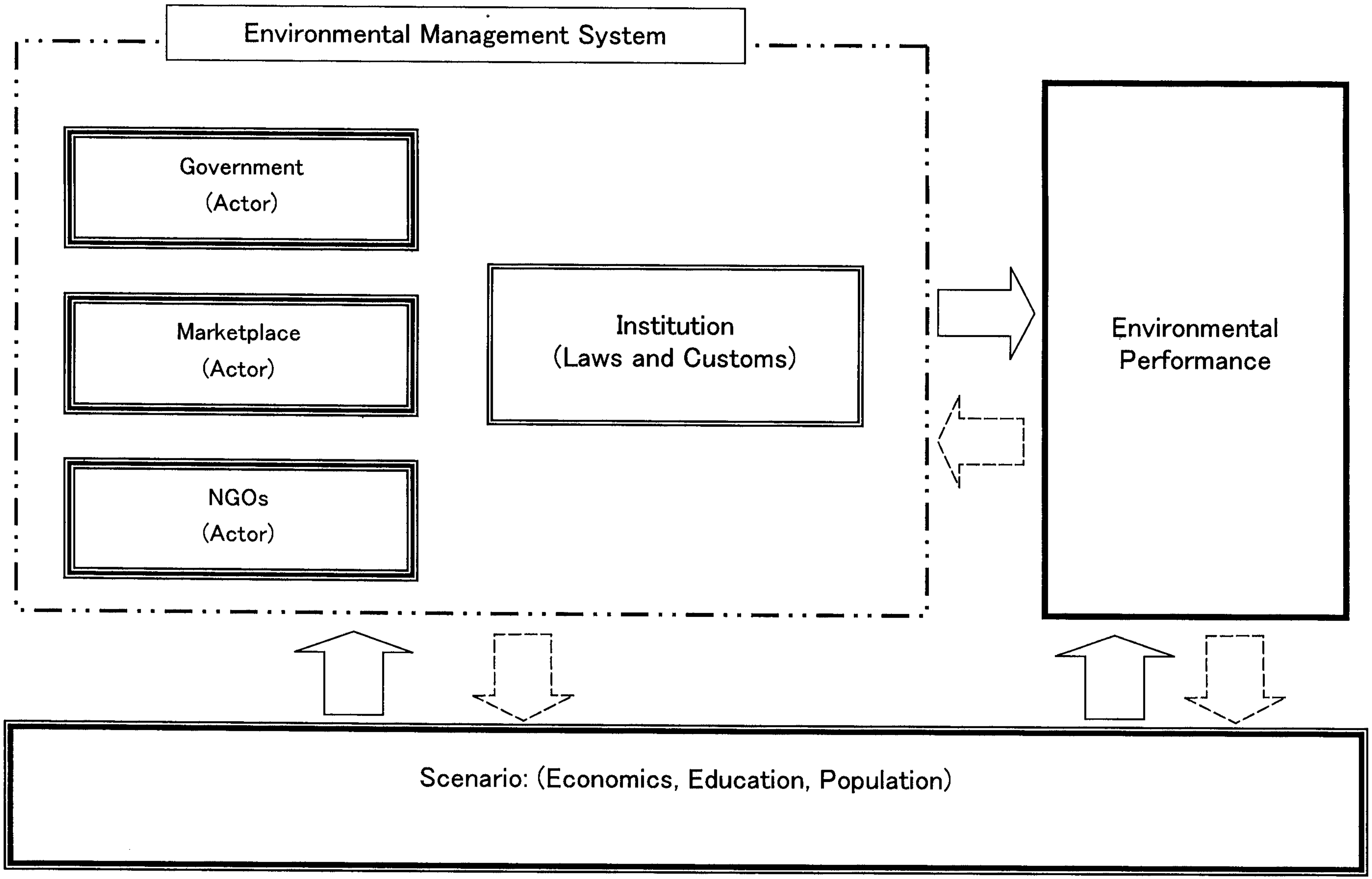
Fig.8 Economic Growth and Sox Concentration in Tokyo



SOURCE: Pollution Control Center In Yokohama(1970), Report of Air Pollution in Yokohama City
Economic Planning Agency In Japan(1974), Provincial Income Stastics, Shiseidou
Environmental Division of Kanagawa(1991), History of Environmental Administration, Gyousei

Fig. 9 Economic Growth and SOx Concentration in YOKOHAMA (Industrial Area)

Fig.2 Structure of Environmental Management System



Source: Matsuoka, S., Kochi, I. and Shirakawa, H. (1999) Social Evaluation on International Environmental Cooperation: a Case of Japan's Environmental Project in Thailand, *Journal of International Development and Cooperation*, 5(1), 11-22