

# **Economic Development and/or Environmental Quality: Emissions of CO<sub>2</sub> and SO<sub>2</sub> in East Asia**

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This paper deals with a question of how the economic development in East Asia has influenced on emissions of CO<sub>2</sub> and SO<sub>2</sub>, thereby considering a larger question of whether or not economic development can coexist with environmental quality. Despite an increased scale of emissions, SO<sub>2</sub> has not so much increased as expected, and rising energy efficiency has made CO<sub>2</sub> emission intensity stabilized, or even declined like in China. These favorable facts are resulted from the efforts of East Asian countries to raise competitiveness in the world market, public awareness of environmental quality, and technology transfers through FDI and ODA. However, if the economic growth rate surpasses the rise in energy efficiency, CO<sub>2</sub> emissions as a whole would continue to increase.

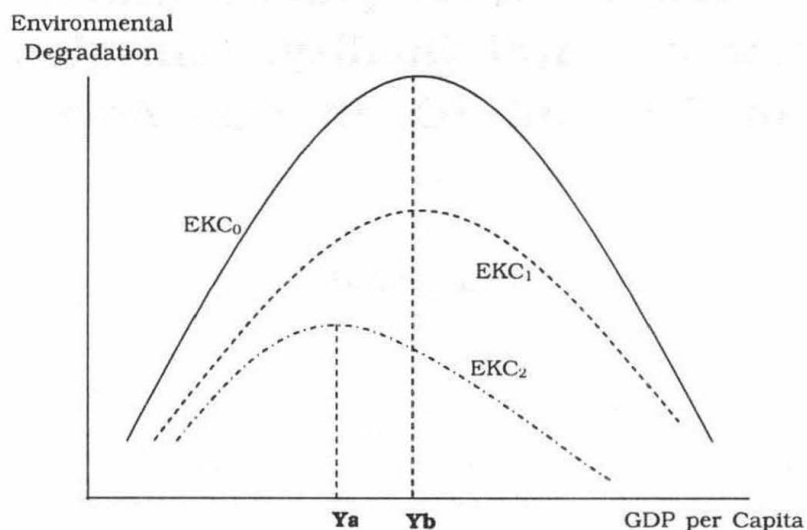
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## **I. Introduction**

This paper deals with a question of how the economic development in East Asia has influenced on the emissions of CO<sub>2</sub>

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**FIGURE 1**  
THE EKC AND ADVANTAGE OF LATECOMER

and  $\text{SO}_2$ , thereby considering a larger question of whether or not economic development can coexist with environmental quality. Indeed, the Kyoto Protocol does not oblige these countries, except for Japan, to cut  $\text{CO}_2$  emissions, but their rapid economic growth has brought about increasing scale of emissions. China, with the second largest emissions of  $\text{CO}_2$  in particular, will be undoubtedly a critical factor for the global warming in the near future. Iwami (2001b) considered the relationship between the economic development and air-pollution from viewpoints of the Environmental Kuznets Curve (EKC) and the "advantage of latecomer." The hypothesis of the EKC states that the environmental quality initially deteriorates with rising income, but later, after the income reaches a certain level, it begins to improve again. Therefore, a graph with income level on the horizontal axis and environmental degradation on the vertical axis shows an inverted U-shaped curve (Figure 1).<sup>1</sup>

If the EKC actually exists, the background to the phenomenon would include 1) the changing composition of industry and

<sup>1</sup>Stern, Common, and Barbier (1996) and Ekins (1997) give good surveys on this topic. For further discussions, see the special issues of *Environment and Development Economics*, 2, 1997 and *Ecological Economics*, 25-2, 1998.

consumption, 2) a growing awareness by citizens of environmental concerns, and 3) the financial capacity for environmental and related investments. With rising income, the center of weight in production and consumption shifts from primary to secondary and then to tertiary industry. In the process of a shift from primary to secondary industry, environmental conditions deteriorate, while the shift from secondary to tertiary industry causes alleviation of the negative impact on the environment. With higher income, citizens become more aware of environmental quality and induce their governments to introduce stricter regulations. Moreover, the investments necessary for environmental protection are only feasible with the financial resources made available by a certain level of income.

An "advantage of latecomer" would imply that countries industrializing later would complete the process in a shorter time and/or with better performances. Factors related to this issue include not only technology transfer, and initiatives on the part of government and private institutions (for example, banks), but also learning from the experiences of advanced countries. Following the analysis of the  $\text{SO}_2$  in Iwami (2001b), we now widen our focus to cover the case of the  $\text{CO}_2$  emissions. The section two initially surveys the relations between economic development, energy consumption, and emissions of  $\text{SO}_2$  and  $\text{CO}_2$ , and then with OLSA (ordinary least square analysis) of panel data, we examine factors affecting emissions, as well as the existence of the "advantage of latecomer." The section three reviews, in more detail, China's characteristics in comparison with other East Asians.

## **II. Emissions and Economic Development**

### *A. Industrialization*

Traditionally, developing countries were considered to be incapable of industrialization. Since around the mid-1970s, however, the middle-income countries called NICs (Newly Industrializing Countries), and later NIEs (Newly Industrializing Economies) have increased manufacturing shares in the world market. During the last couple of decades, Southeast Asian countries, once dominated by primary industrial sectors, have attained higher levels of

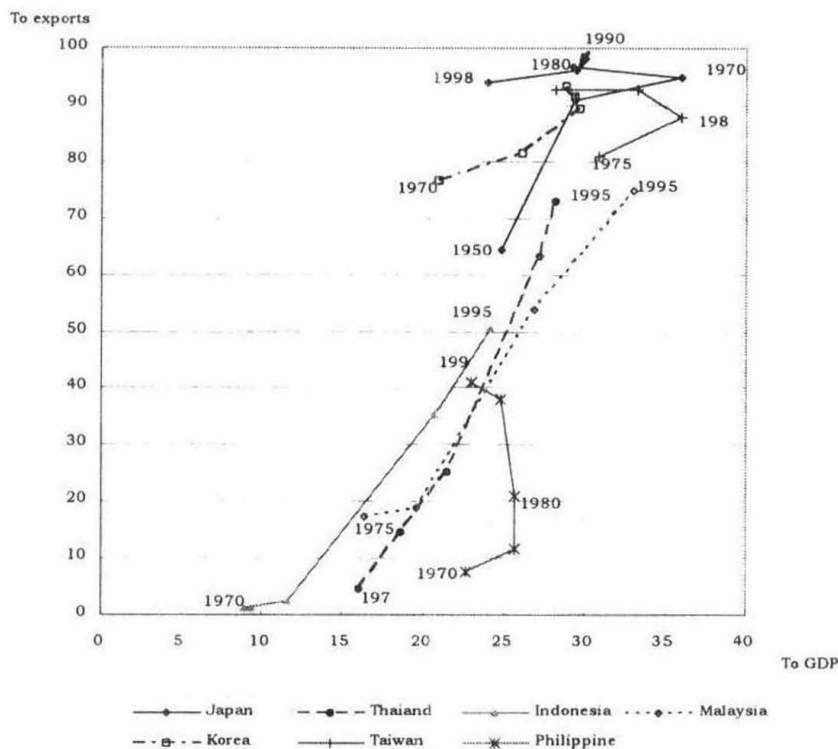
economic development thanks to their rapid industrialization. Their success has been based on open-door policies, in other words, export-led industrialization associated with inward FDI (foreign direct investment). This process is accompanied by the international sequence of industrial transformations, often characterized as the "flying geese pattern of development." The Chinese economic development promoted by reform policies has basically followed the patterns of the neighboring countries. Recently, increased scale of FDI to the coastal areas has led to the expression of "the workshop of the world." Covering from labor-intensive light industries to assembly branch of high-techs such as electronics, and also large-scale heavy industries, not a few branches enjoy the largest output-shares in the world. Although the so-called "socialist market economy" allows rooms for large-scale regulations and government interventions, Chinese government has endeavored to enhance economic efficiency, taking advantage of its entry into the WTO (World Trade Organization).

a) Industrial Structure

Industrialization causes wastes of toxic chemical substances and heavy metals, on the one hand, and leads to larger energy consumption that results in increased emissions of air-pollutants and GHG (greenhouse gas), on the other hand. Such an export-led industrialization as is witnessed in East Asia has naturally both aspects. Generally speaking, the difference in environmental regulations, and their subsequent cost differentials are not large enough to cause a move of industrial basis from the advanced countries to developing countries.<sup>2</sup> However, it is also true that the shift of industrial production abroad, whether caused by an appreciation of the home currency, or by differentials in labor cost as it took place in East Asia from the mid-1980s, results in the international move of the pollution sources. Even without shift of factories, when advanced countries import manufactured goods from developing countries, a similar move of energy consumption and pollution sources appears.<sup>3</sup>

<sup>2</sup>Iwami (2001b).

<sup>3</sup>Suri and Chapman (1998).



Sources: Industrial Structure: ADB. *Key Indicators of Developing Asian and Pacific Countries*. Various Issues. Export Structure: UNCTAD. *Handbook of International Trade and Development Statistics*.

**FIGURE 2**

INDUSTRIAL STRUCTURE IN EAST ASIA (MANUFACTURING SHARE, %)

Figure 2 illustrates the manufacturing shares in GDP on the horizontal axis, and those in total exports on the vertical axis, which reveals a rapid industrialization in the East Asian countries. As for shares in GDP, the Malaysian as of 1995, 33%, stands at the level similar to Japan as of 1970, when the pollution problems became quite serious in the latter country. Yet, the Thai share 28%, Indonesian 24%, and the Philippine 23% stay lower, rather near the Japanese level in the 1980s and the 1990s. In Japan, the manufacturing share stood at a peak in the early 1970s, and it subsequently declined showing a sign of "de-industrialization." Unfortunately, Chinese manufacturing share is not available in a similar way. Taking the share of industrial sector (manufacturing

plus mining and public utilities), in stead, it declined from 42% in 1981 to 37% in 1990, and rose again to 42% in 1997.<sup>4</sup> True, these changes of industrial share do not correspond to an image of "the workshop of the world." Apart from the reliability of the Chinese economic data, in particular before its economic reforms were set in motion, it is necessary to examine the actual situation of Chinese industries, which we discuss below.

The manufacturing shares in total exports, on the other hand, show a more remarkable rise than those in GDP. Since the vertical axis in Figure 2 is scaled down to less than a half, the rise in export shares is, as a matter of fact, far rapid. In other words, the industrialization in Southeast Asian countries has been literally led by rising exports. The manufacturing exports as of 1970 stood at around 1% in Indonesia, the corresponding share in Malaysia was 7%, Philippine 8%, and Thailand 5%, respectively. Primary goods like agricultural products and natural resources occupied the rest. As of 1995, however, the manufacturing exports occupy 53% in Indonesia, 75% in Malaysia, 42% in the Philippines, and 73% in Thailand. Yet, also to note is the fact that the manufacturing exports of Southeast Asian countries stand still far lower than those of Japan, Korea, and Taiwan that started earlier take-off in industrialization.

The rapid industrialization is therefore to be interpreted not simply by the shares of manufacturing or industrial sector, but rather by the speed of their increase. That the shares in Southeast Asian countries still stand at lower levels than that of Japan as of the 1970s might suggest a possibility that the further industrialization would result in a larger scale of environmental degradations. We discuss below what the actual situations are.

### *B. Emissions in East Asia*

#### *a) Emissions and Atmospheric Concentration*

The emissions of both CO<sub>2</sub> and SO<sub>2</sub> are not directly observed,

<sup>4</sup>ADB. *Key Indicators of Developing Asian and Pacific Countries*. 1999. For Chinese long-term statistics, see Nakajima (2002) and Kato and Chen (2002). Both of them do not present manufacturing data alone, but report only those of industrial sector. Moreover, the industrial data were not published until 1979, and its coverage has been continuously, although slightly, revised from the 1980s onwards.

but indirectly estimated from energy consumption and its sources. In contrast, the ambient concentration data are directly monitored, and, to that extent, seem to be more reliable. Yet, since the CO<sub>2</sub> concentration is not usually monitored, the choice of data between emissions or concentration matters solely in the case of SO<sub>2</sub>. The ambient concentration data have also shortcomings, however. Firstly, they are largely influenced by geographical and climate conditions. The climate conditions can be neutralized to a certain extent by using yearly averages and/or modes, but the geographical conditions are not easily dismissed. Particularly by international comparisons, it should be examined whether the observed spots are actually representative. Secondly, when compared with income-level like the EKC discussions, the local income data are not easily available. Since emission amounts are derived from national macroeconomic data, they are more suitable for comparisons across countries and with other macroeconomic statistics.

There are several sources for emission data: for SO<sub>2</sub>, ASL and Associates, *Global Sulfur Emissions Database*<sup>5</sup> and Streets *et al.* (2000) are available, while for CO<sub>2</sub>, IEA · OECD, *Energy Balances of OECD Countries*, *Energy Balances of Non-OECD Countries*, and Marland *et al.*, *Global, Regional and National Fossil Fuel CO<sub>2</sub> Emissions*.<sup>6</sup> They show not a small difference with each other. One reason is the measurement unit, namely whether by sulfur (S) and carbon (C) alone, on the one hand, or sulfur dioxide (SO<sub>2</sub>), and carbon dioxide (CO<sub>2</sub>), on the other hand. SO<sub>2</sub> (1mol=64g) weights twice as much as S (32g), whereas CO<sub>2</sub> (44g) weights 3.7 times as much as C (12g). When adjusted with the latter proportion, the difference between IEA · OECD and Marland *et al.* almost disappears. For example, according to the former data, China's CO<sub>2</sub> emission was 2,552.7 million tons in 1992, while the latter reports 722.2 million tons. Yet, the difference between ASL and Associates, and Streets *et al.* (2000) cannot be attributed to the different units. Considerations of not only various energy sources and their qualities, but also effects of abatement policies and technology seem to cause the difference, but those factors cannot be quantitatively adjusted.<sup>7</sup>

<sup>5</sup><http://www.asl-associates.com/sulfur.htm>.

<sup>6</sup>[http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm).

<sup>7</sup>Besides the human sources, the natural phenomena generate huge

## b) Long-Term Change

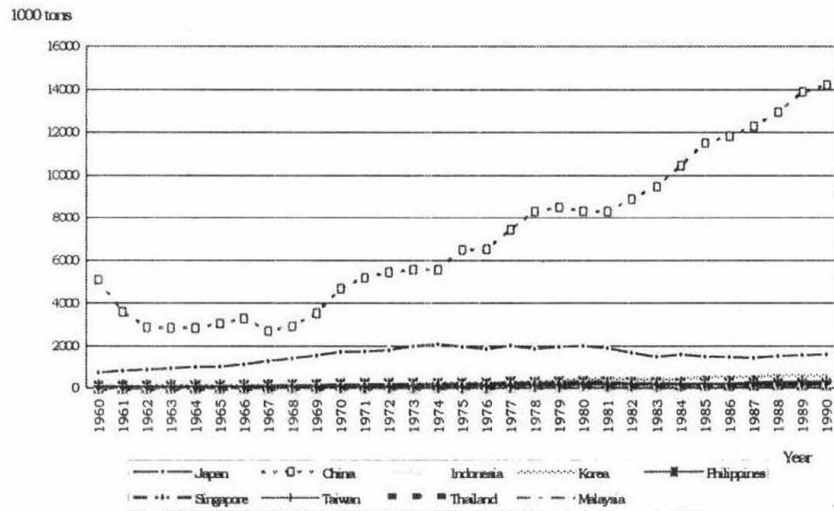
Let us review the long-term trends in the East Asian countries by using ASL and Associates and Marland *et al.* (Figure 3-6), because they cover similar time-periods. Total emissions of both CO<sub>2</sub> and SO<sub>2</sub> are overwhelmingly large in China, and their increasing speed is as well remarkable. Although Japan is the second largest as expected, the gap from China has been widening. As for SO<sub>2</sub>, since Japan's emissions have been decreasing from the early 1980s, China now occupies almost two thirds of the whole East Asian region. Yet, Chinese emissions have, it is said, become smaller than expected, due to regulation policies introduced in the 1990s.<sup>8</sup> As for CO<sub>2</sub>, on the other hand, China has largely increased emissions, and the scale is quite striking in East Asia as well as in the world. It occupied 13.8% of the world total as of 1997. Compared with US emissions of 5.47 billion tons, which occupies 23.8% of the world total, this figure indeed remains smaller. But with current trend of increase, China will overtake USA sooner or later. Looking at emissions per capita, however, Singapore shows remarkably high figures of both SO<sub>2</sub> and CO<sub>2</sub>, which can be attributed to its high level of energy consumption per capita. Also noteworthy is that SO<sub>2</sub> emissions per capita have been declining from the early 1980s, similarly to Japan, which is related to the discussion of the EKC. Although China's SO<sub>2</sub> emission per capita stands near the levels of Japan and Taiwan, its CO<sub>2</sub> emission per capita is far lower than Japan. It remained only 2.6 tons in 1997, whereas USA 20.5 tons, and Japan 9.3 tons. In other words, China's emission corresponds to 13% of USA, and 28% of Japan. Despite a small scale per capita, the country with an enormous population like China represents a huge amount of total emissions. This holds also true for energy consumption. Per capita consumption as of 1997 is 907kg (oil equivalent) in China, while 8,076kg in USA, and 4,984kg in Japan. Then, China consumed per capita ca. 11% of USA, and ca. 18% of Japan. Yet, in total, USA consumed 2,162.2 million tons, China 1,113.1 million tons, while Japan only 514.9 million tons.<sup>9</sup>

amount of SO<sub>2</sub>. In 1991, for example, the Philippine Volcano, Mt. Pinatubo emitted as much SO<sub>2</sub> as the annual emissions in China. Streets *et al.* (2000, p. 4415).

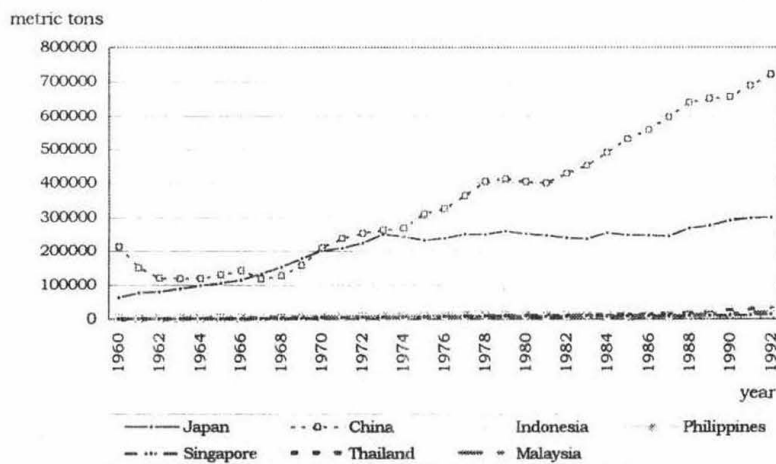
<sup>8</sup>Streets *et al.* (2000, pp. 4421-2).

<sup>9</sup>CO<sub>2</sub> emissions and energy consumption data are taken from IEA. *CO<sub>2</sub> Emissions from Fuel Combustion 1971-97*. Paris 1999.



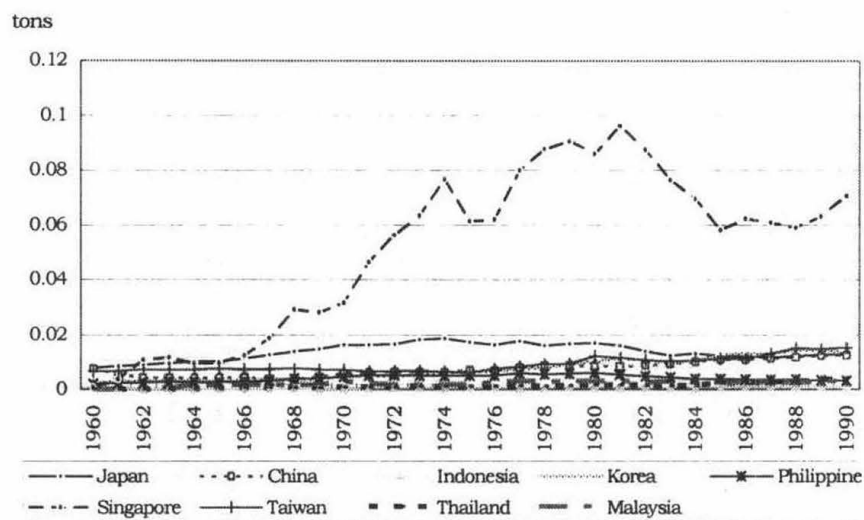


**FIGURE 3**  
SO<sub>2</sub> EMISSIONS IN EAST ASIA (TOTAL)

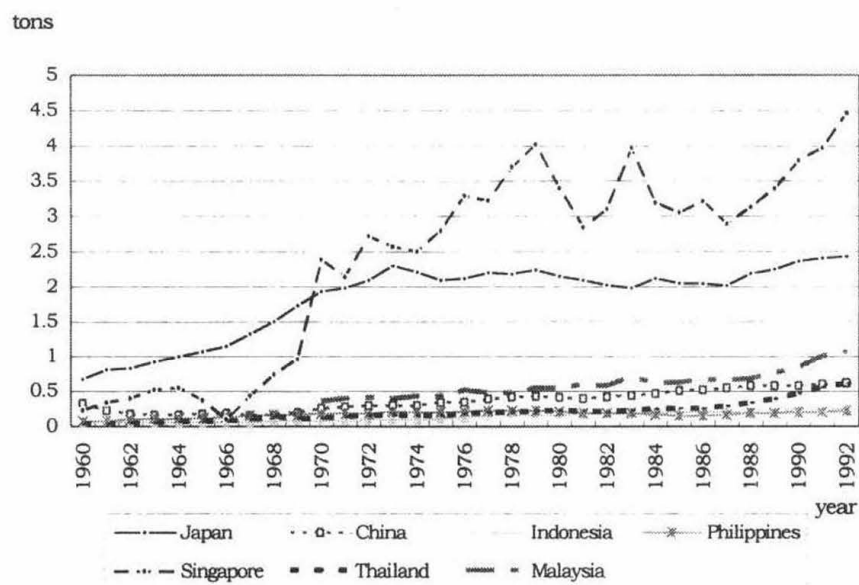


Sources: SO<sub>2</sub> emissions are from ASL and Associates. *Global Sulfur Emissions Database*. <http://www.asl-associates.com/sulfur.htm>. CO<sub>2</sub> emissions from G. Marland et al. *Global, Regional and National Fossil Fuel CO<sub>2</sub> Emissions*. [http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm).

**FIGURE 4**  
CO<sub>2</sub> EMISSIONS IN EAST ASIA (TOTAL)



**FIGURE 5**  
SO<sub>2</sub> EMISSIONS IN EAST ASIA (PER CAPITA)



**FIGURE 6**  
CO<sub>2</sub> EMISSIONS IN EAST ASIA (PER CAPITA)

### C. What Factors Determine Emissions?

Now we examine factors that determine emissions. They are composed of the scale of GDP, and emission intensity, namely emission per unit of GDP (EM/GDP). The latter can be further divided into energy consumption per unit of GDP, namely energy intensity (EC/GDP), on the one hand, and emission coefficient, that is, emission per unit of energy consumption (EM/EC), on the other hand, as the following equation illustrates.

$$EM = GDP \cdot \frac{EM}{GDP} = GDP \cdot \frac{EC}{GDP} \cdot \frac{EM}{EC} = Y \cdot I \cdot e \quad (1)$$

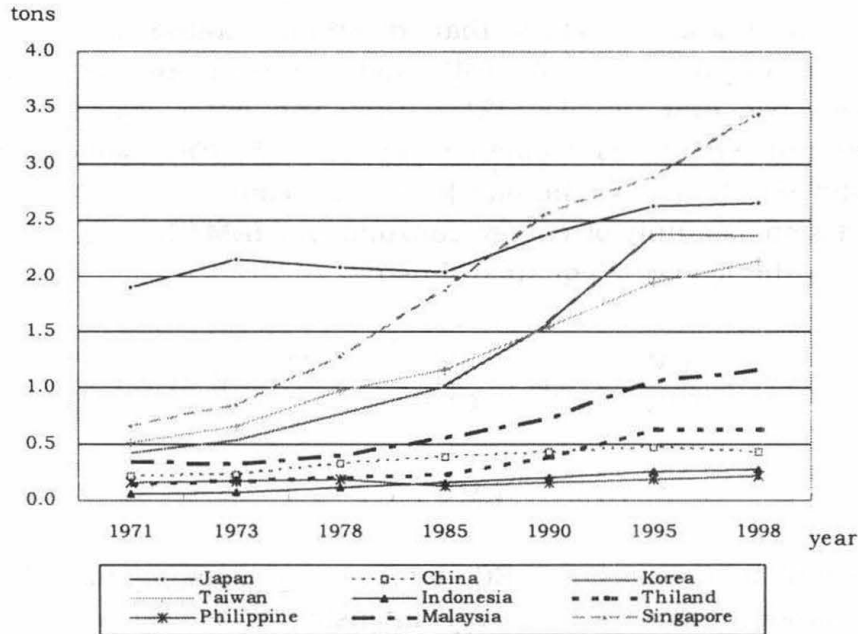
$$\text{therefore} \quad \dot{EM} = \dot{Y} + \dot{I} + \dot{e} \quad (2)$$

where EM: total emissions, EC: total energy consumption, Y: GDP,  $I$ : emission intensity,  $e$ : energy intensity,  $e$ : emission coefficient, and  $\dot{\phantom{x}}$  signs represent the rate of changes.

Even the same scale of GDP may generate different amount of emissions, depending on the emission intensity; or energy intensity and emission coefficient. It is easy to understand that the decline in energy intensity, in other words, the rise in energy efficiency causes a decline in emissions. The energy intensity is determined by not only the innovation of saving energy, but also changes in industrial structures, and mode of living. The emission coefficient depends firstly on the energy source and its quality, and secondly on abatement technology. As for the energy source, the shift from coal to oil, and then to natural gas reduces emissions, while more dramatic decline appears by using natural renewable energy like hydraulic-, wind power and geo-thermal heat. Renewable energy without using fossil fuel generates, in principle, neither CO<sub>2</sub> nor SO<sub>2</sub> directly.

Generally speaking, energy consumption correlates with income level, as Figure 7 illustrates. Interesting to note is that Singapore's energy consumption per capital has increased remarkably from 1971 onwards, and recently stays at a peculiarly high level,<sup>10</sup>

<sup>10</sup>Energy consumption is represented by TFC (total final consumption), which is calculated as TPES (total primary energy supply) minus energy



Note: Energy consumption is TFC. China does not include Hong Kong.

Sources: IEA · OECD. *Energy Balances of OECD Countries 1997-1998*,  
*Energy Balances of Non-OECD Countries 1997-1998*.

**FIGURE 7**

PER CAPITA ENERGY CONSUMPTION (OIL EQUIVALENT)

which corresponds to its per capita emissions of CO<sub>2</sub> and SO<sub>2</sub>. The large energy consumption of Singapore can be attributed to its high income, however. Its GDP per capita in terms of 1990 US dollar (PPP: Purchasing Power Parity) stands at 29,181 US dollars as of 1997, and far exceeds Japan's 20,709 US dollars.<sup>11</sup>

Indeed, energy consumption is also influenced by the industrial structure, as the industrialization increases it. But the increasing weight of tertiary industrial sector is not necessarily accompanied by reduced energy consumption. With rising income and standard of living, households tend to consume larger amount of energy, and

consumed at electricity power plants and oil refineries, plus produced electricity and petrol-products. The TPES is defined as domestic production + imports - exports + changes in stock.

<sup>11</sup>Computed from IEA. *CO<sub>2</sub> Emissions from Fuel Combustion 1971-97*, Paris 1999.

witnessed in OECD countries.<sup>12</sup> Then, the relations between industrial structure and energy consumption, and accordingly emissions of SO<sub>2</sub> and CO<sub>2</sub> are not self-evident.

a) Energy Efficiency and Emission Coefficient

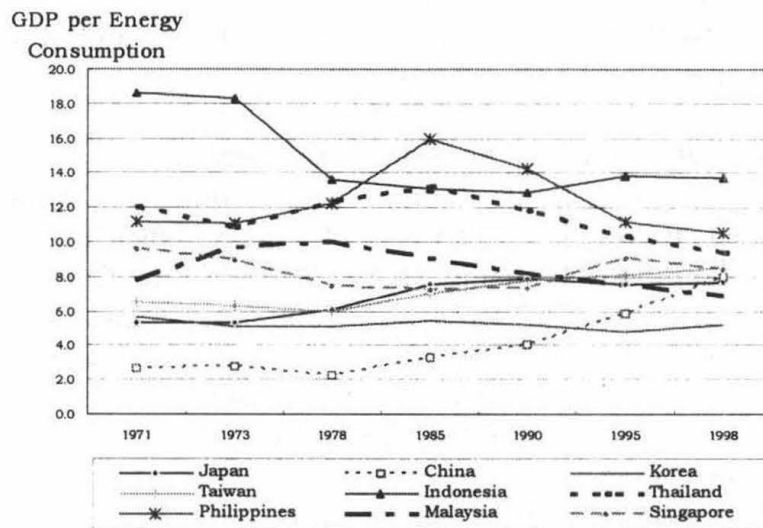
Let us have a look at changes across time and countries in energy intensity, or its reciprocal of energy efficiency. Figure 8 reports an impressively rising energy efficiency of China, followed by Japan's rise between 1973 and 1990, and Taiwan from 1978 onwards. In contrast, Indonesia and Malaysia rather decrease energy efficiency, which might reflect the fact that these countries domestically produce petroleum and natural gas. Every East Asian country shows higher energy efficiency in 1998 than Japan as of 1978. Every country except for Malaysia and Korea enjoys even higher efficiency than Japan as of 1988. This fact suggests that the economic growth in East Asia cannot be explained solely by the large scale input of production factors as is stressed by Krugman (1994).

Yet to note is that energy efficiency can be largely affected by the GDP data. Apart from short-term fluctuations in economic growth, the international comparison of GDP depends on the choice of exchange rates. Figure 8 is based on the US dollar (PPP). When compared in terms of nominal exchange rates, for example, the whole picture looks quite differently. However, this is unavoidable constraint in international comparison of income. The usual procedure is to choose PPP rather than nominal exchange rates that often exhibit extreme volatility in the market.<sup>13</sup>

Then, what kind of factors determine energy efficiency and emission coefficient? Energy efficiency is raised through innovations to reduce production costs. With soaring energy prices, the incentives to reduce costs are strengthened. The motives to reduce emission coefficient is different, except for the case that changing relative prices promote shifts of energy sources. However, an energy source with less emission coefficient is not necessarily cheap. The emission-abatement equipments, moreover, incur additional costs. The efforts to cut emissions are better explained by factors other

<sup>12</sup>Krackeler *et al.* (1998).

<sup>13</sup>In the EKC literature, income is measured for the most part in terms of PPP. See, for example, Stern, Common, and Barbier (1996).



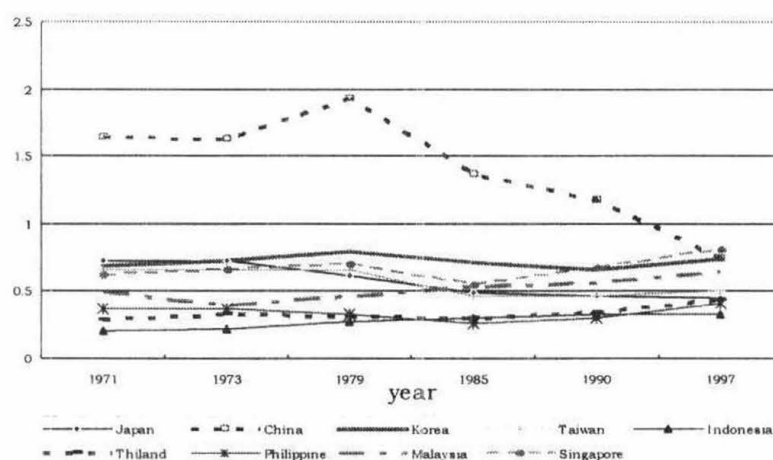
Note: Energy consumption is TFC, and GDP is in terms of US dollar 1990 (PPP). China does not include Hong Kong.

Sources: the same as Figure 7.

**FIGURE 8**  
ENERGY EFFICIENCY

than economic calculations, such as reputation in the society where public opinions are critical of environmental degradation, and/or governmental regulations. Discussions of the EKC tend to attribute these social and political factors simply to the income level.

In the case of CO<sub>2</sub>, although its emissions have recently become a focus of policy issues due to the global warming, their direct, and short-term damages are hard to be recognized. Accordingly, the incentives to reduce emissions remain rather weak. SO<sub>2</sub>, on the other hand, has been regarded as one of the most serious air-pollutants, and monitoring apparatus have been well installed. In the advanced countries, in particular, abatement policies have taken effects. The outcomes of such abatement measures, such as the end-of-pipe desulfurization are indeed confined to SO emissions, but other measures like switching fuels and raising energy efficiency can also indirectly contribute to reducing CO<sub>2</sub> emissions. SO<sub>2</sub> emissions from oil per calorie are, generally speaking, 69% of coal, and those from natural gas 0%. As for CO<sub>2</sub> emissions, oil generates per calorie 83%, and natural gas 62% of coal, respectively.<sup>14</sup>



Note: China does not include Hong Kong.

Sources: the same as Figure 7.

**FIGURE 9**  
CO<sub>2</sub> EMISSION INTENSITY

However, it is also worth noting that the atmospheric SO<sub>2</sub>, when turned into aerosol of sulfuric acid (or sulfate), reflects solar rayon away, and therefore its so-called "umbrella effects" cause rather decreased temperature.<sup>15</sup> If the policies of air-pollution abatement succeed in reducing ambient SO<sub>2</sub> concentration, its ironical side effects are to promote warming. Thus, seen from the viewpoint of the global warming, the double effects of desulfurization to reduce both SO<sub>2</sub> and CO<sub>2</sub> have both positive and negative sides.

Figure 9 illustrates changes in emission intensity of CO<sub>2</sub>. China showed far higher level until 1979 when the continued decline commenced. Subsequently in 1997, it arrived at the level similar to Korea and Singapore. What factors have actually contributed is suggested in Table 1 that shows each contribution of GDP, energy intensity, and emission coefficient from the calculation based on equation (2). While most of the countries report larger average yearly increase of CO<sub>2</sub> emission in the period of 1985-97 than 1971-85, China and Indonesia exceptionally reduce rate of increase in the later period. Moreover, China's increase of 4.3% is the

<sup>14</sup>Yamaguchi (1999, Table 1), Zhang (2000, Table 2).

<sup>15</sup>Bolin (1998, p. 351), Streets *et al.* (2000, p. 4414).

**TABLE 1**  
FACTORS AFFECTING CO<sub>2</sub> EMISSIONS (YEARLY AVERAGE CHANGE. %)

Period	GDP		Energy intensity		Emission coefficient		CO <sub>2</sub> emissions	
	1971 -85	1985 -97	1971 -85	1985 -97	1971 -85	1985 -97	1971 -85	1985 -97
Japan	4.0	2.9	-2.5	-0.2	-0.2	-0.6	1.3	2.1
China	6.8	9.3	-1.5	-7.3	0.1	2.3	5.5	4.3
South Korea	7.4	8.0	0.3	0.3	0.0	0.0	7.7	8.3
Taiwan	8.1	7.3	-0.5	-1.5	-1.9	2.2	5.7	8.0
Indonesia	6.9	7.0	2.5	-0.4	0.3	1.2	9.7	7.9
Thailand	6.3	7.9	-0.7	2.9	0.9	0.4	6.5	11.1
Philippine	3.3	3.7	-2.5	3.4	0.1	0.3	0.8	7.5
Malaysia	6.8	7.5	-1.0	2.2	1.6	-0.6	7.4	9.1
Singapore	7.3	3.9	1.9	-1.2	-2.7	8.4	6.6	11.1

Source: IEA. *CO<sub>2</sub> Emissions from Fuel Combustion 1971-97*. Paris, 1999.

second lowest next to Japan in the period of 1985-97. In view of the fact that China's economic growth rate of 9.3% stood highest among the East Asian countries in that period, the decelerated increase of CO<sub>2</sub> emission is actually extraordinary. This is caused for the most part by the large decline in energy intensity of 7.3%.

### C. Time-Series Analysis

Now we analyze panel data of the East Asian countries from the early 1970s to 1990, putting emission per capita as a dependent variable; and income, energy efficiency and industrial structure as independent variables. We omit the energy consumption as a variable, substituting it for income and industrial structure as the equation below.

$$E = a + bY + cY^2 + dEF + eIS + u \quad (3)$$

where  $E$  on the left side stands for emissions per capita of SO<sub>2</sub> and CO<sub>2</sub> (tons), while on the right side, income,  $Y$  is GDP per capita (US dollar 1990, PPP); energy efficiency,  $EF$  is GDP per unit of energy consumption.  $IS$  is measured by a share of the second industrial sector (not only manufacturing, but including mining, construction, and public utilities) in GDP. Except for  $IS$ , all



**TABLE 2**  
**SO<sub>2</sub> AND CO<sub>2</sub> EMISSIONS IN EAST ASIA**  
(POOLED TIME-SERIES DATA FROM THE EARLY 1970S TO 1990)

Dependent variables:	SO2		CO2	
	(a)	(b)	(c)	(d)
Constant	-33.98 (-4.33)***		-30.57 (-10.56)***	
Y	6.17 (3.08)***	5.66 (8.49)***	6.70 (9.90)***	4.47 (11.58)***
Y <sub>2</sub>	-0.30 (-2.46)**	-0.31 (-7.67)***	-0.32 (-7.14)***	-0.22 (-9.76)***
EF	-1.60 (-5.17)***	-0.29 (-1.96)*	-1.88 (-15.18)***	-0.47 (-5.15)***
IS	3.53 (3.49)***	1.15 (2.11)*	-1.50 (-3.30)***	0.13 (0.37)
Samples	168	168	149	149
$\overline{R^2}$	0.71	0.98	0.94	0.87
Income (US dollar) at turning points	29,144	9,219	37,911	20,869

Notes: *t*-statistics in parentheses. \*significant at 5% level, \*\*significant at 2% level, \*\*\*significant at 1% level. (b) and (d) show results of fixed-effect models.

Sources:

SO<sub>2</sub> emissions: ASL and Associates. *Global Sulfur Emissions Database*, <http://www.asl-associates.com/sulfur.htm>.

CO<sub>2</sub> emissions: G. Marland *et al.* *Global, Regional and National Fossil Fuel CO<sub>2</sub> Emissions*. [http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm).

GDP, Population: A. Heston and R. Summers, *Penn-World Tables 5.6*, <http://datacentre.chass.utoronto.ca/pwt/index.html>.

Industrial structure: ADB. *Key Indicators of Developing Asian and Pacific Countries*. Economic Planning Agency of Japan. *Abstract of Economic Statistics*. Various Issues.

Energy efficiency: IEA · OECD. *Energy Balances of OECD Countries, Energy Statistics and Balances of Non-OECD Countries 1995/96*.

variables are expressed in logarithm, and *u* is an error term. Due to data availability, the starting points are different among nine countries as shown in following parentheses: Japan (1970), Korea (1971), China (1973), Indonesia (1973), Philippines (1973), Singapore (1973), Thailand (1973), Malaysia (1973), and Taiwan (1972), but the end point is the same as of 1990. Moreover, since Taiwan's

CO<sub>2</sub> emissions show an unusual decline almost to a tenth between 1979 and 1980, we try OLSA for CO<sub>2</sub> emissions excluding Taiwan.

However, it is also true that emissions depend on the peculiarities of each country. Table 2, therefore, also presents the results of fixed-effect models. Although emissions, generally speaking, increase along with economic development, and accordingly income level, they might turn to a decline after a certain threshold as the hypothesis of EKC argues. This fact is widely recognized for SO<sub>2</sub>, but opinions differ on the case of CO<sub>2</sub>. One reason for the disagreement is that the income level of the turning point is too high, even though the existence of EKC is statistically proved. Therefore, Table 2 reports the calculated income levels for East Asian countries.<sup>16</sup> We find in the Table following results.

As for SO<sub>2</sub>,

- 1) The OLSA leads to signs of coefficients, positive for linear income, and negative for squared income, respectively; both coefficients are statistically significant. The signs for energy efficiency is negative, in other words, rising efficiency reduces emissions, while the signs for industrial structure is positive. Both coefficients are also statistically significant.
- 2) The fixed-effect model generates almost similar results, apart from small differences that the *t*-statistics for squared income increases, but they somewhat decrease for energy efficiency and industrial structure.
- 3) The turning points stand for income levels of ca. 29,000 US dollars and ca. 9,000 US dollars, which seem to be almost realistic figures. Singapore reports GDP per capita of 29,000 US dollars in 1997; the corresponding figure for USA was 29,849 US dollars. Japan's per capita GDP surpassed 10,000 US dollars already in 1971.<sup>17</sup> As a matter of fact, SO<sub>2</sub> emissions per capita show declines for Singapore and Japan in Figure 5.

The Table also illustrates followings for CO<sub>2</sub>.

- 1) Similarly to SO<sub>2</sub>, OLSA represents signs of coefficients as follows. Positive for linear income, negative for squared

<sup>16</sup>For references, see Iwami (2001a) and (2001b). Suri and Chapman (1998) reports on p. 199, turning points for CO<sub>2</sub> as between 7 million US dollars and 8 million US dollars.

<sup>17</sup>IEA. *CO<sub>2</sub> Emissions from Fuel Combustion 1971-97*.

income, negative for both energy efficiency and industrial structure: all coefficients are statistically significant. Signs for energy efficiency is the same as expected, but contrary to the assumption in the case of industrial structure.

- 2) The fixed-effect model shows almost the same results as the OLSA for linear and squared income, and energy efficiency, but the coefficient for industrial structure is not statistically significant, yet.
- 3) The income levels for turning points stand between 38,000 US dollars and 21,000 US dollars, not so far from those for SO<sub>2</sub>. However, the level of 21,000 US dollars is too low, because neither Singapore nor Japan presents a declining trend of per capita emissions in Figure 6. Extending the observation period further than 1992, Japan's emissions was 9.3 tons, and Singapore 23.5 tons in 1997, implying a continued increase even after 1992 when Japan's emission stood at 8.8 tons and Singapore 15.9 tons, respectively.<sup>18</sup> In this sense, the level of 38,000 US dollars seems to be rather more realistic.

In sum, the EKC holds good for SO<sub>2</sub> as reported in the literature so far. Moreover, not only energy efficiency but also industrial structures present expected results. Since a study on European countries reports a rather vague relationship between industrial structure and SO<sub>2</sub> emissions,<sup>19</sup> the above results for East Asia are worth noting. In other words, de-industrialization in this part of the world might reduce SO<sub>2</sub> emissions.

The results for CO<sub>2</sub> look similar to SO<sub>2</sub> except for the industrial structure. However, the actual decline in per capita emissions has not yet appeared, and we may admit a possibility that the EKC does not hold true for CO<sub>2</sub>. Another difference from SO<sub>2</sub> is that the coefficient for industrial structure in the OLSA shows opposite signs to the theoretical assumption, and no statistical significance is found in the case of the fixed-effect model. This fact might suggest that the industrial structure is largely influenced by characteristics of individual countries. We consider this aspect in the next section.

<sup>18</sup>IEA. *CO<sub>2</sub> Emissions from Fuel Combustion 1971-97*.

<sup>19</sup>De Bruyn (1997).

### E. "Advantage of Latecomer"

East Asian countries have followed the industrialization pattern of developed countries, as mentioned above, shifting one after another from labor-intensive to capital-intensive industries, and then recently, even to technology-intensive industries. While technology transfer itself does not necessarily cause such shifts, they are at least promoted thereby. However, we should note that technology transfer could have a double-edged effect on emissions. On the one hand, it can lead to enlarged industrial capacity, resulting in increased pollutant emissions, but on the other hand, abatement technology can be also made available to the recipient country. Whether the net effect on emissions is positive or negative depends in part on the characteristics of the technology and on levels of public and government awareness.

The former negative effect is related to the degree of industrialization achieved by a country (measured by, for example, the share of manufacturing in the GDP, or other corresponding variables), whereas the latter positive effect is not easily measured. If the level of emissions is positively correlated with the level of industrialization, we can conclude that the negative effect is larger. But if the correlation is either negative or unclear, then it implies that factors other than the negative effects of technology transfer are, in fact, at work.

The preceding Figure 1 shows the "advantage of latecomer" as illustrated by the EKC. Latecomers attain lower levels of environmental degradation than their industrial predecessors when compared at the same income level. The peak of the EKC, however, can stand either at the same income level ( $Y_b$ ) or at a lower one ( $Y_a$ ). When the latecomer traces  $EKC_2$  rather than  $EKC_1$ , this shows that society recognizes environmental damage and protection measures are implemented at an earlier stage of economic development.

We try to examine the "advantage of latecomer" by adding country dummies to equation (3): China *CHN*, Hong Kong *HKG*, Philippine *PHL*, Malaysia *MYS*, Thailand *THA*, Korea *KR*, Taiwan *TW*, Singapore *SG*, and Indonesia *IDN*. The constant stands for the advanced country in the region, namely Japan. If the coefficient for a country dummy shows a minus sign, this means that the country in question generates less emissions than Japan, suggesting the existence of the "advantage of latecomer."

**TABLE 3**  
SO<sub>2</sub>, CO<sub>2</sub> EMISSIONS IN EAST ASIA

Dependent variables.	SO <sub>2</sub> (a)	CO <sub>2</sub> (b)
Constant	-30.37(-11.54)***	-20.69(-13.67)***
Y	5.66(8.49)***	4.47(11.58)***
Y <sup>2</sup>	-0.31(-7.67)***	-0.22(-9.76)***
EF	-0.29(-1.96)*	-0.47(-5.15)***
IS	1.15(2.11)*	0.13(0.37)
KR	-0.05(-0.62)	-0.28(-5.59)***
MYS	-1.24(-13.52)***	-0.66(-12.35)***
THA	-1.24(-13.52)***	-1.11(-16.98)***
PHL	-0.97(-0.81)	-1.06(-13.88)***
TW	-0.23(-2.53)***	
IDN	-1.56(-12.81)***	-0.97(-13.43)***
SG	1.66(26.56)***	0.52(14.52)***
CHN	0.77(4.87)***	-0.16(-1.65)
Sample number	168	149
$\overline{R^2}$	0.98	0.99
Income (US dollar) at turning points	9,219	20,869

Notes: *t* statistics in parentheses. \*Significant at 5% level, \*\*at 2% level, \*\*\*at 1% level, respectively.

Sources: the same as Table 2.

- 1) Table 3 reveals the same coefficients as fixed-effect models in Table 2 for all variables except for country dummies. Country dummies for SO<sub>2</sub> show minus signs for every country except Singapore and China, and coefficients for Malaysia, Thailand, Taiwan and Indonesia are all statistically significant. In the case of CO<sub>2</sub>, on the other hand, every country except Singapore shows minus signs, and coefficients for Korea, Malaysia, Thailand, the Philippines and Indonesia are also statistically significant. The latecomer effects are most evident in these cases. However, in the case of SO<sub>2</sub>, Singapore and China, while for CO<sub>2</sub>, Singapore alone show plus signs, implying larger emissions than Japan. These cases suggest that there do not exist latecomer effects.
- 2) The plus signs for Singapore might be attributed to its

characteristics other than high-income level. The case of China seems to be related to its peculiar industrial structure. The industrial share in China's GDP was as high as 43% in 1973, while it declined to 37% in 1990, as mentioned above. It must be noted, however, that the large industrial share in Chinese economy does not necessarily indicate an "advanced" level of industrialization. The Chinese manufacturing sector in the 1970s contained large numbers of small-scale, local factories that were promoted by the Mao Tse-tung's ideology of self-help (自力更生). As a result, they were equipped with low technology and poor efficiency.<sup>20</sup> These historical heritages certainly have influenced China's emissions as well. In the next section, we have a look at the actualities in China.

### III. The Situation in China

China has several peculiarities that separate from other East Asian countries. Firstly, its vast scale, in particular the population size, makes the total emissions quite large, the second largest next to USA, despite the small amount of per capita emissions. Along with the further growth of Chinese economy, energy consumption and CO<sub>2</sub> emissions per capita will undoubtedly increase. As is well known, USA took it as an excuse not to ratify Kyoto Protocol that China is not obliged to cut emissions.

Secondly, China's energy intensity is (more correctly saying, used to be) high, in other words, energy efficiency is (used to be) low. This character is derived from the historical heritages of "backwardness" in production process and equipments, but recently, as Figure 8 shows, the situation has been largely improved.

The major part of energy consumption in China is occupied by the second industry. In 1980, it occupied as much as 68%, but it subsequently increased to 71% in 1998. The second largest sector is households that occupied 16% in 1980, and 11% in 1998.<sup>21</sup> From these shares seen, the remarkable improvement in energy efficiency has taken place in the industrial sector. The tenth

<sup>20</sup>Sinton *et al.* (1998, p. 814) and Nakagane (1999, p. 480).

<sup>21</sup>Zhang (2001). For energy statistics, see also Sinton *et al.* (1998), Sinton and Fridley (2000).

five-year plan beginning 2001 determined introducing market-mechanism, thereby reforming state-owned firms and the whole economic system. These policies would, if successfully realized, further improve energy efficiency.

#### *A. Rising Energy Efficiency*

The energy production in China declined from a peak in 1996. This is caused by a large decline in coal production that stood at the end of the 1990s at the same level of a decade ago. As a result, coal occupied only 67% of the total energy consumption in 1999 while oil stood at 23%, and natural gas 3%. After 1996, the continual economic growth led to rising energy efficiency, which had appeared, in fact, much earlier since 1977.<sup>22</sup> Yet, because China's GDP is criticized to be overestimated, on the one hand, and coal production underestimated, on the other hand, energy efficiency might not be actually such high.

Zhang (2000) stressed that the rising energy efficiency largely contributed to reduce CO<sub>2</sub> emissions. According to his estimates, economic growth increased emissions by 925 million tons between 1980 and 1997, while the rising energy efficiency reduced them by 432 million tons; the shift of energy sources again by 10 million tons. Then, another question arises how has the rise in energy efficiency been realized?

Sinton and Fridley (2000) indicated contributing factors as follows. 1) The retreat of heavy industries, a large energy consuming sector, and a rise of high-tech and service sector with low energy intensity. 2) Economic reforms that promoted closing inefficient firms, factories and small-scale power stations. 3) The declining coal price that shifted consumption to high-quality coal, and also caused closing down small-scale coalmines. 4) The growing population in urban areas that prefers electricity, gas and LPG (liquefied petroleum gas) to direct use of coal. Rural areas, on the other hand, depend largely on biomass energy. The biomass consumption once amounted to a similar scale to petroleum. Recently it decreased rapidly with the wide use of commercial energy.<sup>23</sup>

We will discuss the actual situation of coal industry below, but

<sup>22</sup>Sinton *et al.* (1998).

<sup>23</sup>Sinton and Fridley (2000, p. 680).

provide here some comments on the points 1) and 2). Generally speaking, the increasing share of the service sector does not necessarily reduce energy consumption in advanced countries. Yet in China, closing old firms and factories that existed since the 1970s has undoubtedly raised energy efficiency. The Chinese electricity power stations, for example, have suffered from low energy efficiency, due to their small size, and equipments of old-vintage. Around three quarters of the total electricity generation depends on coal, the low quality of which leads to not only low energy efficiency, but also to large emissions of SO<sub>2</sub> and CO<sub>2</sub>. Indeed, the new power stations of large scale recently built by foreign capital still use coal, but their energy efficiency has been remarkably improved.<sup>24</sup>

That competition gives incentive to raise efficiency holds also true in the case of energy use. The economic reforms, and open-door policies in China would surely continue to improve energy efficiency. Since a study reports inward FDIs are positively correlated with energy efficiency,<sup>25</sup> capital inflows to developing countries with low efficiency like China are expected to reduce environmental impacts.

#### a) Energy Policy and Coal Industry

China's energy policy has been determined by various considerations such as national security in energy provision, reforming state-owned firms, maintaining employment and environmental protection as well. The tenth five-year plan still takes it for granted that coal remains to be a predominant energy source, but it also aims at a diversification of energy sources, for the sake of energy efficiency and security. At least officially, the "sustainable development" should be pursued from the environmental considerations, although there is not a small gap in China between the official stance and the reality.

The data of coal production that report a declining trend since 1996, remain to be doubtful, because those produced from small coalmines in the rural area are not fully included in the national statistics. Yet, the decline in production is mainly attributed to

<sup>24</sup>Blackman and Wu (1999).

<sup>25</sup>Mielnik and Goldemberg (2002) stress this aspect, although from a rather simple data analysis.



small mines.<sup>26</sup> The actual fact is not so simple. Horii (2003) stressed that, contrary to the common understanding, large-scale national mines are not profitable due to their high labor costs, and that they can survive only with subsidies, whereas small-scale mines without subsidies are competitive enough, thanks to the low production costs. Firstly, because coal beds stay not so deep under the ground, fixed costs do not occupy a large share in production. Secondly, labor costs, a major part of production costs, remain low, due to the lower level of wage rates and security provisions. In short, the geological differences and gap in production costs determine price-competitiveness of small mines. The "scale economy" does not exist in Chinese coal industry.

According to official statistics, national coalmines decreased shares from 55% in 1978 to 39% in 1996, while rural small mines increased in the same period from 14% to 45%. Since the latter constitute integral part of the rural economies, even the central government cannot easily close or consolidate them.

It is often argued that Chinese energy industry is supported by subsidies that tend to lower energy efficiency. Nevertheless, economic reform policies have led to cutting these subsidies. Subsidies to coal, for example, declined from 37% in 1984 to 29% in 1995, while in the case of petroleum, they declined dramatically from 55% in 1990 to 2% in 1995. The cut in coal subsidies by 8% points is reportedly to have raised energy efficiency by more than 30%.<sup>27</sup>

In such a country where command and control economy dominated for such a long time and regional transport facilities are not well equipped as China, a well-integrated market system hardly works.<sup>28</sup> Then, cut in subsidies alone does not always cause enough energy efficiency. Efforts to remove several forms of barriers to market mechanism are indispensable.

#### b) Environmental Policy and Technology Transfer

Iwami (2001b) stated that learning and technology transfer from advanced countries realize the "advantage of latecomer."

In Japan, social awareness and resulted civil movements caused air-pollution controls. We can guess the corresponding situations in

<sup>26</sup>Sinton and Fridley (2000, p. 674).

<sup>27</sup>Zhang (2000, pp. 743-44) and Dua and Esty (1997, p.153).

<sup>28</sup>Horii (2003).

East Asia by looking at opinion polls in Thailand and China (both undertaken in 1994). They show, in fact, larger public awareness than usually expected by observers from developed countries.<sup>29</sup> Citizens in Beijing and Shanghai are concerned about such daily problems as "noise and vibration," "insufficient green areas," "air-pollution," and "river-pollutions." More interestingly, they express large expectations on the role of governments. This fact might imply causality that the social awareness of the environmental quality leads to government actions.

In China, environmental legislations were introduced shortly after the economic reforms set in motion, implying "advanced" environmental policies that reflect the "advantage of latecomer" by learning from experiences in developed countries. Despite these legislations, however, the fact that pollutions actually increased is attributed to defects in the "environmental protection system,"<sup>30</sup> in other words, administrative institutions and manpower are incomplete. It is also true that measures against air-pollutions and acid rain to reduce SO<sub>2</sub> also contribute to cut CO<sub>2</sub> emissions. The technology transfer through FDI and official development assistance (ODA) generates the "advantage of latecomer." In Japan, public opinions have been recently critical of the ODA to China, because of Chinese military buildups and conflict of interests between the two countries. Nevertheless, the ODA for the sake of environmental protections, like measures against the desertification in China, has grown up. Moreover, CDM (Clean Development Mechanism) designed in the Kyoto Protocol has recently gained popularity.<sup>31</sup>

Financial flows from Japan are attractive to Chinese firms, not only for the environmental protections in a narrower sense, but also for introducing more efficient production equipments. Yet, technology transfers provided by the ODA fund are not included in the CDM accounting. In addition, China might hesitate at the moment to participate in such schemes of emission reduction, from consideration of the possibility that the country might be obliged to cut GHG emissions in the future. However, expectations on the technology transfer through CDM are in fact strong,<sup>32</sup> and different

<sup>29</sup>See Nishihira *et al.* (1997).

<sup>30</sup>Li (1999).

<sup>31</sup>For more details of CDM, see Yamaguchi (2002).

<sup>32</sup>See Zhang (2000) for positive opinions on Kyoto Mechanism.

opinions seem to exist within the Chinese government.

#### IV. Concluding Remarks

Economic development in East Asia is accompanied by an increased scale of CO<sub>2</sub> and SO<sub>2</sub> emissions. In particular, China's emissions are enormous. Yet, SO<sub>2</sub> emissions have not so much increased as expected, not only in East Asia as a whole, but also in China. Concerns about continued growth of SO<sub>2</sub> emissions are not realistic any more in the region.<sup>33</sup> As for CO<sub>2</sub>, rising energy efficiency has made emission intensity stabilized, or even declined like in China. These favorable facts are resulted from the efforts of East Asian countries to raise competitiveness in the world market, public awareness of environmental quality, and technology transfer through inward flows of FDI and ODA. However, if the economic growth rate surpasses the rise in energy efficiency, CO<sub>2</sub> emissions would continue to increase. Whether or not economic development in East Asian countries, in particular China, causes a further rise in CO<sub>2</sub> emissions, is not predictable, depending on the gap between economic growth and a decline in emission intensity. It is yet worth noting that the emissions intensity has been declining, except for a few countries.

The OLSAs show the inverted U-shaped curves for SO<sub>2</sub> and CO<sub>2</sub> emissions, as the EKC hypothesis argues. The income level at the turning points suggests that the CO<sub>2</sub> emissions per capita have already entered, or will soon enter a declining phase, which, as a matter of fact, stands against the reality. Therefore, the estimated results from econometric analyses need to be examined carefully together with actual experience. Needless to say, the econometric estimation depends on the reliability of macroeconomic data: PPP, economic growth rate, energy consumption and, emission amounts *etc.* As is well known, Chinese data are not free from suspicion. Nevertheless, seen from experience in the neighboring countries, the conclusion in this paper must not be so much away from the actualities.

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<sup>33</sup>Streets *et al.* (2000, p. 4422).

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