Environmental Issues in Economic Development : Reappraisal of CO_2 Emissions in Asia

Osaka, Hitoshi
Department of International Economy and Business, Faculty of Economics, Kyushu University : Associate Professor : Development Economics, International Economics

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Environmental Issues in Economic Development

—Reappraisal of CO_2 Emissions in Asia[1]—

Hitoshi OSAKA

1. Introduction

Climate change is the greatest concern in the current world. Environmental issues associated with economic development have been highlighted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, in 1992, and adopted Agenda 21. Since then, many international and regional conferences on the environmental issues for sustainable development have been organized. For example, the follow-up meeting for Agenda 21, the World Summit on Sustainable Development was held in Johannesburg, South Africa, in 2002. Moreover, the United Nations Climate Change Conference, COP 13 (the Conference of the Parties 13), was also held in Bali, Indonesia, in 2007. The environmental considerations have become the major issues in economic development, however the objective of this paper is very modest. In this paper, we revise our previous estimates (Osaka, 2001, 2002, 2005) and attemp to review the current status of the regional CO_2 emissions in Asia and the Pacific.

United Nations Environment Programme (hereafter, UNEP, 1999) reports that greenhouse gas emissions per capita such as carbon dioxide (hereafter, CO_2) and sulfur dioxide were slightly reduced among developed countries in West Europe during the period of 1990-95 due to technological development. It is however observed that CO_2 emissions are aggravated again and the speed of technological development has not met with the increase of CO_2 emissions. UNEP (1999) also concerns environmental degradation in Asia and the Pacific associated with further economic growth and industrialization which signifies the increasing demand for energy and resource consumption. According to UNEP (1999), in Asia and the Pacific about 80% of the energy sources are the fossil fuels, and they indicate 41% of the world consumption. Moreover, the annual growth rate of the international CO_2 emissions is 2.6% on the average for the period

1) This paper is the English version of Osaka (2001, 2002, 2005) with the revised estimates. It is submitted without the formal English editing. It should be also noted that the financial assistance is from the Japan Society for the Promotion of Science (JSPS, No.17530215).

of 1975-95, but it is twice larger in Asia and the Pacific. In addition, the averaged years for doubling the energy demand are 28 years for the world, but they are just 12 years for the Asian region. UNEP (1999) especially notes that the demand for cheap and abundant coals in China, India and Mongolia is increasing at the 6.5% annual growth rate, and the increasing CO_2 emissions are problematic. Environmental degradation has been also concerned in other regions such as Middle East, North Africa, and the former socialist countries in East Europe and Central Asia. Especially in Middle East, industrialization associated with the development of oil industries and population growth have led to the high level of energy consumption, and its trend is expected to further continue. The consumption of fossil fuels in North America is also large and the United States shows the largest consumption both as the single country and the per capita base. Further, it is seriously concerned that the environmental issues might be placed not as the immediate agenda but as the future assignment in many developing countries and the economies in transition since economic growth is the most imminent target for such countries.[2)]

Consequently, the environmental issues are not necessarily the domestic issues but also the international issues such as the air pollutions and the international river pollutions. Based on such aspects of the environmental issues, various regional co-operations are organised in Asia and the Pacific. According to the United Nations Economic and Social Commission for Asia and the Pacific (hereafter, UN-ESCAP, 2001), the examples of such regional environmental co-operations are South Asia Cooperative Environment Programme (SACEP), South Asian Association for Regional Cooperation (SAARC), ASEAN Senior Officials on the Environment (ASOEN), Council for Regional Organizations of the Pacific (CROP), South Pacific Regional Environment Programme (SPREP), etc.[3)]

In this paper, we reexamine the trade-off between economic development and environmental degradation, especially concerning CO_2 emissions in the framework of the environmental Kuznets curve hypothesis (hereafter, EKC), once again based on Osaka (2001, 2002, 2005). In Chapter 2, we review the literature. We moreover conduct the descriptive data analysis and the regression analysis in Chapter 3 and Chapter 4 followed by the concluding remarks in Chapter 5.

2) UNEP (1999). It should be noted that the regional classification of UNEP is slightly different from ours in this analysis.

3) Please refer to UN-ESCAP (2001) for the details of these regional environmental cooperations. The analysis on such regional environmental cooperations are out of our scope in this paper.

2. Literature Review

The inverted U curve relationship between income level and inequality is initially hypothesized by Kuznets (1955, 1957), and this Kuznets hypothesis is recently extended to the environmental issues which increasingly receive the attentions. This environmental Kuznets curve (EKC) may explain the relationship between economic development and environmental degradation as follows. In the initial stage of economic development, the agricultural sector is the main economic activity which does not emit many pollutants. The economic activity then shifts toward the industrial sector which emits more pollutants associated with industrialization and economic development. In the late stage of economic development, the service sector is becoming the main economic activity which may emit less pollutants. In this process of the change of industrial structure in economic development, the relationship between income level and environmental degradation exhibits the inverted U curve shape. The notable empirical literature for this relationship of EKC are for example Hettige-Lucas-Wheeler (1992), Selden-Song (1994), Shafik (1994), Grossman-Krueger (1995), Islam (1997), Hilton-Levinson (1998), and Ekins (2000) which estimate various environmental data. Their supports for EKC are however various and depend on the model specifications and pollutants in their analyses.

Hettige-Lucas-Wheeler (1992) points out that the industrial wastes are increasing over time and it is particularly evident in the low income countries. They observe that it is due to the strengthening environmental regulations in developed countries since the 1970s which have increased the overseas production. Selden-Song (1994) examines EKC with employing various environmental data such as SPM, CO, SO_2 and NO_X from 30 countries over the 1970s and 1980s, and suggests further environmental degradation. Grossman-Krueger (1995) conducts the regression analysis and indicates the per capita income level of US$8000 (the 1985 price) as the turning point of EKC for their environmental data such as air pollutions of SPM and SO_2 and water pollution. Moreover, Islam (1997) emphasizes the need of the prompt policy measures against the regional environmental degradation in Asia in his empirical analysis. Hilton-Levinson (1998) analyzes the automobile exhaust fumes for 48 countries over 20 years and observes that more consumption of leaded gasoline aggravates air pollution. They suggest the importance of the legal framework and the need of technological development to combat environmental degradation.

As shown on the above, many previous studies employ the cross-country data analysis whilst Lim (1997) provides the case study for South Korea in examining EKC. According to Lim (1997), EKC is supported for the cases of SO_2, NO_2, BOD (biochemical oxygen demand) and the wastes from households. However, the environmental data for CO_2, deforestation and industrial wastes do not indicate EKC and show further degradation. Lim (1997) suggests that environmental degradation more depends on the environmental regulations and policy measures, and EKC can be observed for pollutants whose regulations have been introduced in the earlier period and their introductions have led to the favorable outcomes.[4)]

Upon the above literature, we may conclude that the supports for EKC are various and depend on the environmental data. However, we can still find the common features from their conclusions as follows.

- Regardless of the supports for EKC, many environmental data suggest the environmental degradation in many developing countries.
- Many developed countries, which show the improvement of the environment, have introduced the environmental regulations and the active policy measures for environmental management.

In sum, the importance of environmental regulations and the active policy measures for environmental management could be suggested from the literature. It may further imply that the introduction of environmental regulations and policy measures may improve the turning point in case EKC is supported.

3. Descriptive Data Analysis

The critics to EKC are partly based on the environmental data which are used in the empirical analyses. As noted before, Hettige-Lucas-Wheeler (1992), Selden-Song (1994), Grossman-Krueger (1995), and Islam (1997) examine the air pollution, but the environmental data for the air pollution are various. For example, Selden-Song (1994) employs the densities of SPM, CO, SO_2 and NO_X in the air as the proxies for the air pollution. Moreover, GDP per capita is often used as the proxy for the income level and economic development. Stern *et al* (1996) uses the PPP-based GDP per capita whilst we employ GDP per capita at the constant price from World Bank (2007) which provides more data across countries. We moreover use the data of CO_2 emissions[5)] from World Bank (2007) as the proxy for the environmental data.

4) Please see Ekins (2000) who also provides the useful literature review.

5) The data of CO_2 emissions in World Bank (2007) are based on the data from Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, in the United States, whose data are derived from the burning of fossil fuels and the manufacture of cement. Please see World Bank (2007) for the details of data and the data source for CO_2 emissions.

3.1 Overview of CO_2 emissions

Osaka (2005) empirically supports EKC in case of CO_2 emissions per output[6] (hereafter, CO2GDP) based on the cross-country analysis over 174 countries for the 1960-1998 period. Moreover, Osaka (2005) shows the relatively larger CO2GDP in the former socialist countries and the smaller CO2GDP in the Sub-Saharan African countries, and suggests further increase of CO_2 emissions associated with industrialization in developing countries. Based on Osaka (2005), the following cross-country regression is reestimated for the 1960-2003 period.

$$ENV = 1.537 + 1.409Y - 0.094Y^2$$
(SE) ** (0.279) ** (0.075) ** (0.005)

R^2: 0.057 σ: 0.883 F-test: 185.1 [0.000]
Number of countries: 178 Observations: 6135
** ( ): 1% statistical significance (SE: standard error), and please refer to Table 1.

ENV is LCO2GDP (CO2GDP in log) and Y is LGDPH (GDP per capita (GDPH) in log, the constant 2000 price, US$). Figure 1 shows the original data and the estimated EKC by the cross-country regression. The estimated turning point indicates US$1803 (GDPH) and 915g (CO2GDP), and supports EKC though R^2 is relatively low. Moreover, Table 1 shows the cross-country regression results for each year for the 1960-2003 period whilst Figure 2 indicates each year's estimated turning point for GDPH and CO2GDP since 1975 whose regression results show the F-test and the parameter values for Y and Y^2 at the 5 % statistical significance. Figure 2 indicates the decreasing trend of the turning points for GDPH until the early 1990s. The increasing TP(GDPH) and the slightly higher TP(CO2GDP) in the 1990s might be due to the data of the former socialist countries which we need further investigations.

3.2 CO_2 emissions in Asia

Osaka (2002) indicates that the DAC (Development Assistance Committee) members of OECD (Organization for Economic Cooperation and Development) show the highest income level in terms of GDP per capita (GDPH) associated with the lowest CO_2 emissions per GDP (CO2GDP) on the average whilst the South Asian and the Sub-Saharan African countries show both the lowest GDPH and CO2GDP. Moreover, the middle-income countries such as the non-DAC European countries, the Asian and Pacific, and the Latin American and Caribbean countries

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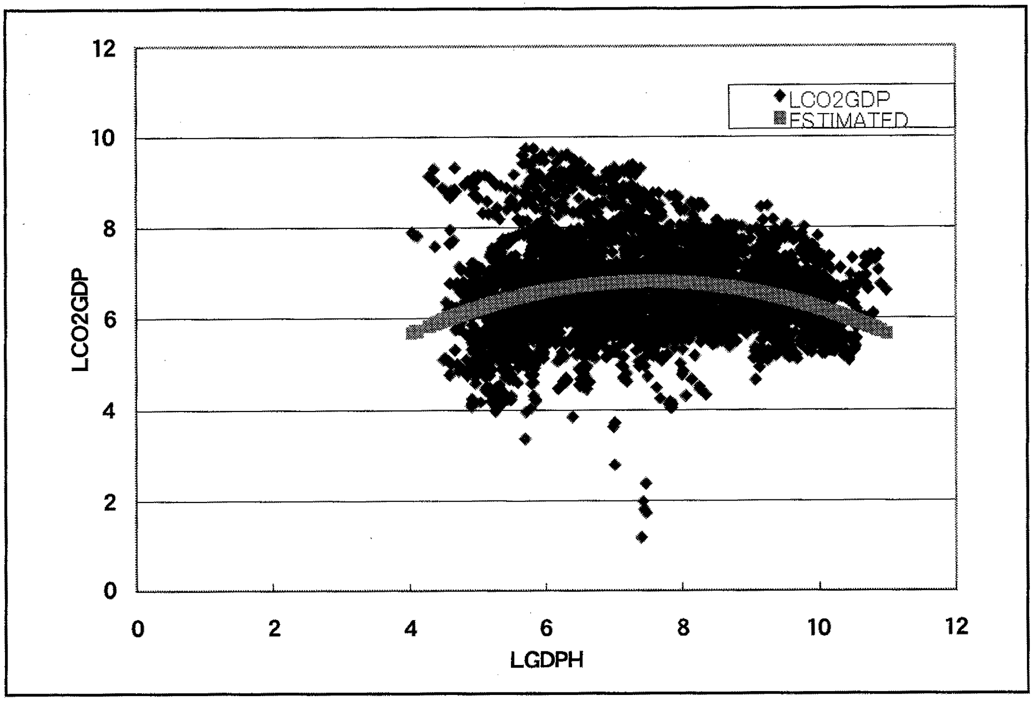
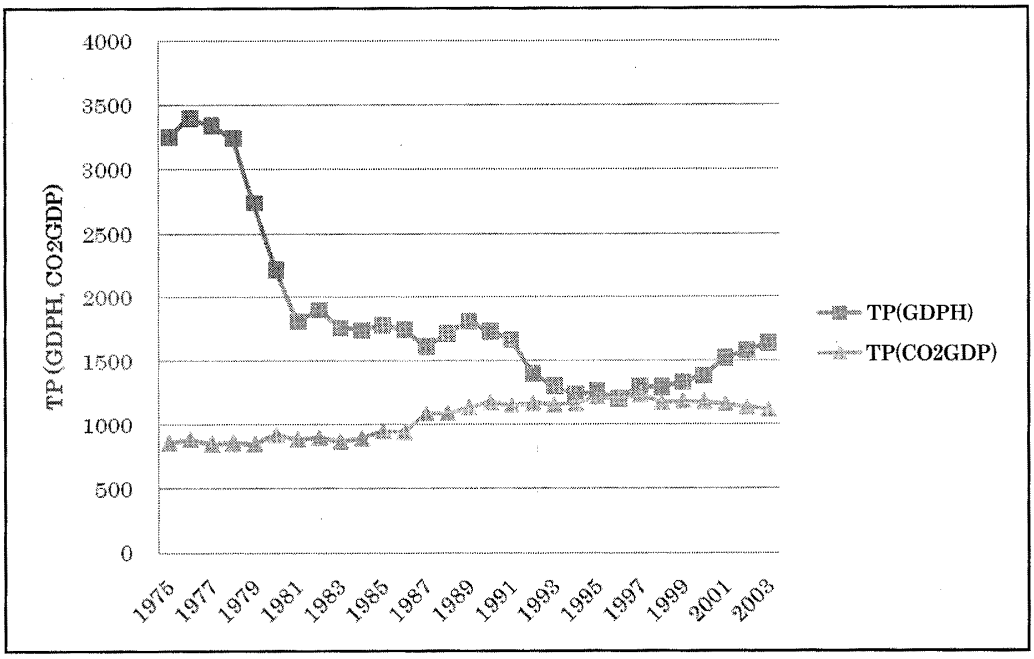
6) It should be noted that one unit output is equal to 1 US$ of GDP in our analysis.

Figure 1: CO_2 Emissions and Income Level (the cross-country data)
(1960-2003, 178 countries, 6135 observations)



Data Source: World Bank (2007) and author's estimation
Notes:
LCO2GDP: CO_2 emissions per GDP (g, CO2GDP in log)
LGDPH: GDP per capita (the constant 2000 price, US$, GDPH in log)
ESTIMATED: estimated environmental Kuznets curve

Figure 2: Turning Point of the Environmental Kuznets Curve



Notes: the data are based on Table 1
TP(GDPH): GDPH at the turning point (the constant 2000 price, US$)
TP(CO2GDP): CO2GDP at the turning point (g)

Table 1: Cross-country Regression (Dependent variable: LCO2GDP, 1960-2003)

YEAR	C	LGDPH	SLGDPH	R^2	F	σ	Obs	TP (GDPH)	TP (CO2GDP)
1960	** 9.339	−1.005	0.076	0.039	1.788	0.973	92	741	412
1961	** 9.773	−1.108	0.082	0.043	2.018	0.917	93	857	416
1962	** 7.783	−0.555	0.045	0.040	1.905	0.919	95	488	431
1963	** 8.617	−0.766	0.057	0.037	1.807	0.902	96	782	431
1964	** 7.822	−0.559	0.045	0.036	1.797	0.930	98	526	433
1965	** 6.709	−0.215	0.021	0.024	1.229	0.945	104	176	470
1966	* 6.167	−0.056	0.010	0.022	1.165	0.927	106	17	441
1967	* 4.476	0.409	−0.020	0.038	2.090	0.868	108	28045	712
1968	* 4.470	0.453	−0.025	0.026	1.407	0.868	109	10076	705
1969	* 4.871	0.365	−0.020	0.018	0.976	0.843	110	10500	706
1970	3.228	0.819	−0.049	0.037	2.131	0.808	114	4136	765
1971	2.441	+ 1.044	+ −0.064	0.054	* 3.177	0.768	115	3580	822
1972	2.507	+ 1.025	+ −0.063	0.050	+ 2.988	0.784	116	3551	809
1973	+ 3.285	+ 0.827	−0.050	0.041	+ 2.465	0.770	117	4160	839
1974	+ 3.272	+ 0.821	−0.049	0.042	+ 2.524	0.763	118	4340	821
1975	2.219	* 1.123	* −0.069	0.058	* 3.626	0.739	121	3249	862
1976	1.740	* 1.241	* −0.076	0.073	* 4.667	0.726	121	3401	885
1977	2.474	* 1.053	* −0.065	0.049	* 3.135	0.744	124	3340	851
1978	2.412	* 1.075	* −0.066	0.048	+ 3.044	0.746	124	3241	859
1979	2.841	* 0.987	* −0.062	0.037	+ 2.344	0.738	125	2737	851
1980	2.459	* 1.134	* −0.074	0.042	+ 2.968	0.777	137	2214	922
1981	2.336	* 1.186	* −0.079	0.045	* 3.311	0.811	142	1811	885
1982	1.337	** 1.447	** −0.096	0.066	** 5.005	0.796	145	1899	897
1983	1.708	** 1.354	** −0.091	0.061	* 4.610	0.798	145	1759	868
1984	1.473	** 1.426	** −0.096	0.071	** 5.527	0.791	148	1743	892
1985	0.901	** 1.591	** −0.106	0.081	** 6.455	0.815	150	1779	949
1986	0.933	** 1.584	** −0.106	0.074	** 6.018	0.849	153	1744	939
1987	−0.208	** 1.950	** −0.132	0.107	** 9.120	0.898	156	1613	1088
1988	−0.908	** 2.123	** −0.143	0.121	** 10.560	0.889	157	1712	1092
1989	−1.526	** 2.283	** −0.152	0.137	** 12.350	0.877	158	1812	1137
1990	−1.650	** 2.339	** −0.157	0.119	** 11.210	0.999	169	1732	1178
1991	−1.234	** 2.234	** −0.151	0.113	** 10.540	1.006	169	1669	1157
1992	−0.100	** 1.978	** −0.136	0.112	** 10.490	1.010	170	1403	1173
1993	0.562	** 1.811	** −0.126	0.105	** 9.925	1.010	172	1305	1162
1994	0.929	** 1.724	** −0.121	0.112	** 10.830	0.981	174	1235	1171
1995	0.439	** 1.868	** −0.131	0.155	** 15.920	0.883	176	1263	1225
1996	0.887	** 1.752	** −0.124	0.153	** 15.610	0.877	176	1202	1211
1997	0.105	** 1.958	** −0.137	0.177	** 18.690	0.854	177	1298	1238
1998	0.408	** 1.859	** −0.130	0.159	** 16.400	0.877	177	1296	1177
1999	0.191	** 1.915	** −0.133	0.176	** 18.670	0.844	178	1332	1190
2000	−0.058	** 1.972	** −0.136	0.189	** 20.310	0.828	177	1385	1181
2001	−0.345	** 2.021	** −0.138	0.193	** 20.500	0.792	174	1523	1166
2002	−0.098	** 1.937	** −0.131	0.172	** 17.780	0.797	174	1584	1138
2003	0.101	** 1.870	** −0.126	0.157	** 16.050	0.804	175	1637	1119
ALL	** 1.537	** 1.409	** −0.094	0.057	** 185.100	0.883	6135	1803	915

Data Source: World Bank (2007) and author's estimation

Notes:

C: constant

LCO2GDP: CO_2 emissions per GDP (g, CO2GDP in log)

LGDPH: GDP per capita (the constant 2000 price, US$, GDPH in log)

SLGDPH: LGDPH x LGDPH

R^2: the goodness of fit

F: the F-test

σ: the standard error of regression
Obs: the number of observations
TP(GDPH): the estimated turning point of the environmental Kuznets curve for GDPH
TP(CO2GDP): the estimated turning point of the environmental Kuznets curve for CO2GDP
ALL: the cross-country analysis with the pooling data (all available data)
**: statistical significance at the 1% level
*: statistical significance at the 5% level
+: statistical significance at the 10% level

tend to show the relatively middle-level GDPH and CO2GDP on the average. These observations may support EKC as shown in Figure 1 though there might be various cases in each region. Osaka (2002) also noted that the standard deviation of CO2GDP is the smallest for OECD-DAC countries, followed by the low income countries in Sub-Sahara Africa, South Asia, and Middle East and North Africa. On the other hand, the higher standard deviation for CO2GDP can be found in the non-DAC European countries, Central Asia, and East Asia and the Pacific.[7]

We now focus on the Asian and Pacific countries based on Osaka (2002, 2005), which can be further subdivided into 6 sub-regions of the Asian developed countries (DC), the Asian newly industrialized countries (NICS), South-east Asia, South Asia, the Pacific countries and the Asian economies in transition. Table 2 shows the overview of GDPH and CO2GDP for 6 sub-regions: average, minimum, maximum values and standard deviations. There are several observations from Table 2. First, the Asian DC indicates the largest averaged GDPH, followed by NICS, the Pacific countries, South-east Asia, the Asian economies in transition and South Asia. The standard deviations show the similar pattern. However, if we exclude Japan from the Asian DC and Brunei from South-east Asia, the standard deviations for GDPH become smaller in each sub-region. NICS and the Pacific countries moreover show the larger standard deviations for GDPH which suggest the larger income disparities across countries and over time in these sub-regions. In particular, the lowest GDPH for NICS is shown by South Korea in 1960 and its largest GDPH is by Hong Kong in 2003, and the larger standard deviation in this sub-region may suggest the rapid economic growth over time. On the other hand, the larger standard deviation in the Pacific countries may be derived from the different reasons. It might be due to the different natural endowments and the resources for tourism among countries in this sub-region though we need the investigations in detail. Moreover, the standard deviations for GDPH in South Asia and the Asian economies in transition are relatively small.

We now turn to the regional CO2GDP in Asia. In Table 2, it is evident that the Asian economies in transition indicate the highest CO2GDP in all statistics compared with those for other sub-regions, *i.e.* average, minimum, maximum values and standard deviation. As noted in

7) See Osaka (2002) for the details of analysis.

UNEP (1999) and Osaka (2002), it might be due to more pollution-emitting economic activities in the former socialist countries, including the Asian economies in transition. Moreover, South Asia and South-east Asia show the larger CO2GDP after the Asian economies in transition, but their figures are not so largely different from those for other sub-regions. When we look at the averaged CO2GDP, the Asian DC shows the smallest figure among 6 sub-regions. Moreover, Nepal indicates the smallest CO2GDP (58.5) in 1961 whilst Mongolia shows the largest figure (16857.3) in 1992. In overall, the Asian economies in transition and South Asia show the relatively higher CO2GDP and the smaller GDPH whilst the Asian DC indicates the lower CO2GDP and the higher GDPH.

4. Regression Analysis

4.1 Model framework

Based on Osaka (2002, 2005), we follow Grossman-Krueger (1995) and Ekins (2000) in examining the relationship between economic development and environmental degradation, here especially EKC for income level and CO_2 emissions, and employ the following specifications which also consider the linear and cubic models.

$$ENV = \alpha_1 + \alpha_2 Y + \alpha_3 DUM$$
$$ENV = \beta_1 + \beta_2 Y + \beta_3 Y^2 + \beta_4 DUM$$
$$ENV = \gamma_1 + \gamma_2 Y + \gamma_3 Y^2 + \gamma_4 Y^3 + \gamma_5 DUM$$

ENV indicates the environmental variable, here LCO2GDP (CO2GDP in log), and Y is the variable for income level, LGDPH (GDPH in log). DUM moreover signifies the regional dummy variables. In particular, the following conditions are required in order to support EKC.

$$\beta_2 > 0, \text{ and } \beta_3 < 0 \ (|\beta_2| > |\beta_3|)$$

4.2 Basic regression results

Table 3 shows the regression results with the pooling data. Models 1 and 2 are the linear models, Models 3 and 4 are the quadratic models, and Models 5 and 6 are the cubic models, respectively. Moreover, Models 2, 4 and 6 include the regional dummy variables. There are mainly 4 observations from the results. First, the statistically significant relationship between LGDPH and LCO2GDP is observed both in the linear and quadratic models whilst the cubic models do not show it. Moreover, the inclusion of the dummy variables lowers the statistical significance of LGDPH in Model 2. Second, Models 3 and 4 suggest the validity of EKC. Though

Table 2: Descriptive Data Analysis for GDPH and CO2GDP (1960-2003)

Region	GDPH				CO2GDP				Obs	Noc
	AVG	MIN	MAX	STDEV	AVG	MIN	MAX	STDEV		
Asian DC	16847	7099	37244	8229	606.7	249.3	1038.2	257.0	132	3
(Ex.Japan)	13019	8185	22405	3356	750.3	497.9	1038.2	187.3	88	2
NICS	10144	1110	26236	6797	636.1	117.3	1934.1	409.3	154	4
South-east Asia	2977	193	25530	5315	1051.4	117.8	2994.5	472.6	229	8
(Ex.Brunei)	994	193	4081	887	1012.2	117.8	1831.0	439.8	199	7
South Asia	399	134	2383	361	913.7	58.5	2704.9	718.7	253	7
Pacific countries	3482	374	14601	4536	648.8	104.6	2284.9	364.5	300	10
Transition	493	72	1671	341	7346.6	1224.3	16857.3	3542.0	183	9
Total Asia	4559	72	37244	7023	1749.8	58.5	16857.3	2725.6	1251	41

Data Source: World Bank (2007) and author's estimation
Notes:
AVG: the averaged value
MIN: the minimum value
MAX: the maximum value
STDEV: the standard deviation
Obs: the number of observations
Noc: the number of countries
GDPH: GDP per capita (the constant 2000 price, US$)
CO2GDP: CO_2 emissions per GDP (g)
Asian DC (developed countries): Australia, Japan, New Zealand (3 countries)
NICS (Asian newly industrialized countries): Hong Kong (China), Singapore, South Korea, Macao (China) (4 countries and regions, Macao is conveniently included in this sub-region)
South-east Asia: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand, Timor-Leste (8 countries)
South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka (7 countries)
Pacific countries: Fiji, French Polynesia, Kiribati, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu (10 countries)
Transition (Asian economies in transition): Azerbaijan, China, Kazakhstan, Kyrgyz Rep., Mongolia, Tajikistan, Turkmenistan, Uzbekistan, Vietnam (9 countries)

the parameter values have changed, the statistical significances of LGDPH and SLGDPH remain at the 1% level in both Models 3 and 4. Third, Models 5 and 6 indicate the cubic models are not relevant. The cubic term of the income level, here QLGDPH, exhibits the statistical significance only at the 10% level in Model 6. Lastly, the results demonstrate the validity of the regional dummies in the regressions. For example, the dummy variables mostly show the statistical significances at either 1% or 5% level in Models 2, 4 and 6. The inclusions of the regional dummies also improve the regression results with the higher R^2. Moreover, the parameter values for the regional dummies suggest the lower LCO2GDP for NICS and the Pacific countries as well as the higher LCO2GDP for the Asian economies in transition, whose results are somewhat consistent with our previous descriptive data analysis in Table 2.

In a nutshell, we may conclude the followings from our regression results. First, EKC is statistically observed in Asia and the Pacific, demonstrated by Models 3 and 4. The estimated parameter values and signs are also in line with our expectations. Second, our regression results

Table 3: Regression Results (1)
Dependent variable: LCO2GDP (Obs: 1251)

	Linear Model		Quadratic Model		Qubic Model	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
C	8.204	5.959	5.345	0.320	5.921	4.101
(SE)	**(0.134)	**(0.201)	**(0.762)	(0.550)	+(3.510)	+(2.244)
LGDPH	−0.196	0.036	0.594	1.647	0.348	0.029
(SE)	**(0.018)	+(0.020)	**(0.208)	**(0.149)	(1.475)	(0.943)
SLGDPH	–	–	−0.052	−0.106	−0.018	0.119
(SE)	–	–	**(0.014)	**(0.010)	(0.203)	(0.130)
QLGDPH	–	–	–	–	−0.002	−0.010
(SE)	–	–	–	–	(0.009)	+(0.006)
Dummy						
NICS	–	−0.038	–	−0.236	–	−0.263
(SE)	–	(0.079)	–	**(0.078)	–	**(0.079)
SEAST	–	0.603	–	0.353	–	0.352
(SE)	–	**(0.090)	–	**(0.089)	–	**(0.088)
SOUTH	–	0.307	–	0.221	–	0.222
(SE)	–	**(0.105)	–	*(0.100)	–	*(0.100)
PACIF	–	0.100	–	−0.223	–	−0.229
(SE)	–	(0.082)	–	**(0.084)	–	*(0.084)
TRANS	–	2.568	–	2.428	–	2.426
(SE)	–	**(0.105)	–	**(0.101)	–	**(0.101)
R^2	0.086	0.616	0.097	0.649	0.097	0.650
F-test	**118.0	**331.9	**66.9	**328.8	**44.6	**288.5
σ	1.014	0.659	1.009	0.630	1.009	0.629

Data Source: World Bank (2007)
Notes:
Obs: the number of observations
R^2: the goodness of fit
F: the F-test
σ: the standard error of regression
LCO2GDP: CO_2 emissions per GDP (g, CO2GDP in log)
C: constant
(SE): the standard error
LGDPH: GDP per capita (the constant 2000 price, US$, GDPH in log)
SLGDPH: LGDPH x LGDPH
QLGDPH: LGDPH x LGDPH x LGDPH
Dummy: the regional dummy variables (please refer to Table 2 for the countries in each sub-region)
NICS: the Asian newly industrialized countries
SEAST: South-east Asian countries
SOUTH: South Asian countries
PACIF: the Pacific island countries
TRANS: the Asian economies in transition
**: statistical significance at 1 % level
*: statistical significance at 5 % level
+: statistical significance at 10 % level

suggest the validity of the dummy variables in the regressions. Moreover, the estimated parameter values for Model 4 suggest the turning point for the income level (GDPH) in Asia as US$2323, which is higher than US$1803, the estimated turning point for GDPH in the world-wide cross-country regression in Table 1.[8] In addition, based on the data of World Bank (2007), 27 countries among 38 sample countries in 2003, which are used for the regional analysis in Asia and the Pacific, show the lower income level than that of the estimated turning point for EKC in Model 4. It suggests that CO2GDP may increase along with further economic growth in Asia and the Pacific.

4.3 Extended regression analysis

Many previous literature with the exception of Seldon-Song (1994) consider the supplementary variables in addition to the variables for the income level and the environmental data in the regressions. For example, Grossman-Krueger (1995) and Islam (1997) additionally use the variables for population density and the regional dummies. Hilton-Levinson (1998) includes population density and the dummy variable for the sampling year. Upon these analyses, we also include several supplementary variables in the regressions. We consider the following specification upon our previous analysis.

$$\mathrm{ENV} = \delta_1 + \delta_2 \mathrm{Y} + \delta_3 \mathrm{Y}^2 + \delta_4 \mathrm{S} + \delta_5 \mathrm{DUM}$$

Same as the previous specification, ENV indicates the environmental data, here LCO2GDP, Y for the income level (LGDPH), and DUM for the regional dummy variables. In addition, S signifies the variables which may influence the regression results. The selection of the supplementary variables is rather *ad hoc,* however these data are all available from World Bank (2007). We finally include the following variables in the regressions: the GDP growth rate (YG), the lagged GDP growth rate (YGLAG), the population growth rate (POPG), the investment ratio (LINV), trade openness (LOPEN), the output ratio of the agricultural sector in GDP (LAGR) and the output ratio of the industrial sector in GDP (LIND).[9]

The regression analysis with the supplementary variables may offer the following insights. First, YG and YGLAG can be seen as the proxies which examine the impacts of economic growth

8) The regional regressions for EKC in Asia and the Pacific should be considered as suggestive rather than conclusive due to the relatively small sample size, especially compared with those with the world-wide cross-country data.

9) L, the first capital letter of the variables, indicates that those variables are in log. Moreover, all data are based on World Bank (2007).

on the CO_2 emissions. Second, POPG may show the impacts of the population growth on the environment. Population density is often regarded as one of the causes of environmental degradation such as water pollution, soil degradation, and air pollution. Since we are not able to get the data for population density across countries and over time, we instead use the population growth rate as its proxy in this analysis. Based on Furtado-Belt (2000), the world population is expected to grow to 8.3 billion in 2025 and 10 billion in 2050, respectively. Moreover, population tends to grow much faster in developing countries so that it is interesting to see the impacts of population growth on the CO_2 emissions.

Third, LINV can be seen as the proxy which examines the impacts of investment activities on the CO_2 emissions whilst LOPEN is expected to show those of trade in goods and services. The impacts of both trade and investment activities on the CO_2 emissions are not simple since these activities may have two dimensions. First, the expansion of both activities may produce the positive outcomes on the environment. If trade and investment activities are able to contribute to technical innovation and the introduction of new technologies which enhance the environmental management and resource conservation, here the reduction of CO_2 emissions, the expansion of both activities produces the positive outcomes. On the other hand, if the expansion of both activities simply leads to the increase of production without the environmental consideration in particular, it may signify further environmental degradation. Moreover, the improvement of production technologies does not necessarily contribute to the environmental management, but it could lead to more production of dangerous and toxic chemicals from the complex production methods which negatively affect the environment.[10] Further, the environmental regulations in developed countries may promote the foreign direct investment (FDI) in developing countries which do not have the similar environmental regulations, and hence aggravate the environment. LINV and LOPEN thus have two dimensions on the environment which need to be considered in the regressions.

Lastly, LIND and LAGR are used as the direct and indirect proxies for industrialization. Since industrialization is often seen as the main cause of the environmental degradation with the emissions of pollutants, we expect its negative impacts on the CO_2 emissions. In a nutshell, we expect the negative impacts of POPG and LIND on LCO2GDP which signify the positive parameter values in the regressions. On the contrary, LAGR is expected to show the negative sign. Moreover, the signs for YG, YGLAG, LINV and LOPEN are ambiguous. LINV and LOPEN are in particular considered to have two dimensions of positive and negative impacts.

Based on the above considerations, we conduct the regressions and the results are exhibited

10) See Furtado-Belt (2000), p.77.

on Table 4. Due to the data availability problem for the supplementary variables, the total number of observations is reduced to 741 from 1251. Model 7 is the same specification with Model 4 in Table 3. Model 8 includes all supplementary variables whilst Model 9 excludes YGLAG. Moreover, the insignificant variables at 10% level are nested in Model 10.

Table 4 provides 3 observations. First, the estimated parameters for LGDPH and SLGDPH in all models indicate the statistical significances at 1% level in line with our expectation, which support EKC for the CO_2 emissions. Second, all supplementary variables also show the statistical significances at least at 5% level in all models. Consequently, POPG, LAGR and LIND show the expected signs and these variables suggest the negative impacts of population growth and industrialization on the reduction of CO_2 emissions whilst the agriculture sector's output has the opposite impact. Jointly with the positive parameter values for LIND and LINV, industrialization and investment activities will aggravate the CO_2 emissions. Moreover, the negative parameter values for YG, YGLAG, and LOPEN suggest that economic growth and trade openness positively contribute to the reduction of CO_2 emissions in Asia and the Pacific. Third, the regional dummy variables highlight the lower CO_2 emissions in the Pacific countries as well as the higher CO_2 emissions in the Asian economies in transition which are consistent with our regression results in Table 3.

In sum, the regressions with the supplementary variables show the statistically significant parameter values for both LGDPH and SLGDPH with the expected signs and values, and hence support EKC. Moreover, our extended regression analysis highlights the positive impacts of economic growth, trade openness and the share of agricultural sector's output on the reduction of CO_2 emissions in Asia and the Pacific as well as the negative impacts of population growth, investment and industrialization. As noted in our descriptive data analysis in Table 2, the regression results also statistically indicate the larger CO_2 emissions in the Asian economies in transition.

4.4 Preliminary time-series data analysis

The time-series data for GDPH and CO2GDP are relatively available since 1960 across countries so that we preliminary investigate the long-run relationships among them.[11] EKC is often investigated with the cross-country data since the sufficient time-series data are not readily available. The cross-country analysis for the investigation of EKC is however based on the assumption that the sample countries follow the similar development patterns one another.

11) We examine the static long-run relationship (SLR) for our co-integration analysis with using the econometric package of PcGive 10. The relevant data are based on World Bank (2007).

Table 4: Regression Results (2)
Dependent variable: LCO2GDP (Obs: 741)

	Model 7	Model 8	Model 9	Model 10
C	0.354	−1.265	−1.077	−1.306
(SE)	(0.672)	*(0.642)	+(0.646)	*(0.568)
LGDPH	1.896	2.339	2.308	2.296
(SE)	**(0.189)	**(0.230)	**(0.232)	**(0.199)
SLGDPH	−0.132	−0.166	−0.164	−0.162
(SE)	**(0.013)	**(0.017)	**(0.017)	**(0.013)
YG	−	−0.014	−0.020	−0.014
(SE)	−	**(0.004)	**(0.003)	**(0.004)
YGLAG	−	−0.015	−	−0.015
(SE)	−	**(0.004)	−	**(0.004)
POPG	−	0.052	0.045	0.054
(SE)	−	*(0.021)	*(0.022)	*(0.021)
LINV	−	0.242	0.213	0.244
(SE)	−	**(0.061)	**(0.061)	**(0.060)
LOPEN	−	−0.363	−0.345	−0.363
(SE)	−	**(0.039)	**(0.039)	**(0.037)
LAGR	−	−0.164	−0.162	−0.145
(SE)	−	**(0.050)	**(0.050)	**(0.037)
LIND	−	0.374	0.367	0.387
(SE)	−	**(0.074)	**(0.074)	**(0.069)
Dummy				
NICS	−0.380	−0.091	−0.142	−
(SE)	**(0.099)	(0.136)	(0.136)	−
SEAST	−0.221	−0.034	−0.081	−
(SE)	(0.145)	(0.188)	(0.190)	−
SOUTH	−0.222	−0.058	−0.104	−
(SE)	(0.161)	(0.199)	(0.201)	−
PACIF	−0.774	−0.212	−0.247	−0.160
(SE)	(0.147)	(0.177)	(0.179)	*(0.079)
TRANS	1.803	1.937	1.908	1.988
(SE)	**(0.159)	**(0.215)	**(0.217)	**(0.063)
R^2	0.728	0.782	0.777	0.782
F-test	**281.0	**185.8	**195.1	**237.1
σ	0.553	0.498	0.503	0.498

Data Source: World Bank (2007)
Notes: in addition, please refer to Table 3
YG: the GDP growth rate (%)
YGLAG: the lagged GDP growth rate (%, 1 lag)
POPG: the population growth rate (%)
LINV: the investment ratio (=(gross fixed capital formation/GDP)*100, %, log)
LOPEN: trade openness (=((export+import)/GDP)*100, %, log)
LAGR: the agricultural sector's output ratio (% in GDP, log)
LIND: the industrial sector's output ratio (% in GDP, log)

Our previous cross-country analysis with the pooling data is also based on this assumption, however the statistically significant regional dummy variables in our regressions may question it. In order to supplement to our cross-country analysis with the pooling data, we examine the long-run relationships among the variables of our interest, based on the data from World Bank (2007). We moreover focus on the industrialization variable. We thus investigate the co-integrating relationships among LCO2GDP, LGDPH, SLGDPH, and LIND. It should be also noted that we limit our investigation to the countries which provide more than 30 observations of the time-series data. The meaningful time-series data analysis usually requires the large sample. Though 30 observations may not be sufficient enough on this consideration, we preliminary conduct the time-series analysis in this section. 14 countries are selected for this investigation from 41 Asian countries in our sample.[12)]

In prior to the co-integration analysis, we conduct the unit roots tests for our concerned variables of LCO2GDP, LGDPH, SLGDPH, and LIND. The augmented Dickey-Fuller (ADF) unit roots test is employed, and the most variables indicate the I (1) property except for the following variables which may suggest I (0): LIND for Australia, LCO2GDP for China, LCO2GDP for Nepal, LCO2GDP and LIND for South Korea, LCO2GDP and LIND for Japan, and LIND for Pakistan. Since our sample is the small size which may produce the bias and the test power of ADF is well known to be low, we conventionally decide to treat all variables as I (1) and proceed to the co-integration analysis.[13)]

Table 5 shows the summary of the co-integration tests. The co-integrating relationships among variables can be found for 7 countries out of 14 countries. However, the diagnostic tests question the validity of the test results for South Korea and Thailand so that our co-integration tests finally show the long-run relationships among the concerned variables for Australia, New Zealand, Indonesia, Malaysia, and Nepal. It is interesting to note in particular that the co-integration tests show the long-run relationships among variables for Indonesia and Malaysia in Model 14. Indonesia and Malaysia have shown the rapid economic growth associated with industrialization. Our test results may thus suggest further increase of CO_2 emissions in both countries associated with industrialization and economic growth. Moreover, the co-integrating relationships among variables are also found in Nepal which is one of the low income countries in our sample. It may suggest that the environmental consideration is also consequent even in the low income countries.

12) Please see Table 5 for the list of 14 countries.
13) The details of the unit roots test results will be submitted upon request.

Table 5: Summary of the Co-integration Tests
Dependent variable: LCO2GDP

		Model 11	Model 12	Model 13	Model 14	Period
	(Variables)	LGDPH	LGDPH SLGDPH	LGDPH LIND	LGDPH SLGDPH LIND	
Asian DC	Australia		Yes			1971-2003
	Japan					1971-2003
	New Zealand	Yes				1971-2001
NICS	South Korea	Yes* (A, W)				1960-2003
South-east Asia	Indonesia			Yes	Yes	1960-2003
	Malaysia		Yes		Yes	1970-2003
	Philippines					1960-2003
	Thailand			Yes* (H)	Yes* (H, N)	1960-2003
South Asia	India					1960-2003
	Nepal	Yes		Yes	Yes	1965-2003
	Pakistan					1960-2003
	Sri Lanka					1960-2003
Pacific countries	Fiji					1963-2003
Transition	China					1960-2003

Notes: the details of the co-integration tests will be submitted upon request.
LCO2GDP: CO_2 emissions per GDP (g, CO2GDP in log)
LGDPH: GDP per capita (the constant 2000 price, US$, GDPH in log)
SLGDPH: LGDPH x LGDPH
LIND: the industrial sector's output ratio (% in GDP, log)
Yes: the co-integrating relationship at the 5% statistical significance (no indication suggests that the co-integrating relationship is not found at the 5% statistical significance)
*: any diagnostic test problems at the 5% statistical significance (A: autocorrelation, H: hetroschedasticity, N: normality, W: Wald test for the static long-run relationship)

4.5 Supplementary descriptive data analysis: the regional trend of CO_2 emissions

Our previous analysis is exclusively based on the environmental data of CO_2 emissions per GDP, CO2GDP. As shown in our analysis, we statistically support EKC in our regressions. The empirical support for EKC signifies the plausible reduction of CO_2 emissions per GDP beyond the turning point associated with economic development. Our regression analysis suggests the income level of US$1803 as the possible turning point for the world. Though our empirical analysis shows the validity of EKC, the favorable outcome of the reduction of CO_2 emissions consequently depends on the particular condition, *i.e.* the reduction speed of CO2GDP needs to exceed the GDP growth rate. Otherwise, the total CO_2 emissions will continuously increase associated with economic growth though the CO_2 emissions per GDP decline.

Table 6 indicates the regional trend of CO_2 emissions with the data for 6 sub-regions and 6 countries in Asia and the Pacific. 6 countries are listed in the world top 20 emitting countries by total CO_2 emissions for 2004 in the Carbon Dioxide Information Analysis Center (2008).

Moreover, Table 6 exhibits CO_2 emissions for the year of 1990, 1997 and 2003: the baseline year of CO_2 emissions for the reduction target agreed on the Kyoto Protocol, the adopted year of the Kyoto Protocol, and the year for the latest available data of CO_2 emissions in World Bank (2007), respectively. Table 6 consequently demonstrates that CO_2 emissions have been increasing over time in both Asia and the world. Though the analysis on the Kyoto Protocol is out of our scope in this analysis, it is evident in Table 6 that CO_2 emissions tend to increase regardless of the discussions for the Kyoto Protocol in 1997. Moreover, the world CO_2 emissions have been increased by 19% during the 1990-2003 period. The increase of CO_2 emissions in Asia and the Pacific is much larger and shows the 51% increase during the same period. Moreover, we find 5 observations.

First, all sub-regions in Asia and the Pacific show the increase of CO_2 emissions over time. Second, 6 regional countries which are listed in Carbon Dioxide Information Analysis Center (2008) indicate more than 80% of the total CO_2 emissions in this region. China exhibits the largest share of 45.7% in 2003, followed by India of 14.0%, and Japan of 13.6%: the total CO_2 emissions of 3 countries indicate more than 70% of the regional CO_2 emissions. Third, the growth of CO_2 emissions appears to reflect each country's economic growth. In particular, China, India, South Korea and Indonesia indicate about 73%-98% increase of CO_2 emissions between 1990 and 2003 whose countries are well known for the rapid economic growth. Fourth, though the overall regional CO_2 emissions in Asia and the Pacific are increasing over time, there are some changes for the sub-regional shares. For example, the Asian DC reduces its share whilst NICS, South-east Asia and South Asia increase their regional shares. Fifth, the Asian economies in transition remain as the largest CO_2 emitting countries in Asia and the Pacific whose CO_2 emissions are however largely dominated by China.

In a nutshell, the total CO_2 emissions in Asia and the Pacific are increasing over time, and their growth is much larger than that of the world. Though our previous regressions empirically support EKC with using the data of CO_2 emissions per GDP, our observations in this section consequently suggest the further increase of CO_2 emissions associated with the higher economic growth in this region. Table 6 may moreover indicate that the reduction of the regional CO_2 emissions depends on the larger emitting countries. In particular, China, India and Japan seem to be responsible for it.

5. Concluding Remarks

In this paper, we have statistically shown the relationship between income level and CO_2 emissions. Our empirical support for EKC indicates that CO_2 emissions per GDP exhibit the

Table 6: Regional Trend of CO_2 Emissions in Asia

	1990		1997		2003	
	%	(Growth)	%	(Growth)	%	(Growth)
AsianDC	22.7	(100)	19.5	(111)	17.9	(119)
NICS	5.2	(100)	6.6	(165)	6.0	(173)
South-east Asia	5.9	(100)	9.1	(199)	8.7	(223)
SouthAsia	12.8	(100)	14.9	(151)	15.8	(187)
Pacific countries	0.1	(100)	0.1	(126)	0.1	(134)
Transition	53.3	(100)	49.8	(121)	51.5	(145)
Total	100.0	(100)	100.0	(129)	100.0	(151)
China	39.8	(100)	42.3	(137)	45.7	(173)
India	11.2	(100)	13.2	(151)	14.0	(188)
Japan	17.8	(100)	15.0	(109)	13.6	(115)
S.Korea	4.0	(100)	5.4	(176)	5.0	(189)
Indonesia	2.5	(100)	3.6	(187)	3.3	(198)
Australia	4.5	(100)	4.1	(116)	3.9	(130)
Sub-total	79.8	(100)	83.6	(135)	85.5	(161)
Region	26.8		31.7		33.9	
World	[22501809]	(100)	[24527448]	(109)	[26750889]	(119)

Data Source: World Bank (2007) and author's estimation

Notes: please refer to Table 2 for each sub-region (in addition to Table 2, South-east Asia includes Myanmar, South Asia includes Afghanistan, the Pacific countries include American Samoa and Guam, and the Asian economies in transition includes North Korea on the above data)

%: the share of CO_2 emissions in the region

( ): the growth index of the total CO_2 emissions for each country/sub-region compared to the 1990 figure (the baseline year is 1990)

Region: the regional share of CO_2 emissions in the world (%)

[ ]: the total CO_2 emissions in the world (kt)

inverted U-curve shape associated with the income level, and may start declining beyond the turning point. Our empirical analysis moreover suggests the following considerations.

The regressions with the supplementary variables offer several useful insights. First, the negative impacts of industrialization on the CO_2 emissions are shown by the cross-country analysis. The preliminary time-series data analysis for several countries, including Indonesia and Malaysia, also exhibit the long-run relationships among the concerned variables. Indonesia and Malaysia can be seen as the representatives of the second generation of the Asian NICS, which show the rapid economic growth in the short period associated with industrialization. Our analysis suggests the increase of CO_2 emissions behind the scene, and may imply the further increase of CO_2 emissions if the Asian countries continuously depend on industrialization for economic growth. Interestingly, our regression results show that economic growth itself does not necessarily lead to the increase of CO_2 emissions. It should be also noted that population growth has the negative impacts on the CO_2 emissions. It might be due to the reason that population growth tends to worsen population density which has the negative impacts on the environment and resource management as suggested by Islam (1997), for example.[14] The consequent policy implications might be derived from the experiences of South Korea. South Korea is well known to be one of the fastest growing countries in the region. However, as Chun (1999) noted, South Korea has taken various policy measures for the environment conservation and pollution control since around 1980.[15] The positive outcomes are examined by Lim (1997), and our data for South Korea also show that the CO_2 emissions per GDP seem to be slowed associated with economic growth.[16]

Though our empirical analysis supports the validity of EKC which signifies the possible reduction of CO_2 emissions per GDP beyond the turning point, our supplementary descriptive data analysis crucially indicates that the overall CO_2 emissions are continuously increasing over time in Asia and the Pacific. In particular, CO_2 emissions are increasing in the countries with the rapid economic growth, including China, India, NICS and South-east Asian countries. Moreover, 6 large CO_2 emitting countries of China, India, Japan, South Korea, Indonesia and Australia indicate more than 80% of the regional CO_2 emissions. These emitting countries are certainly responsible for CO_2 emissions in the region.

Moreover, our empirical analysis may suggest the significances of the change of industrial structure, technical innovation, and technology transfers from developed countries to developing countries for the reduction of CO_2 emissions. In order to facilitate these activities, the environmental cooperation needs to be promoted both regionally and internationally. Developed countries are expected to take the strong leadership towards the goals not simply because developed countries are wealthy and possess the advanced environment-friendly technologies but also they themselves are the large CO_2 emitting countries both at present and historically. For example, based on World Resources Institute (2002), the United States is the largest CO_2 emitting country in the world for the 1900-1999 period and indicates 30.3% of the total CO_2 emissions during the period, followed by Europe (27.7%), the former Soviet Union (13.7%), the Asian developing countries including China and India (12.2%), the Latin American and Caribbean countries (3.8%), Japan (3.7%), Middle East (2.6%), Africa (2.5%), Canada (2.3%), and Australia (1.1%), respectively. These statistics may indicate that some developing countries as well as developed countries are also responsible for the CO_2 emissions.

Lastly, our empirical analysis consequently suggests that the total CO_2 emissions steadily increase associated with economic growth in Asia and the Pacific. The policy measures for the

14) Islam (1997), pp.24-25.
15) Chun (1999), p.154.
16) It should be noted that Lim (1997)'s data for CO_2 emissions are different from those in our analysis.

reduction of CO_2 emissions thus need to be seriously considered in both developed and developing countries of the region. As noted in UN-ESCAP (2001), if the countries in Asia and the Pacific continuously consume various resources for economic growth, further environmental degradation of air, water and soil are likely to happen. Therefore, the policy measures for the environment management and resource conservation are increasingly important for the regional sustainable economic development. Finally, many issues remain to be our future assignments, including the effects of the environmental policy measures such as the Kyoto Protocol and other environmental regulations on the CO_2 emissions and other pollutants.

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〔Associate Professor, Graduate School of Economics, Kyushu University〕