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Economic Development and/or Environmental Quality: Emissions of CO_2 and SO_2 in East Asia

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Abstract

This paper deals with a question of how the economic development in East Asia has influenced on emissions of CO_2 and SO_2, thereby considering a larger question of whether or not economic development can coexist with environmental quality. Despite an increased scale of emissions, SO_2 has not so much increased as expected, and rising energy efficiency has made CO_2 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_2 emissions as a whole would continue to increase.

Key words: Environmental Kuznets Curve, advantage of latecomer, SO_2 and CO_2 emissions, industrialization, East Asia

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1. Introduction

This paper deals with a question of how the economic development in East Asia has influenced on the emissions of CO_2 and 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 CO_2 emissions, but their rapid economic growth has brought about increasing scale of emissions. China, with the second largest emissions of CO_2 in particular, will be undoubtedly a critical factor for the global warming in the near future.

Iwami (2001b) considered the relation 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).[2]

If the EKC actually exists, the background to the phenomenon would include 1) the changing composition of industry and 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 SO_2 in Iwami (2001b), we now widen our focus to cover

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[2] 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.

the case of the CO_2 emissions. The section two initially surveys the relations between economic development, energy consumption, and emissions of SO_2 and 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.

2. Emissions and Economic Development

2. 1 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).

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. [3]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 source. Even without shift of factories, when advanced countries import manufactured goods from developing countries, a similar move of energy consumption and pollution source appears.[4]

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.[5] 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 almost 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 stood at around 1% in Indonesia as of 1970, 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, 70% in Malaysia,

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[3] Iwami (2001b).
[4] Suri and Chapman (1998).
[5] ADB, *Key Indicators of Developing Asian and Pacific Countries 1999.* For Chinese long-term statistics, see Nakajima(2002) and Kato・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.

42% in the Philippines, and 71% 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 may suggest a possibility that the further industrialization would result in a larger scale of environmental degradations. We discuss below what the actual situations are.

2．2 Emissions in East Asia

Emissions and atmospheric concentration

The emissions of both CO_2 and SO_2 are not directly observed, 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_2 concentration is not usually monitored, the choice of data between emissions or concentration matters solely in the case of SO_2.

The ambient concentration data have 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 among countries and with other macroeconomic statistics.

There are several sources for emission data: for SO_2, ASL and Associates, *Global Sulfur Emissions Database* [6] and Streets *et al.* (2000) are available, while for CO_2, IEA・OECD, *Energy Balances of OECD Countries, Energy Balances of Non-OECD Countries,* and Marland *et al.*, "Global, Regional and National Fossil Fuel CO_2 Emissions". [7] 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_2,and carbon dioxide CO_2, on the other hand. SO_2 (1mol=64g)

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[6] http://www.asl-associates. com / sulfur.htm.
[7] http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm.

weights twice as much as S (32g), whereas CO_2 (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_2 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 different 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.[8]

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_2 and SO_2 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_2, 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.[9] As for CO_2, on the other hand, China has largely increased emissions, and the scale is quite striking in East Asia as well as in the world, occupying 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_2 and CO_2, which can be attributed to its high level of energy consumption per capita. Also noteworthy is that SO_2 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_2 emission per capita stands near the levels of Japan and Taiwan, its CO_2 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

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[8] Besides the human sources, the natural phenomena generate huge amount of SO_2. In 1991, for example, the Philippine Volcano, Mt. Pinatubo emitted as much SO_2 as the annual emissions in China. Streets *et al.* (2000) p. 4415.
[9] Streets *et al.*(2000),pp.4421-22.

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. [10]

2. 3 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.

$$EM = GDP \cdot \frac{EM}{GDP} = GDP \cdot \frac{EC}{GDP} \cdot \frac{EM}{EC}$$

$$= Y \cdot \Gamma = Y \cdot I \cdot e \qquad (1)$$

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

where EM : total emissions, EC : total energy consumption, Y: GDP, Γ : emission intensity, I: energy intensity, e : emission coefficient, and · 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

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[10] CO_2 emissions and energy consumption data are taken from IEA, *CO_2 Emissions from Fuel Combustion 1971-1997,* Paris 1999.

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_2 nor SO_2 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,[11] which corresponds to its per capita emissions of CO_2 and SO_2. 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.[12]

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 the growing service sector itself increases demand for electricity as witnessed in OECD countries.[13]Then, the relations between industrial structure and energy consumption, and accordingly emissions of SO_2 and CO_2 are not self- evident.

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. Anyway, 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 the same year. 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).

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[11] Energy consumption is represented by TFC (total final consumption), which is calculated as TPES (total primary energy supply) minus energy 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.

[12] Computed from IEA, *CO_2 Emissions from Fuel Combustion 1971-1997,* Paris 1999.

[13] Kracker *et al* (1998).

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 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. [14]

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 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 attribute these social and political factors simply to the income level.

In the case of CO_2, 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_2, 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_2 emissions. SO_2 emissions from oil per calorie are, generally speaking, 69% of coal, and from natural gas 0%. As for CO_2 emissions, oil generates per calorie 83%, and natural gas 62% of coal, respectively.[15]

However, it is also worth noting that the atmospheric SO_2, when turned into aerosol of sulfuric acid (or sulfate), reflects solar rayon away, and therefore its so-called "umbrella effects" cause rather decreased temperature. [16] If the air-pollution abatement policies succeed in reducing ambient SO_2 concentration, its ironical side

[14] In the EKC literature, income is measured for the most part in terms of PPP. See, for example, Stern, Common, and Barbier (1996).

[15]Yamaguchi (1999) Table 1, Zhang(2000), Table2.

[16] Bolin (1998), p.351, Streets *et al.* (2000), p.4414.

effects are to promote warming. Thus, seen from the viewpoint of the global warming, the double effects of desulfurization to reduce both SO_2 and CO_2 have both positive and negative sides.

Figure 9 illustrates changes in emission intensity (emission per unit GDP) of CO_2. China showed far higher level until 1979 when the continued decline began, but subsequently in 1997, it arrived at the level of 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_2 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 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_2 emission is actually extraordinary. This is caused for the most part by the large decline in energy intensity of 7.3%.

2. 4 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.

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

where E on the left stands for emissions per capita of SO_2 and CO_2 (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 IS, all 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 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_2 emissions show an unusual decline almost to a tenth between 1979 and 1980, we try OLSA for CO_2 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 commonly recognized for SO_2, but opinions differ on the case of CO_2. 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. [17]We find in the Table following results.

As for SO_2,

1) The OLSA leads to signs of coefficients, positive for linear income, and negative for squared income, respectively, and 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 level between 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. [18] As a matter of fact, SO_2 emissions per capita show declines for Singapore and Japan in Figure 5.

The Table also illustrates followings for CO_2.

1) Similarly to SO_2, OLSA represents signs of coefficients as follows. Positive for linear income, negative for squared income, negative for both energy efficiency and industrial structure, and 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 for linear and squared income, and energy efficiency as the OLSA, but different for industrial

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[17] For references, see Iwami (2001a) and (2001b). Suri and Chapman(1998) reports on p.199, turning points for CO_2 as between 7 million US dollars and 8 million US dollars,
[18] IEA, *CO_2 Emissions from Fuel Combustion 1971-1997.*

structure, which coefficient 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_2. 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. [19]In this sense, the level of 38,000 US dollars seems to be rather more realistic.

In sum, the EKC holds good for SO_2 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_2 emissions,[20] the above results for East Asia are worth noting. In other words, de-industrialization in this part of the world might reduce SO_2 emissions.

The results for CO_2 look similar to SO_2 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_2. Another difference from SO_2 is that the coefficient for industrial structure in the OLSA shows opposite signs to the theoretical assumption, and no statistical significance 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.

2.5 "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 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 made available to the recipient country. Whether the net effect on emissions is positive or negative depends in part on the characteristics of the

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[19] IEA, *CO_2 Emissions from Fuel Combustion 1971-1997.*

[20] De Bruyn (1997).

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 (Yb) or at a lower one (Ya). 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 the latecomer".

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_2 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_2, 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. In the case of SO_2, however, Singapore and China, while for CO_2, Singapore alone show plus signs, implying larger emissions than Japan. These cases suggest that there do no exist latecomer effects.
2) The plus signs for Singapore can be attributed to its high-income level as the former section discusses. But 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.[21] These historical heritages certainly have influenced China's emissions as well. In the next section, we have a look at the situation in China.

3. 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_2 emissions per capita will 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 large 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. From these shares seen, the remarkable improvement in energy efficiency has taken place in the industrial sector. The tenth five-year plan beginning 2001 determined introducing market-mechanism, thereby reforming national firms and the whole economic system. These policies would, if successfully realized, further improve energy efficiency.

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

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[21] Sinton *et al* (1998), p.814, Nakagane (1999), p.48.

led to rising energy efficiency, which had appeared, in fact, since 1977. [22] 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.

But Zhang (2000) stressed that the rising energy efficiency largely contributed to reduce CO_2 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, and the shift of energy sources again reduced 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, which 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, but recently it decreased rapidly with the wide use of commercial energy. [23]

We will discuss the actual situation of coal industry below, but provide here some comments on the points 1) and 2). Generally sparking, the increasing share of the service sector does not necessarily reduce energy consumption in advanced countries. But in China, closing old firms and factories 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_2 and CO_2. Indeed the new power stations of large scale recently built by foreign capital still use coal, but their energy efficiency has been remarkably improved.[24]

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 foreign direct investments are positively correlated with energy efficiency, [25] capital inflows to

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[22] Sinton *et al* (1998).
[23] Sinton and Fridley (2000), p.680.
[24] Blackman and Wu (1999).
[25] Mielnik and Goldemberg (2002) stress this aspect from a rather simple data analysis.

developing countries with low efficiency like China are expected to reduce environmental impacts.

Energy policy and coal industry

China's energy policy has been determined by various considerations such as national security in energy provision, reforming national 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 small mines. [26] 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 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. In short, 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 tried to cut 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 the 8% points is reportedly to have raised energy efficiency by more than 30%.[27]

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[26] Sinton and Fridley (2000), p.674.

[27] Zhang (2000),pp.743-44, Dua and Esty(1997),p.153.

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. [28]Then, cut in subsidies alone does not always cause enough energy efficiency. Efforts to remove several forms of barriers to market mechanism are indispensable.

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 East Asia by looking at opinion polls in Thailand and China (both undertaker in 1994). They show, in fact, larger public awareness than usually expected by observers in developed countries.[29] Citizens in Beijing and Shanghai are, concerning 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 consciousness 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, that pollutions actually increased is attributed to defects in the "environmental protection system," [30] in other words, administrative institutions and manpower are incomplete. It is also true that measures against air-pollutions and acid rain to reduce SO_2 also contribute to cut CO_2 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. [31]

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[28] Horii(2003).
[29] See Nishihira *et.al* (1997).
[30] Li (1999).
[31] For more details of CDM, see Yamaguchi (2002).

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. On the other hand, expectations on the technology transfer through CDM are in fact strong[32], and different opinions seem to exist within the Chinese government.

4. Concluding Remarks

Economic development in East Asia is accompanied by an increased scale of CO_2 and SO_2 emissions and, in particular, China's emissions are enormous. Yet, SO_2 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_2 emissions are not realistic any more in the region. [33] As for CO_2, 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_2 emissions would continue to increase. Whether or not economic development in East Asian countries, in particular China, causes a further rise in CO_2 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_2 and CO_2 emissions, as the EKC hypothesis argues. The income level at the turning points suggests that the CO_2 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 compared 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

[32] See Zhang (2000) for attitudes toward Kyoto Protocol.
[33] Streets *et al.* (2000), p.4422.

not be so much away from the actualities.

Figure 1 the EKC and Advantage of Latecomer

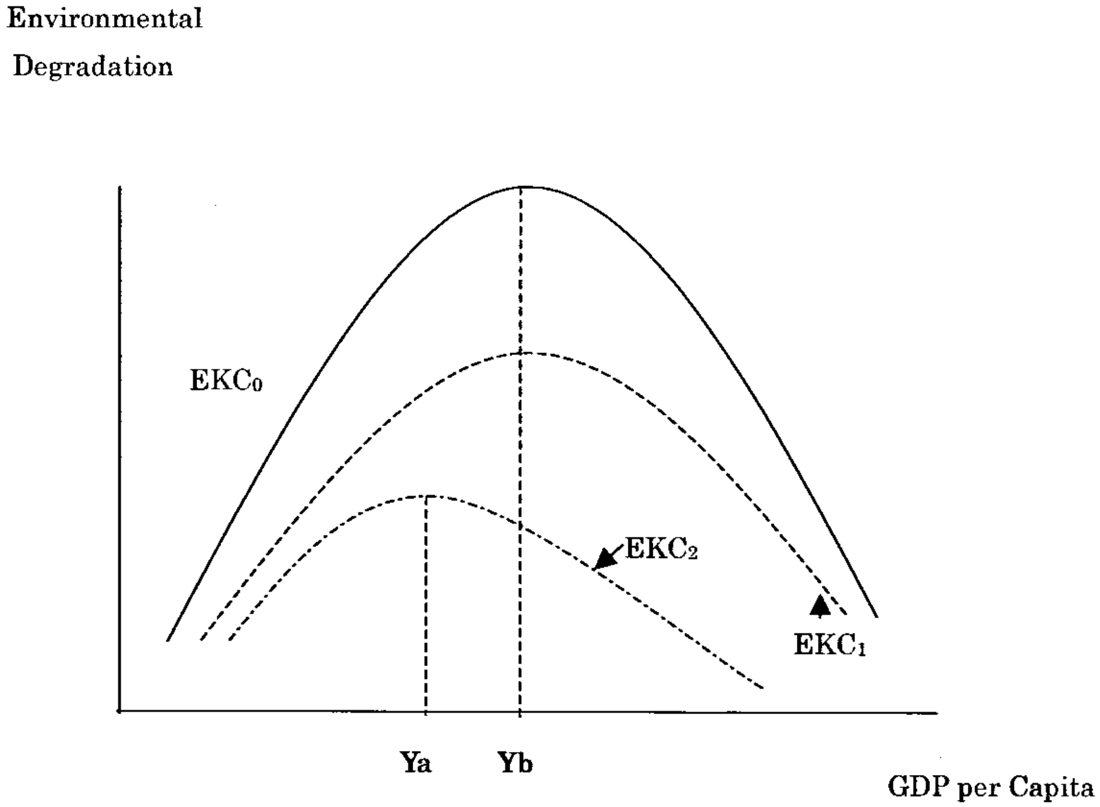
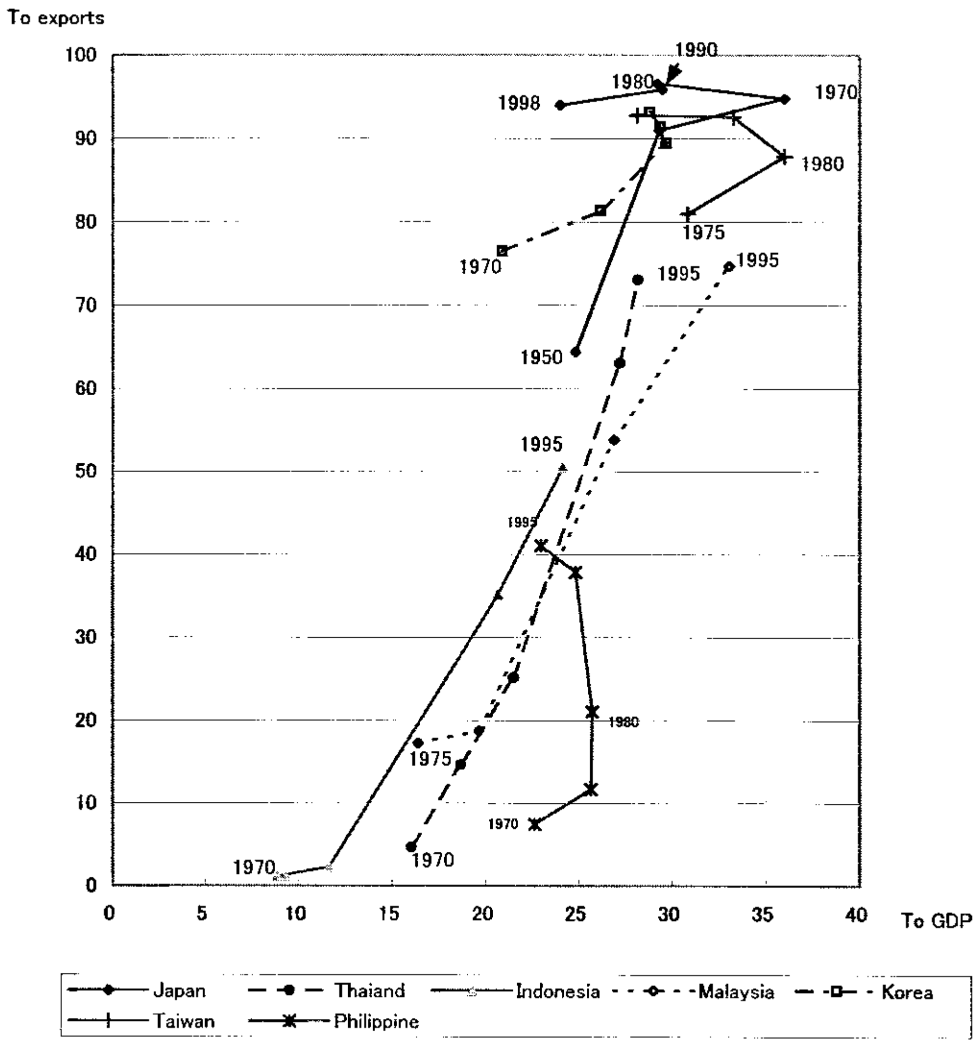


Figure 2 Industrial Structure in East Asia (manufacturing share, %)



Source: Industrial structure : ADB, *Key Indicators of Developing Asian and Pacific Countries*, various issues. Export structure : UNCTAD, *Handbook of International Trade and Development Statistics.*

Figure 3　SO_2 Emissions in East Asia (total)

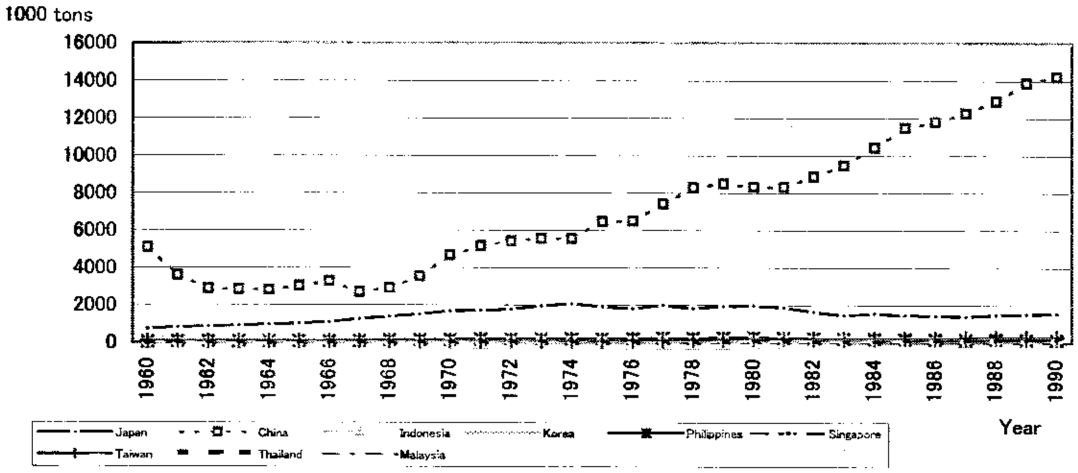
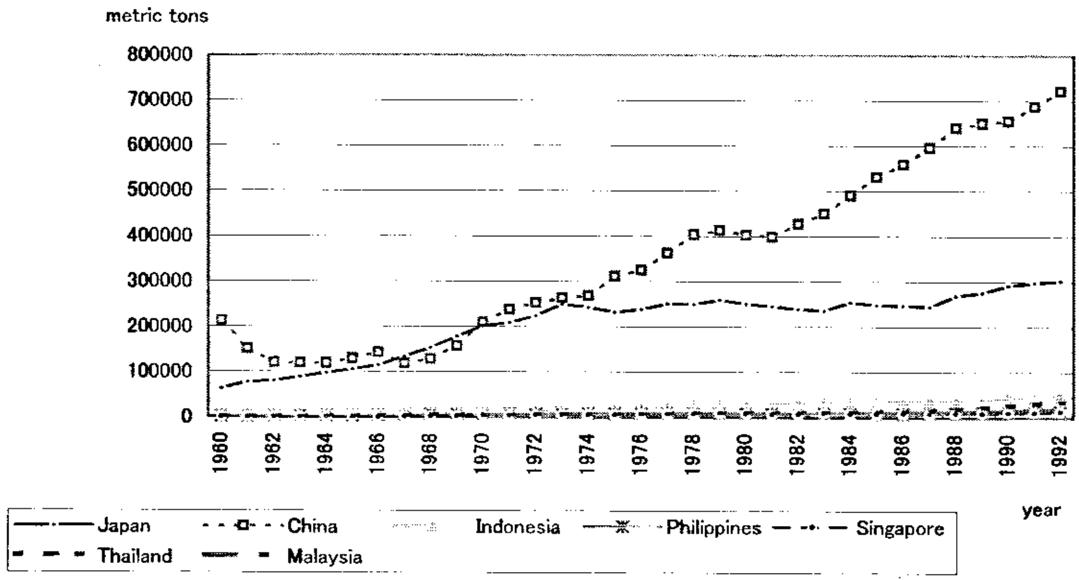


Figure 4　CO_2 Emissions in East Asia (total)



Source : SO_2 emissions are from ASL and Associates, *Global Sulfur Emissions Database*, http://www.asl-associates. com/sulfur.htm. CO_2 emissions from G. Marland *et.al.*, "Global, Regional and National Fossil Fuel CO_2 Emissions," http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm.

Figure 5 SO_2 Emissions in East Asia (per capita)

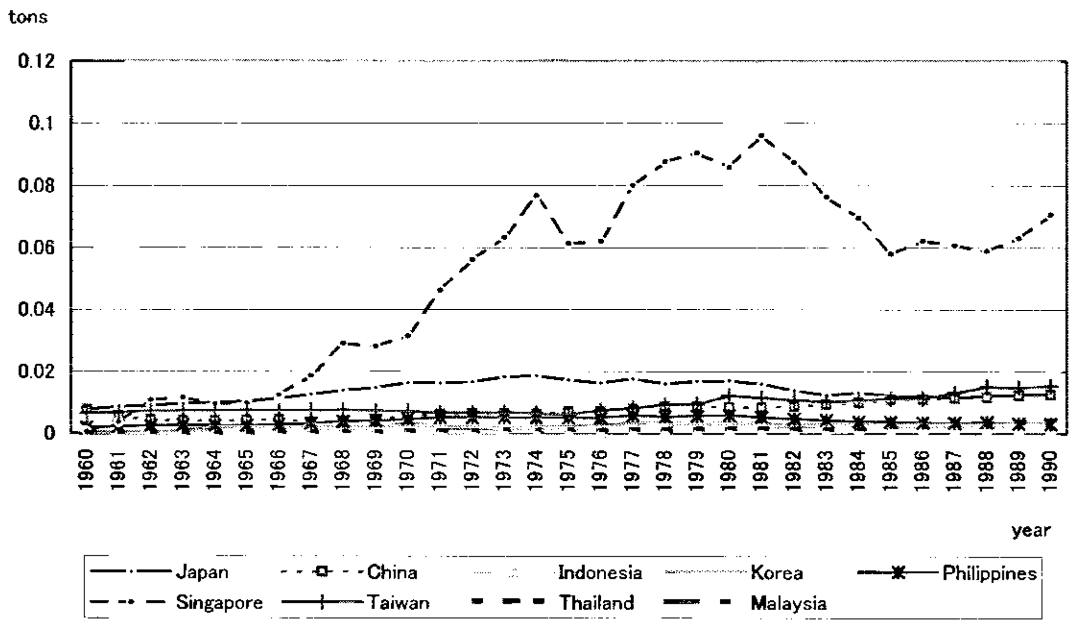


Figure 6 CO_2 Emissions in East Asia (per capita)

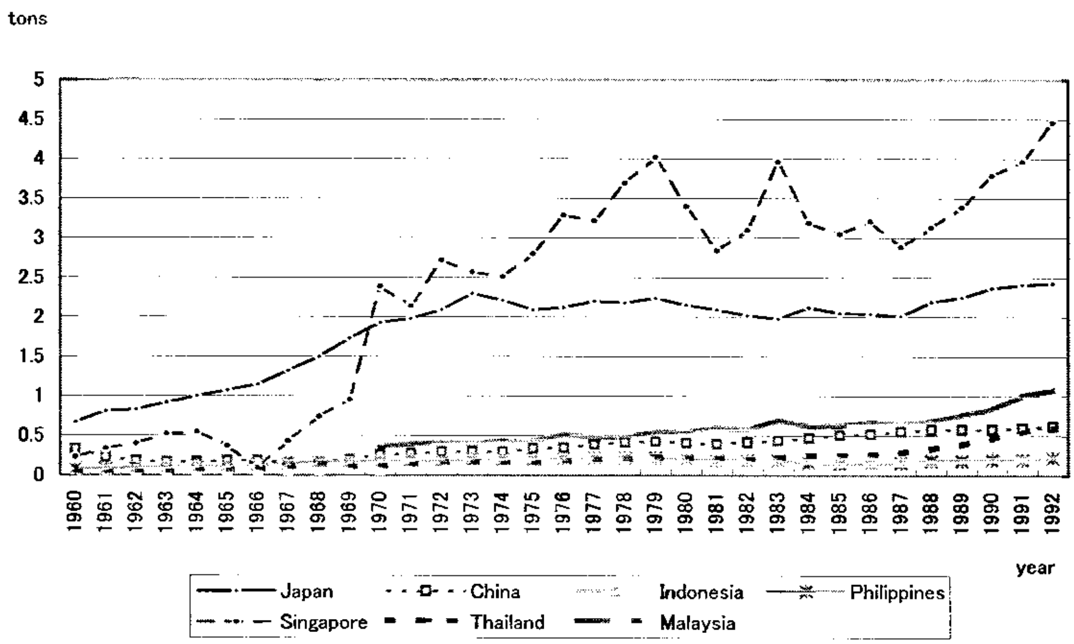
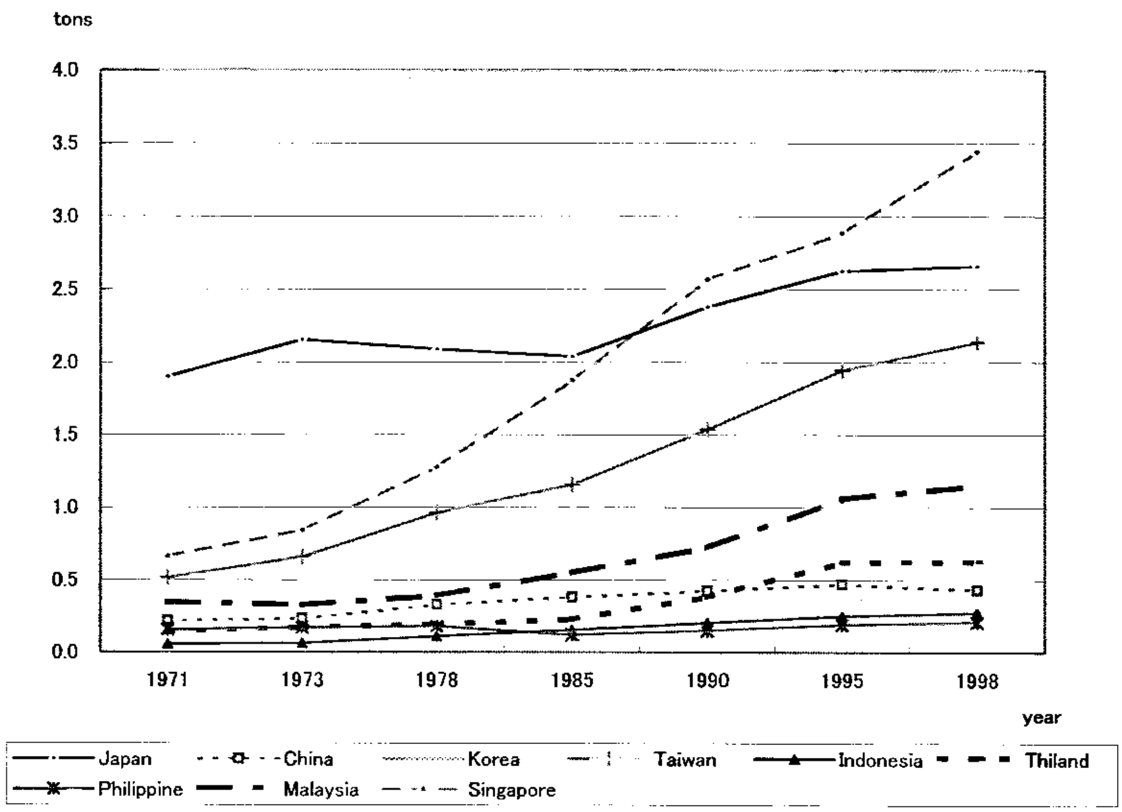


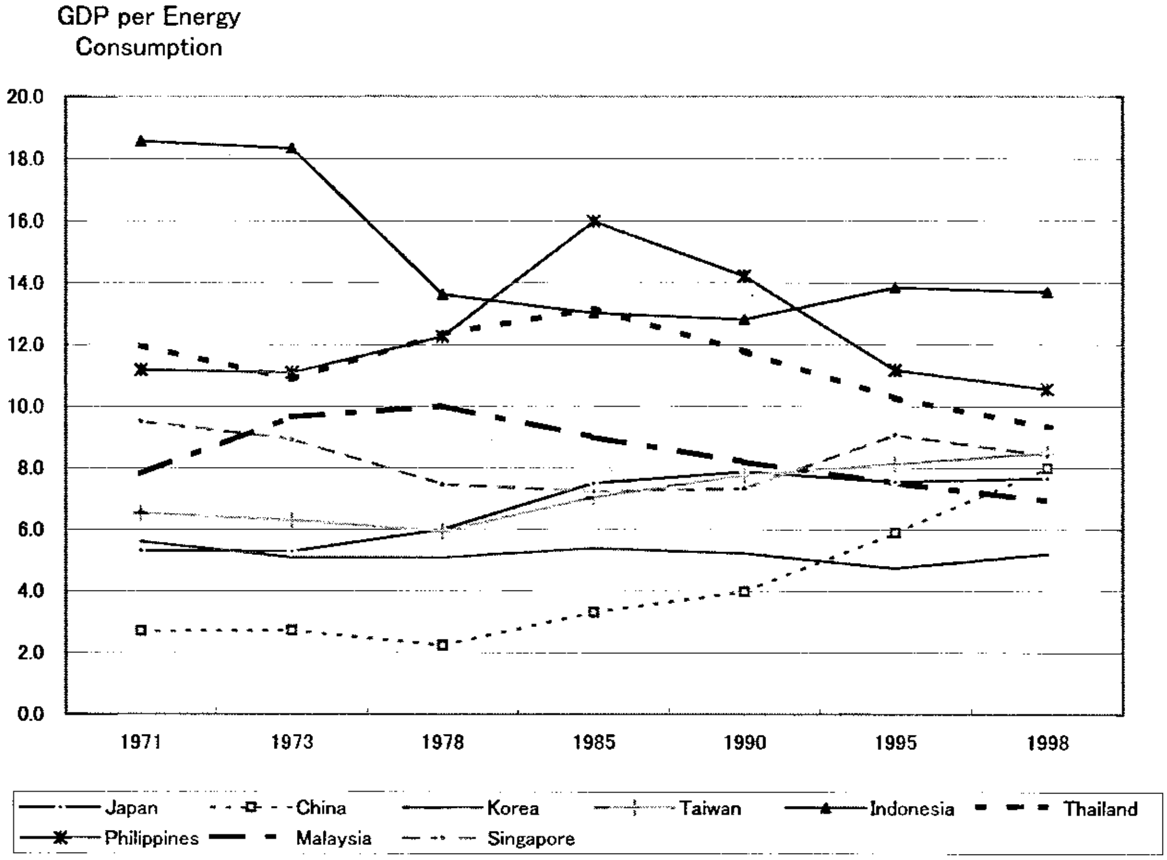
Figure 7 Per capita Energy Consumption (oil equivalent)



Source : IEA・OECD, *Energy Balances of OECD Countries 1998-1999, Energy Balances of Non-OECD Countries 1998-1999*

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

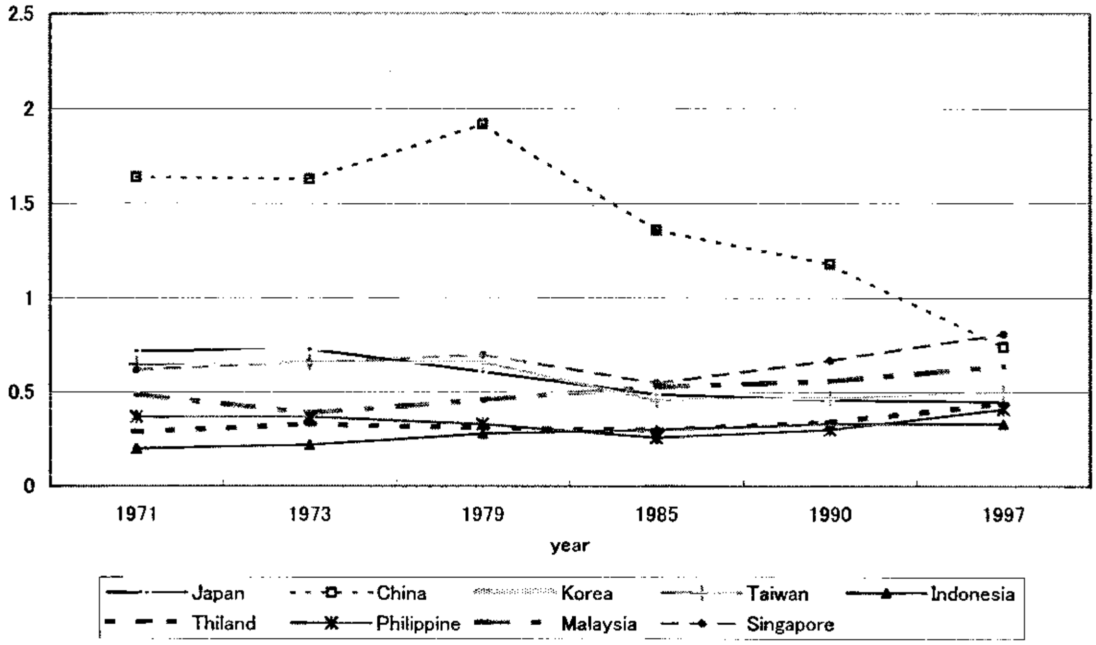
Figure 8 Energy Efficiency



Source : the same as Figure 7.

Note: Energy consumption is TFC, and GDP is in terms of US dollar1990 (ppp). China does not include Hong Kong.

Figure 9 CO_2 Emission Intensity



Source : the same as Figure 7.

Note: China does not include Hong Kong.

Table 1. Factors Affecting CO_2 Emissions (yearly average change, %)

	GDP		Energy intensity		Emission coefficient		CO2 emissions	
Period	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_2 Emissions from Fuel Combustion 1971-1997*, Paris 1999.

Table 2. SO_2 and CO_2 Emissions in East Asia (pooled time-series data from the early 1970s to 1990)

Dependent variables:	SO_2		CO_2	
	(a)	(b)	(c)	(d)
Constant	-33.98		-30.57	
	(-4.33)***		(-10.56)***	
Y	6.17	5.66	6.70	4.47
	(3.08)***	(8.49)***	(9.09)***	(11.58)***
Y_2	-0.30	-0.31	-0.32	-0.22
	(-2.46)**	(-7.67)***	(-7.14)***	(-9.76)***
EF	-1.60	-0.29	-1.88	-0.47
	(-5.17)***	(-1.96)*	(-15.18)***	(-5.15)***
IS	3.53	1.15	-1.50	0.13
	(3.49)***	(2.11)*	(-3.30)***	(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

Data sources: SO_2 emissions: ASL and Associates, *Global Sulfur Emissions Database*, http://www.asl-associates. com /sulfur.htm.

CO_2 emissions : G. Marland *et.al.*, "Global, Regional and National Fossil Fuel CO_2 Emissions," 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 (ed.), *Abstract of Economic Statistics,* various issues.

Energy efficiency : IEA・OECD, *Energy Balances of OECD Countries, Energy Statistics and Balances of Non-OECD Countries 1995/1996.*

Note: 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.

Table 3. SO_2, CO_2 Emissions in East Asia

Dependent variables.	SO_2 (a)	CO_2 (b)
Constant	-30.37	-20.69
	(-11.54) ***	(-13.67) ***
Y	5.66	4.47
	(8.49) ***	(11.58) ***
Y^2	-0.31	-0.22
	(-7.67) ***	(-9.76) **
EF	-0.29	-0.47
	(-1.96) *	(-5.15) ***
IS	1.15	0.13
	(2.11)*	(0.37)
KR	-0.05	-0.28
	(-0.62)	(-5.59) ***
MYS	-1.24	-0.66
	(-13.52) ***	(-12.35) ***
THA	-1.24	-1.11
	(-13.52)***	(-16.98) ***
PHL	-0.97	-1.06
	(-0.81)	(-13.88) ***
TW	-0.23	
	(-2.53)***	
IDN	-1.56	-0.97
	(-12.81)***	(-13.43) ***
SG	1.66	0.52
	(26.56)***	(14.52) ***
CHN	0.77	-0.16
	(4.87)***	(-1.65)
sample number	168	149
$\overline{R}^2$	0.98	0.99
income (US dollar) at turning points	9,219	20,869

Source: the same as Table 2. Note: t statistics in parentheses. *Significant at 5% level, ** at 2% level, ***at 1% level, respectively.

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