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The "Advantage of Latecomer" in Abating Air-Pollution: The East Asian Experience

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Abstract

Between the early 1970s and the mid-1980s, air pollution in Japan, in particular that caused by sulfur dioxide (SO_2), was reduced to a remarkable degree. This reduction resulted from responses to mounting civil protest: governmental regulation policy on the one hand, and innovation of abatement technology and energy efficiency on the other. In large East Asian cities, despite rapid economic growth, air pollution is less severe than it was in Japan in the early 1970s. This is because both government and industry in East Asia took early initiatives to prevent environmental degradation, learning from the experiences of developed countries.

Key words: Industrialization; Air Pollution; Environmental Kuznets Curve; East Asia; Advantage of latecomer.

0. Introduction

During its period of high-speed economic growth, Japan suffered from "distortion of economic growth," as witnessed by various kinds of industrial pollution. This problem, however, was, for the most part, successfully remedied by means of abatement measures from the early 1970s onwards. Many East Asian countries have subsequently recorded "miraculous" economic success by adopting development policy similar to that employed in Japan, policy that has come to be associated with a heavy impact on the natural environment, as in Japan.

> "No other region has as many heavily polluted cities, and its rivers and lakes are among the world's most polluted. In short, Asia's environment has been under attack. While rapid economic development has created dynamism and wealth, Asia has, at the same time, become dirtier, less ecologically diverse, and more environmentally vulnerable."[2] "Asia" characterized by "rapid economic development " in this context undoubtedly implies "East Asia."

Researching the environmental situations of the region, however, O'Connor (1999) concluded that countries that have industrialized later have been apt to succeed in environmental preservation, thanks to learning from the experiences of, and receiving technology from, developed countries.[3] Whether or not such an "advantage of the latecomer" actually exists is the starting point of this paper. If East Asian countries have actually enjoyed healthier natural environments than Japan during their respective high growth periods, what factors have contributed to this difference, and how have these countries learned from the experiences of Japan and other developed countries?

Gerschenkron (1962, chapter 1) pointed out the importance of "borrowed technology" as an "advantage of backwardness," while stressing that banks, governments and even prevailing ideologies in later-industrialized countries play different roles from those in advanced countries. As regards the latter point, we can raise the question of whom, and with what motivation, takes the

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[2] ADB (1997), p.199. See also Iwami (2001).

[3] Grossman (1995) expresses a similar opinion.

initiative to introduce new technology to developing countries. In the case of environmental protection, such technology transfer is not a natural development, since new measures usually require additional costs, and sometimes conflict with economic development policy. An investigation into the conditions under which environmental protection is actually feasible, therefore, will help us to understand the scope of development policy in developing countries.

This paper focuses on air pollution, as discussions of the Environmental Kuznets Curve (EKC) often characterize it as one of the environmental problems that tends to improve at higher income levels. In other words, analysis of the case of air pollution may provide us with clues as to how to solve the conflicts between economic development and environmental preservation.

1. The EKC and Air Pollution

The hypothesis of the EKC states that the quality of the environment initially deteriorates with rising income, but later, after 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.[4]

It is questionable, indeed, whether the EKC actually applies to any aspect of environmental quality, but the World Bank (1992) has delineated an inverted U-shaped curve for air pollution in the form of SPM (suspended particulate matter) and sulfur dioxide (SO_2). Thereafter, Shafik (1994), Selden and Song (1994), Grossman and Krueger (1995), and Panayotou (1995) have all presented econometrically similar results with respect to air pollutants.

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 issues other than immediate material survival and induce their governments to introduce stricter environmental regulation. Likewise, the investments necessary for environmental protection are only feasible with the financial resources made available by a certain level of income.

In order to examine the EKC empirically, however, we must be aware of several points. Firstly, much research is based upon cross-sectional analysis due to the limited availability of time-series data. While such limits are unavoidable, we should also be aware that factors other than income level

[4] Stern, Common and Barbier (1996) and Ekin (1997) give good surveys on this topic. For further discussion, see the special issues of *Environment and Development Economics*, 2, 1997 and *Ecological Economics*, 25-2, 1998.

have varying effects in different countries.[5] Nevertheless, large quantities of pooled cross-sectional time-series data yield more accurate results than time-series data alone, as Shafik (1994) and Grossman and Krueger (1995) have shown.

Secondly, we should note the fact that data often vary considerably according to time and place of measurement. The atmospheric concentration of SO_2 in Jakarta as of 1996, for example, presents the lowest monthly average of 0.002ppm in January, and the highest average of 0.008ppm, four times as much as the lowest figure, in August and September. Concentrations of oxidized nitrogen (NOx) for the same year show the lowest figure of 0.005ppm in January, and the highest figure of 0.093ppm, approximately 19 times as much as the lowest figure, in July.[6]

In addition, different locations, whether big cities, rural areas or industrial zones, record significant differences in air pollution levels even within the same country. It is questionable, then, whether we can meaningfully compare a country's environmental situation with its GDP per capita as calculated on a national basis. In a country with as vast an area as China, for example, it would be preferable to use regional income figures, where possible.

The third point is the question of whether using data for emissions amounts or for atmospheric concentration is more reliable in investigating SO_2 and carbon dioxide (CO_2) levels. Atmospheric concentration levels are directly observed, while emissions data are indirectly estimated from energy consumption and the sulfur content of each energy source.[7] Panayotou (1995), for example, employs consumption data for petrol, coal and natural gas to calculate emissions in developing countries and, consequently, his figures reflect neither energy efficiency nor improvements in end-of-pipe technology. However, employing concentration data raises another question of whether the observation spot is actually representative.

Fourthly, even if emissions amounts for air pollutants might seem to be directly linked to income levels, they may be influenced by factors other than income. For example, while concentration of economic activity and population seem to increase air-pollution, they also tend to promote measures of pollution abatement. Atmospheric pollution is usually observed in large cities with large populations and the quality of urban air is usually a greater concern to policy-makers than that in rural areas even if the situation in the latter is more serious. The differences between developed countries, moreover—between North America on the one hand, and Japan and Europe on the other—are attributed to differing degrees of geographical population concentration.[8]

However, whether spatial concentration increases or decreases air pollution is a matter for

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[5] Selden and Song (1994), however, distinguish fixed-effects and random-effects. There do exist case studies on Asian countries; see, for example, Vincent (1997) for Malaysia, and Wu (1998) for Taiwan.
[6] Badan Pusat Statistik, *Environmental Statistics of Indonesia*, 1998.
[7] Kaufmann *et al*. (1998), p. 210.
[8] Kaufmann *et al*. (1998), pp. 218-9. Selden and Song (1994) also conclude that higher population density is accompanied by smaller emissions.

empirical examination. As a matter of fact, preventive measures are taken in response to such factors as political initiatives by citizens, and when financial capabilities so permit. While it is true that both of these factors are, to a certain extent, related to income level, the former political factor is difficult to measure quantitatively. At any rate, empirical research including factors other than income may lead to ambiguous results.

2. Is there Evidence for the Existence of an "Advantage of latecomer?"

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 developed countries.

East Asian countries have followed the industrialization pattern of developed countries, 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 can have a double-edged effect on air pollution. 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 pollution 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 pollution 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.

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.

OLS Analysis of SO_2 Emission

Now, we rely on OLSA (ordinary least-square analysis) with pooled cross-sectional time-series data for SO_2 emission from 9 East Asian countries: Japan, Taiwan, China, Korea, the Philippines, Singapore, Indonesia, Malaysia and Thailand, with a structural equation of (1).

$$EM = a+bY+cY^{2+}dEF+eIS+fD1+gD2+u \quad \text{--------------- (1)}$$

Where *EM* represents SO_2 emissions per capita (tons) as a dependent variable. SO_2 emissions are determined by energy consumption and the efficiency thereof, as well as by energy source and end-of-pipe abatement technology. Since emissions data are constructed from energy consumption, however, it makes no sense to regress emissions on energy consumption. In addition to the income, we include as explanatory variables energy efficiency *EF* (GDP per unit of energy consumption, US dollars, 1990 PPP per kg. oil equivalent); *IS* (the manufacturing share in GDP, except for China, where *IS* represents the share of the secondary industrial sector, including not only manufacturing, but also mining, construction, electricity, gas and water); and *u* is error term. Apart from *IS*, variables are expressed in logarithm. While energy price may indeed affect energy consumption and, accordingly, SO_2 emissions, energy price is not included in the equation, since most of the data belongs to the period after the first oil crisis of 1973.

Moreover, we add dummy variables for latecomers. The latecomer is defined by an index of *IS* in 1990 divided by *IS* in 1973. A large index here indicates rapid industrialization between 1973 and 1990, hence denoting latecomer status. D_1 stands for those countries with an index larger than 1, but smaller than 1.5: the medium latecomers, namely, Korea, the Philippines, and Singapore. D_2 stands for an index larger than 1.5: the latest comers, so to say, namely, Indonesia, Malaysia, and Thailand. Countries with an index smaller than 1, namely, Japan, Taiwan and China, have experienced a decline in manufacturing share. We call them the predecessors that are represented by the constant of the equations.

Yet, it may sound odd to characterize China as a predecessor rather than a latecomer. The industrial share of China's GDP was, in fact, as high as 43% in 1973, while it declined to 37% in 1990. It must be noted, however, that the large share of second industry in the 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 associated with low technology and poor efficiency.[9] Consequently, we also carried out an OLSA that excluded China.

Equation (a) in Table 1 represents the estimated results of the OLSA without dummies. Equations (b) and (c) represent those including dummies: the former is composed of all 9 countries, while the latter excludes China. As it happens, equation (c) does not reveal any significant differences from equation (b).

EF should be negatively correlated to emissions; in other words, higher energy efficiency reduces emissions. Equations (a) (c) show that energy efficiency is accompanied by minus signs as expected, with sufficient statistical significance. In addition, the estimated coefficients of both linear and quadratic *Y*s show the signs expected from the inverted U-shaped curve, with statistically significant t-statistics. As for *IS,* equation (a) shows plus signs with significant t-statistics as expected: higher industrialization increases emissions. But equations (b) and (c) do not show enough statistical significance to *IS*, suggesting that the share of manufacturing is better interpreted in terms of the speed of industrialization, reflected in dummy variables.

The signs of estimated coefficients for D_1 and D_2 are the most relevant to our discussion. D_1, representing medium latecomers, shows a plus sign, suggesting a tendency towards greater emissions than the predecessors. On the other hand, however, D_2, the latest comers, shows a minus sign; in other words, a tendency towards reduced emissions. The advantage of latecomer , then, is evident in the latter case.

Comparing Atmospheric Concentrations

Here, we use atmospheric concentration data to examine to what extent the latecomer actually performs better in the case of air pollution. “Latecomer” in this context has a double connotation: the first expresses the relationship between East Asian countries and Japan, while the second refers to that between Japan and Western countries. Japan was a latecomer in the early 1970s when it made such remarkable progress with pollution abatement. In this paper, however, we discuss mainly the first connotation.

Figures 2~4 show the relationship between air pollution, SO_2, TSP (total suspended particulates), and NO_2 (nitrogen dioxide) on the vertical axes, and income level on the horizontal axes. TSP represents different types of matter, depending on the environmental standards of each country. Japan, Malaysia and Singapore, for example, use SPM (more strictly speaking, PM10), whereas Thailand uses both TSP and PM10. Income level is expressed in terms of US dollars, 1995 PPP.

The observation spots are all in large cities, mostly capital cities. The situation of air-pollution can be largely different among cities, depending on the geographical location and the distance from the industrial area, for example. True that some Chinese cities are said to show high concentration of atmospheric pollutants. Apart from individual information on specific areas, however, data comparable across countries are difficult to collect. Given the difference even within a country, using income at a national level rather than at a local level, as in Figures 2-4, might be misleading. Yet, local income data are not similarly available across countries. Despite these limits, following observations are worth noting.

Japan

The line plotted in each figure shows air pollution in Japan. SO_2 in Japan decreased remarkably from 126μg/m^3 in 1970 to 30μg/m^3 in 1988, when average incomes stood at 11,395 US dollars and 20,092 US dollars, respectively. Thereafter, SO_2 concentration remained almost at the same level, despite rising income. NO_2 increased from 60μg/m^3 to 100μg/m^3 in the 1970s and then decreased to

[9] Sinton *et al.* (1998), p.814.

75μg/m^3 in the early 1980s, forming a wave, but stayed almost unchanged thereafter, albeit at a higher level.[10] TSP, which was not observed in the early 1970s, decreased between 1974 and 1980, followed by a slight increase. Generally speaking, however, it did not show significant change.

Among the air pollutants, the improvements followed different patterns, with that of SO_2 on the one hand contrasting with that of NO_2 and TSP on the other. We discuss in the next section what happened in the 1970s when SO_2 pollution was remarkably reduced.

East Asian Countries

Comparing the East Asian countries (■in Figures 2-4) with Japan, it turns out that equal levels of SO_2 concentration are attained with lower income levels in the Philippines, Thailand, Malaysia, Indonesia, China, Korea and Singapore. This trend can also be observed in the case of NO_2 concentration in China, Thailand, Indonesia and Singapore. As for TSP, however, it is clear that the environmental conditions of Indonesia, China, Thailand and Philippines are far worse; they have two or three times the amount of TSP, when compared with Japan as of 1974.

The high level of TSP on the one hand, and the low level of NO_2 on the other, can be attributed to the quality of automobile engines. Automobiles used in East Asian countries are relatively of old vintage, and their engines, not well maintained, tend to cause incomplete combustion, thereby discharging greater amounts of TSP but less NOx. Automobile engines of high quality enable complete combustion, and more NOx, but fewer TSP, are emitted into the air.[11] However, converting to such engines would incur too great a cost on car drivers in these countries.

Indeed, the source of TSP is not always automobiles alone. In Bangkok, under the real estate boom before the currency crisis broke out, construction sites may have been another major generation source. In large cities away from industrial areas, however, automobile engines are considered to be the main cause. In Malaysia, large cities and rural areas have different sources of TSP. Diesel engines account for one third of TSP in large cities, while in rural areas, biomass (trees) burning accounts for one third.[12] The share of transportation as the source of TSP is 35% in Jakarta, and 45% in Manila as of the early 1990s.[13]

Developed Countries

[10] According to "The State of Air Pollution in 1990" (in Japanese), the Air Quality Protection Bureau, Environmental Agency of Japan, NO_2 concentration declined remarkably from 0.044ppm in 1971 to 0.019ppm in 1977, and thereafter it stabilized. This is similar to the trend of SO_2 reduction shown in Figure 2. However, to note is the fact that this NO_2 data is an average compiled from many observation stations, the number of which rapidly increased from 36 in 1971 to 891 in 1977. Figure 3, on the other hand, uses data from a fixed point observation.

[11] Interview at the Japan Bank for International Cooperation, November 10, 2000.

[12] *Malaysian Environmental Quality Report 1993*, p.9.

[13] World Bank (1997a and 1997b).

Compared with Japan's air pollution, Western countries in general, including Australia and New Zealand (Δ in Figures 2-4), show a better situation. This fact implies that there is no clear evidence of the advantage of latecomer between Japan and Western countries. As was discussed above, good urban air quality in European countries is sometimes attributed to population density; however, we also see that the United States and Australia show the similar levels of SO_2 concentration to other Western countries. Nevertheless, this is quite natural because both the US and Australian data are observed in big cities, which have almost the same population densities as those in other developed countries.

De Bruyn (1997) stated that it was not the changing industrial structure in Germany and the Netherlands that led to reduced SO_2 emissions, but, rather, policy factors supported by international agreements made the greatest contribution. In East Asia, the increased industrialization is accompanied by a decline in SO_2 concentrations, although similar international agreements do not exist among the countries. The question still remains, then, of why SO_2 levels remain relatively low.

The analysis has not yet explained which factors are actually at work in reducing emissions. They include, for example, a shift of fuels from coal to petroleum, natural gas, and even to uranium, as well as the innovation of end-of-pipe abatement technology. We will discuss these factors in more detail in Section 3 below.

3. Japan's Experience

Political Initiative

Let us review several backgrounds to the rapid decrease of air pollutants, especially SO_2, in Japan beginning in the early 1970s.

Firstly, to note is the fact that civil movements had a significant impact on government policy from the latter half of the 1960s. For abating air pollution, in particular, a symbolic case was the "Yokkaichi Pollution Lawsuit" sued in 1967, which appealed against damage to health (chronic bronchitis, asthma, and pulmonary disease) caused by exhaust gases from oil refineries and electric power plants. Against this background, the Basic Law for Environmental Pollution Control, and the Air Pollution Control Law were legislated in 1967 and 1968, respectively, and followed by the establishment of the Environment Agency in 1971.

In responding to the civil movements, local governments took the initiative, while the national government followed suit somewhat reluctantly. The Pollution Control Agreement of 1964 between Yokohama City and the Electric Power Development Co., Ltd. was the first example, and the second was the agreement between the Tokyo Metropolitan Government and Tokyo Electric Power Co. in 1968.[14] It should be remembered, however, that the voices raised by residents forced local

[14] Terao (1994), and Tokyo Electric Power Co. (1983). For abatement policies, see also Teranishi (1994), and Akiyama and Ueda (1994).

governments to implement such measures, and that the firms, on their part, accepted them, with a desire not to injure the relationship with the residents.

Generally speaking, the pollutions that attracted public attention in the high-growth period was concentrated in specific areas. In the case of the heavy and chemical industrial zones located along the Pacific coastline such as Tokyo and Yokohama, the high political consciousness of the residents was one of the driving forces for anti-pollution policies. In cities like Kita-kyushu, called a "company-castle town," it was not easy for residents to raise their voices against a big company providing a great many local employment opportunities. In such situations, however, there might be room for local government to play a mediating role.

Regulation and Policies

Under the Soot and Smoke Regulatory Law of 1962 and the Air Pollution Control Law of 1968, the Japanese government gradually strengthened control of oxidized sulfur (SOx), and environmental standards were upgraded almost every year from the first regulation in 1968 to the eighth in 1976. Photochemical smog in a residential area of Tokyo (Suginami) turned public attention to NOx as a serious air pollutant for the first time, leading to enactment of ambient and emissions standards in 1973, somewhat later than in the case of SO_2.

Total emissions control for SOx was introduced to Tokyo, Osaka and Yokohama in 1974, and applied similarly for NOx to the same three cities in 1981. This system of assigning a fixed amount of discharge to each factory was introduced because the prior regulation was flawed, in the sense that it defined only the maximum concentration of discharges, and that larger total amounts of SOx and NOx could be discharged if diluted with water and air.

With regard to exhaust control for automobiles, the US Air-pollution Control Act of 1970, called the Muskie Act, constituted a milestone. This legislation stimulated competition between Japanese and US automobile companies to develop technologies achieving its standard within five years. In Japan, the first automobile exhaust controls were determined in 1966, and the Vehicle Exhaust Standard was notified in 1973, setting strict standards for that time in line with the Muskie Act.[15] NOx standards became yet stricter between 1975 and 1978. Earlier than any other country, Japan actively engaged in regulating lead-containing gasoline, and regular gasoline was unleaded in 1975.

Teranishi (1994) states that the years after the first oil crisis are characterized by the retreat of anti-pollution policy. Certainly, the NOx standard was toned down in 1978 in order to give depressed industries some breathing space.[16] This was certainly a factor in the increased atmospheric concentration of NO_2 in the latter half of 1970s as indicated in Figure 3. Nevertheless,

[15] Hama-uzu (2000).
[16] The environmental standard for NO_2 in 1973 stated "0.02ppm per hour of daily average," but in 1978 it was modified to "between 0.04 and 0.06ppm or less", Akiyama and Ueda (1994).

efforts to save energy were promoted in response to the energy prices hike. As a result, SO_2 pollution was reduced even during the period of "retreat." This is an interesting example of the way that the environmental situation can be improved by the efforts of governments and the private sector despite supposedly unfavorable economic conditions.

Administrative guidance, then, played a major role in pollution abatement, as it has with other industrial policies. The direct regulations worked very effectively in delimiting maximum emissions. They were flawed, however, insofar as they provided no incentives to decrease emissions beyond the imposed limit. Further reductions could only be achieved by continuously lowering the maximum limit.

Indirect, market-friendly policies were also employed in part. Tax-cuts were applied to those firms that implemented the abatement measures. The governmental financial institution (the Development Bank of Japan) also provided special loans to oil refineries and electric power plants to construct desulfurizing equipment and natural gas (LNG) storages respectively. The fact that these policies were actively implemented during the first half of 1970s suggests that they were important elements in decreasing SO_2 pollution.[17]

Technical Aspects

Measures to reduce SOx emissions include 1) switching to fuel with low sulfur content, 2) desulfurization of crude oil, and 3) end-of-pipe desulfurization. Until the early 1970s, "low sulfurization" was the predominant approach. In particular, switching to fuel with low sulfur content was the preferred measure due to its low cost. End-of-pipe desulfurization, moreover, was not technically feasible in the 1960s. In addition, power plants built higher chimneys, thereby dispersing polluted smoke and reducing SOx concentrations.

In the high-growth period, the major consumers of energy were the electricity, steel and petrochemical industries. In response to pollution regulation, the electricity and steel industries employed "direct burning of crude oil" and "naphtha burning," thereby reducing emissions of oxidized sulfur, as crude oil and naphtha contain less sulfur than heavy oil. However, directly burning crude oil without first refining it produced the side effect of depriving the petrochemical industry of opportunities to acquire raw materials. Consequently, oil refinery firms tried to develop techniques for direct desulfurization of crude oil. [18]

However, the situation changed dramatically after the oil crisis. Securing crude oil became an urgent priority and the "low-sulfurization" policy of shifting to oil with less sulfur content became less important. As a result, during the period from the mid-1970s to the mid-1980s, SOx reduction was realized firstly by energy saving policy, secondly by the improvement of desulfurization

[17] For more details, see Terao (1994).
[18] Terao (1994).

technology, and only thirdly by fuel conversion.[19]

Power plant desulfurization technology was actively developed in Japan and is of the highest international standard.[20] The unique process of two-step combustion accompanied by denitrification is seldom seen in other countries. Consumption of LNG (natural gas) rapidly increased after the first oil crisis. LNG has been used in large cities with high population density and, thus, high probability of damage by air pollution.

The fact that NOx abatement measures came after those for SOx, corresponds with the order of recognition on the part of the public and the administrative authorities. "Conversion of fuel" makes no sense in the case of NOx, which is generated by the oxidization of nitrogen in the air. NOx emissions were reduced by means of the technologies of two-step combustion and flue-gas denitrification. Measures to control exhaust gases were developed in accordance with strict environmental standards, decreasing NOx from automobiles.

4. East Asian Countries

Policy Response

In Southeast Asia, authorities in charge of environmental administration were established in the 1970s, almost simultaneously with Japan. An exceptionally early example is the Philippine National Water and Air Control Commission established in 1964, followed by the Indonesian National Environmental Committee (later reorganized as the Ministry of Development and Environment), and the Singaporean Ministry of Environment, which were both established in 1972, the Malaysian Ministry of Science, Technology, and Environment in 1974, and the Thai National Environmental Committee in 1975. Air-monitoring systems were introduced relatively early in the Philippines and Singapore, in 1970 and 1971 respectively. In other ASEAN countries like Indonesia, Malaysia and Thailand these systems were introduced somewhat later in the 1970s.[21]

Southeast Asian countries, then, established environmental protection facilities early on, before the period of their respective remarkable economic growth. Except for in the Philippines, however, monitoring systems were, in fact, developed rather later, from the late 1980s to the 1990s, as increased number of air-monitoring equipments and a shift from manual to automatic measurement during that period suggest.

Southeast Asian authorities introduced American standards (Singapore and Malaysia) for air pollution, and the Japanese (Singapore) and European (Thailand, Malaysia) standards for vehicle exhaust, respectively, implying that they followed the examples of the developed countries.

Did, as in Japan, civil movements cause these administrative actions? The Japanese case suggests

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[19] Environmental Agency of Japan, *Environmental White Paper for the Year 1990*, p.128. .

[20] Interview at the Tokyo Electric Power Co., November 17, 2000.

[21] Matsuoka *et al.* (2000).

that public authorities and local government in particular should play active roles. The question is whether or not the civil "voice" both reaches and is received by government.

Funatsu (2000) found that civil movements and NGOs (non-governmental organizations) in Thailand focus mainly on water pollution and large scale projects like dams, but rarely on air pollution. However, according to an NGO named with respect to air pollution, recent improvement of air pollution in Bangkok resulted from policy enacted by the Metropolitan Area Governor, who is also an adviser of the NGO.[22] Yet it is difficult to determine objectively how important civil movements have actually been. Another example is Singapore, where NGOs are scarce in the shadow of a "tough" government, but environmental policies are quite progressive due to the presence of talented technocrats. This case represents another counterexample to Japan.

Energy Efficiency

Energy consumption in East Asia has increased remarkably in line with economic growth. Krugman (1994) once characterized the pattern of economic development in this region as being caused by large inputs of production factors rather than by rising productivity.[23] Does this explanation also hold good in the case of energy?

Table 2 reveals that energy consumption per capita increased in every country during the two decades from 1973 onwards. However, energy efficiency in terms of GDP per unit of energy consumption increased greatly in China from 1978,[24] followed by a lower rise in Japan, Taiwan, and the Philippines (up to the mid-1980s), while it declined in Korea (from the mid-1980s), Malaysia and Indonesia (until 1990). From these figures seen, East Asia has not displayed an across-the-board pattern of immense energy consumption, but is, rather, composed of contrasting groups.

In 1995, energy efficiency in East Asian countries, except for Korea, is higher than Japan as of 1973. Even when compared with Japan in 1995, Taiwan, Indonesia, Thailand, the Philippines and Singapore perform better. That these East Asian countries show higher energy efficiency than Japan as of the mid-1970s corresponds to the low level of SO_2 concentrations they show in Figure 2.

Desulfurization

The greatest barrier to introducing desulfurization equipment is its high cost. However, Thailand was the second Asian country after Japan to install desulfurization equipment in electricity power generation, due to Japan's financial support through ODA.[25] On the other hand, despite its lower

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[22] Interview at the Anti-Air Pollution and Environmental Protection Foundation, Bangkok, March 8, 2001.
[23] Krugman (1994).
[24] For more details of energy efficiency in China, see Sinton *et al.* (1998), and Sinton and Fridley (2000)
[25] Imura and Katsumura (1995), p.259.

cost, denitrification has not been widely introduced, mainly because of the low concern about NOx in developing countries.

A shift to fuels with low sulfur content is less expensive and, accordingly, more easily undertaken. According to the energy sources of electricity generation shown in Table 4, atomic energy greatly increased in Japan, Korea and Taiwan between the 1970s and 1990s, whereas in Southeast Asian countries except for the Philippines, natural gas increased its share as an energy source. There is no doubt that increasing shares of atomic energy and natural gas contribute to reduced SO_2 emissions, while the increasing share of coal in every country results in a counter-balance.

In Malaysia, exploitation of natural gas from the 1970s through the 1980s was a major factor in power stations switching energy source from imported oil to natural gas in the mid-1980s, causing a significant decline in SO_2 emissions.[26] China, while producing large amounts of coal, seems to have decreased its total energy consumption, in particular that of coal, since 1997.[27] This change in China, the largest energy consumer in East Asia, has surely had a great impact. As a whole, we can conclude that these shifts in energy sources have reduced SO_2 emissions in East Asia.

Mobile Source

Let us remember that the data in Figures 2-4 were collected in big cities, where the main air pollutants come from mobile sources, namely, automobiles. Apart from Indonesia, ASEAN countries adopted European exhaust emissions standards. Table 5 shows that regulations on gasoline cars in Thailand, the Philippines, and Malaysia are stricter than the Japanese standards of 1973. Diesel Cars are also, generally speaking, more strictly regulated (except for CO regulations in the Philippines and Malaysia, which are almost the same as the Japanese standards of 1986). Exhaust regulations in ASEAN 3, then, are not only in place but are stricter than those of high-growth period Japan.

Such regulations, however, may be only superficially strict, as their effectiveness depends largely on the controlling system and technical staff; in other words, on whether vehicle inspection is actually enforced. In Malaysia, the Motor Vehicle Rule of 1995 enforces inspection programs only on commercial vehicles, which represent 11% of the total vehicles in use. In Thailand, inspections are required only at the time of initial delivery from factories.[28]

It is to be noted, however, that exhaust controls do not contain standards for controlling SO_2 emissions; in other words, exhaust controls have contributed little, if anything, towards reducing SO_2 concentrations. In Shanghai, as of 1999, 46% of SO_2 emissions came from electricity power plants,

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[26] Vincent (1997), p.421.
[27] Sinton and Fridley (2000).
[28] Ishak (2001), Global Environmental Forum (1999), p.9.

31% from other industrial sources, and 23% from households. In both Manila and Jakarta, as of 1992, almost two thirds of SO_2 emissions were discharged from industrial sources, and the second greatest source in Manila was power plants.[29]

Technology Transfer

Developed countries can impact developing countries by means of technology transfer on the one hand, and the "export of pollution" on the other. The former represents an "advantage," and the latter a "disadvantage," for the latecomer. Whether or not technology is successfully transferred depends on the accumulation of human capital on the part of the receiving country, a prerequisite for which is that the people there actually recognize the need for it. That new air pollution monitoring equipment began to be widely used in the 1980s implies that such conditions actually existed.

Asian governments, it is said, are apt to prefer the most "advanced" technology in new manufacturing plants due to issues of "national prestige". As a result, environmental protection technology is also of the highest quality. For example, in the case of the Bao Shan Iron Plant near Shanghai, the first phase of construction was completed in 1985, with the technical support of the Nippon Steel Corp. Both the manufacturing process and environmental protection measures were of the same quality as those in Japan. [30] In such cases, the level of equipment is far beyond the needs of the receiving country.

When the receiving country lacks the human capital necessary to accommodate an introduced technology, developed countries are further required to bridge the gap.[31] Japan has been using JICA (the Japan International Cooperation Agency) for this purpose, and Singapore provides Indonesia with technical training for air pollution monitoring.[32] The cost of technology transfer is also very important for receiving countries. As the "Green Aid Plan" provided by Japan to China and Thailand shows, ODA is often associated with the transfer of environmental technology. When pollution crosses national boundaries as in the case of acid rain, environmental protection technology is more easily transferred. Even without such conditions, a shift in the concept of ODA towards environmental concerns helps to strengthen international cooperation.

Export of Pollution

Repetto (1995), as well as Grossman and Krueger (1995), stated that cost differentials in environmental regulations are not large enough to promote a shift of factories to less regulated countries. Indeed, the case of Japanese foreign direct investment (FDI) needs to be examined in more detail. But during the 1980s, the high exchange rate of the yen essentially accelerated the efforts of

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[29] Quan (2001), World Bank (1997a and 1997b).
[30] Interview at Nippon Steel Corp., May 26, 2000, and Imura and Katsuhara (1995), pp.191-3.
[31] Panayotou (1995), pp.33-4.

Japanese firms to expand their manufacturing base into Southeast Asia.[33] During periods when exchange rates fluctuate to a large extent, the influence of cost differentials in environmental protection is far smaller, if not negligible.

More generally stated, does the new international division of labor, with developed countries as importers of manufactured goods and developing country as exporters, cause a shift of pollution sources to developing countries? Suri and Chapman (1988) state that rapid industrialization in developing countries leads to export of manufactured goods, thereby increasing energy consumption. East Asian countries undoubtedly fit this description. However, we should note that export-led industrialization in the region has not been accompanied by as high level of SO_2 concentration as was seen in Japan at a corresponding income level.

5. Concluding Remarks

From the early 1970s to the mid-1980s, Japan actively engaged in abatement of air pollution, in particular SO_2, to great effect. Indeed, this development corresponds to the EKC hypothesis, but should not be regarded as the automatic result of economic development, such as a change in industrial structure. Firstly, civil movements against pollution forced local and central governments to introduce regulation policy. Secondly, firms producing the pollutants succeeded in converting to fuels with less sulfur content, innovating desulfurization processes, and promoting energy efficiency.

In East Asia, despite rapid economic growth, SO_2 pollution in big cities is less serious than it was in Japan in the 1970s. Administrative authorities in these countries took the initiative in environmental protection and firms succeeded in reducing SO_2 emissions by raising energy efficiency and employing alternative sources of energy. These initiatives reflect efforts to learn from the experiences of developed countries, which in itself suggests the validity of the advantage of latecomer hypothesis.

While technology transfer is often characterized as definitive of the advantage of latecomer , there do remain barriers to such transfer due to, for example, the high cost of equipment and insufficient technical capability on the part of the receiving country. These barriers, however, can be removed by means of international cooperation.

To finish, let us comment on the possibility of whether the study of SO_2 reduction gives any hints for CO_2 case. Some researchers argue that the inverted U-shaped curve is found also for CO_2 emissions. But this is merely an econometric result since the income level for the upper turning point is too high to have been yet realized.[34] Seen from another angle, this implies that the advantage of latecomer is only available when developed countries have accumulated experience and related

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[32] Ministry of the Environment, Singapore, *1999 Pollution Control Report*, p.30.
[33] See for example, MITI (1999), p.122.
[34] Suri and Chapman (1998), p.199.

technical capabilities. These conditions are satisfied in the case of air pollutants like SO_2, but not yet for CO_2.

However, conclusions drawn from the SO_2 case help us to understand the prerequisites for reducing CO_2. If developed countries actually succeed in creating abatement technology for CO_2, this will surely affect the development policy in developing countries. Noteworthy is the lesson that the predecessors can guide the latecomers by means of both the innovated technology and shared experience.

Table 1 Estimated results of SO_2 Emission Equations: pooled time-series data from the early 1970s to 1990

Dependent variable: SO_2 Emissions of East Asia

	(a)	(b)	(c)
Constant	-33.98	-26.40	-36.32
	(-4.33)***	(-5.09)***	(-5.51)***
Y	6.17	4.49	6.61
	(3.08)***	(3.30)***	(3.93)***
Y^2	-0.30	-0.20	-0.32
	(-2.46)**	(-2.42)**	(-3.16)***
EF	-1.60	-1.64	-0.67
	(-5.17)***	(-8.70)***	(-2.53)***
IS	3.53	1.72	-0.77
	(3.49)***	(1.77)*	(-0.59)
D1		0.92	0.91
		(7.64)***	(6.98)***
D2		- 0.50	- 0.74
		(-2.76)***	(-3.40)***
Samples	168	168	150
$\overline{R}^2$	0.71	0.90	0.91

Data Sources: SO_2 emissions: ASL and Associates, *Global Sulfur Emissions Database*, http://www.asl-associates. com /sulfur.htm. Income and 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 1995/1996.*

Note: t-statistics in parenthesis. *significant at the 10% level, **significant at the 2% level, ***significant at the 1% level.

Table 2 Energy Consumptions, Energy Efficiency and SO_2 Emissions in East Asian Countries

	Energy Consumptions per capita (ton of oil equivalent)				Energy Efficiency (GDP per unit counsumption, US dollar per kg)			
	1975	80	90	95	1975	80	90	95
Japan	2.9	2.97	3.55	3.96	4.00	4.55	5.26	5.00
China	0.53	0.6	0.75	0.88	1.18	1.30	2.13	3.03
Korea	0.67	1.08	2.13	3.29	4.35	3.57	3.85	3.45
Taiwan	0.94	1.58	2.36	3.06	4.55	4.17	5.00	5.26
Indonesia	0.33	0.4	0.55	0.61	3.85	4.17	4.76	4.35
Thailand	0.44	0.49	0.78	1.09	4.55	5.26	5.88	5.88
Philippines	0.4	0.44	0.45	0.49	5.00	5.56	4.76	4.35
Malaysia	0.61	0.81	1.23	1.86	5.26	5.56	4.76	4.35
Singapore	2.04	2.65	4.94	7.19	4.17	4.35	3.85	3.70

Source: IEA, Energy Balances of OECD Countries, Energy Balances of Non-OECD Countries.

Table 3 Energy Sources For Electricity in East Asian Countries

	1973						1996					
Energy Sources	Coal	Oil	Gas	Nuclear	Hydro	Total	Coal	Oil	Gas	Nuclear	Hydro	Total
Japan	8.0	73.2	2.3	2.1	14.4	456,387	18.2	21.0	20.2	30.2	8.1	1,000,436
China	61.5	15.7	-	-	22.8	166,800	75.8	5.3	0.2	1.3	17.4	1,080,018
Korea	9.1	82.3	-	-	8.7	14,825	35.2	18.5	12.1	33.1	1.1	223,598
Taiwan	6.9	76.7	-	-	16.4	20,735	42.1	21.4	4.2	26.1	6.2	144,930
Indonesia	-	55.8	-	-	44.2	3,624	24.3	17.7	42.3	-	12.2	66,706
Tahiland	3.5	69.5	-	-	27.0	6,971	20.0	29.3	42.0	-	8.4	87,467
Philippines	0.1	85.7	-	-	14.2	13,186	13.2	49.6	0.1	-	19.3	36,663
Malaysia	-	76.6	-	-	23.4	4,783	3.7	32.0	54.2	-	10.1	51,382
Singapore	-	100.0	-	-	-	3,719	-	78.7	18.7	-	-	24,100

Note: Energy Source in %, Total in GWh.

Source: IEA, Energy Balances of OECD Countries, Energy Balances of Non-OECD Countries.

Table 4 Automobile Exhaust Regulations in ASEAN4

<u>Gasoline Car</u>

	CO	HC+NO x	
Thailand	2.2g/km	0.5g/km	from January 1999
Philippines	2.72g/km	0.97g/km	from January 2000
Indonesia	no regulations		
Malaysia	2.2g/km	0.5g/km	from January 2000

Japan (1973 standards)

CO 26.0g/km HC 3.8g/km NOx 3.0g/km,

therefore, HC+NOx 6.8g/km

Japan (1975 standards)

CO 2.7g/km HC 0.39g/km NOx 1.60g/km

Therefore, HC+NOx 1.99g/km

<u>Diesel Car</u>

	CO	HC+NOx	
Thailand	1.0g/km	0.7g/km	from January 1999
Philippines	2.72g/km	0.97g/km	from January 2000
Indonesia	no regulations		
Malaysia	2.72g/km	0.97g/km	from January 2000

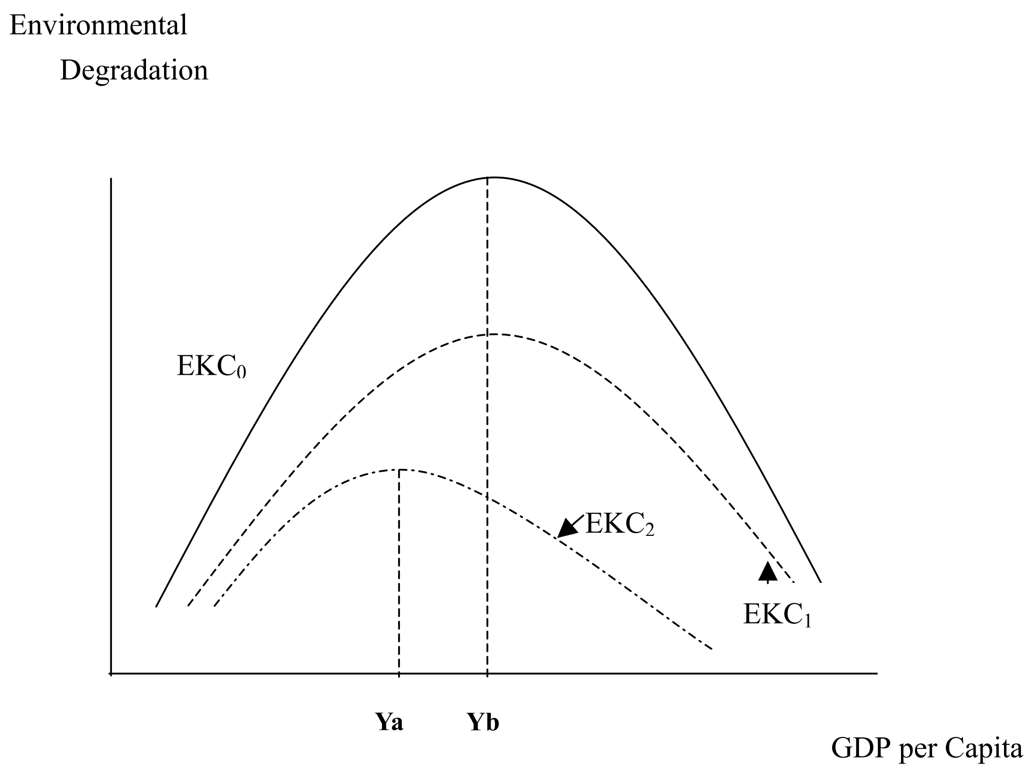
Japan (1986standards)

CO 2.7g/km HC 0.62g/km NOx 0.98g/km,

Therefore, HC+NOx 1.6g/km

Source: Toyota Motor Co., and Hama-uzu (2000).

Figure 1 the EKC and Advantage of latecomer



Note: Panayotou (1995) Figure 2.5 modified.

Figure 2. SO_2 Concentration and Income Level

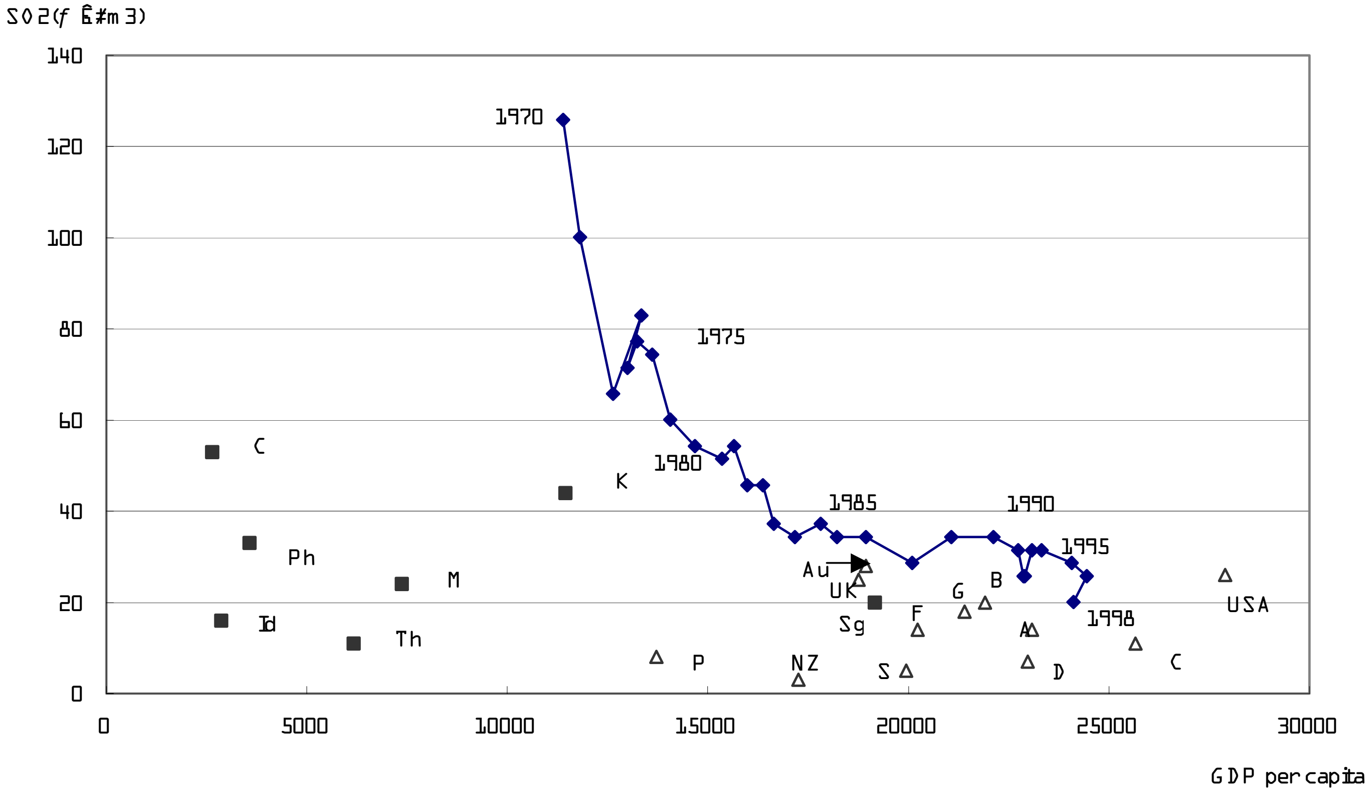


Figure 3. NO$_2$ concentration and Income Level

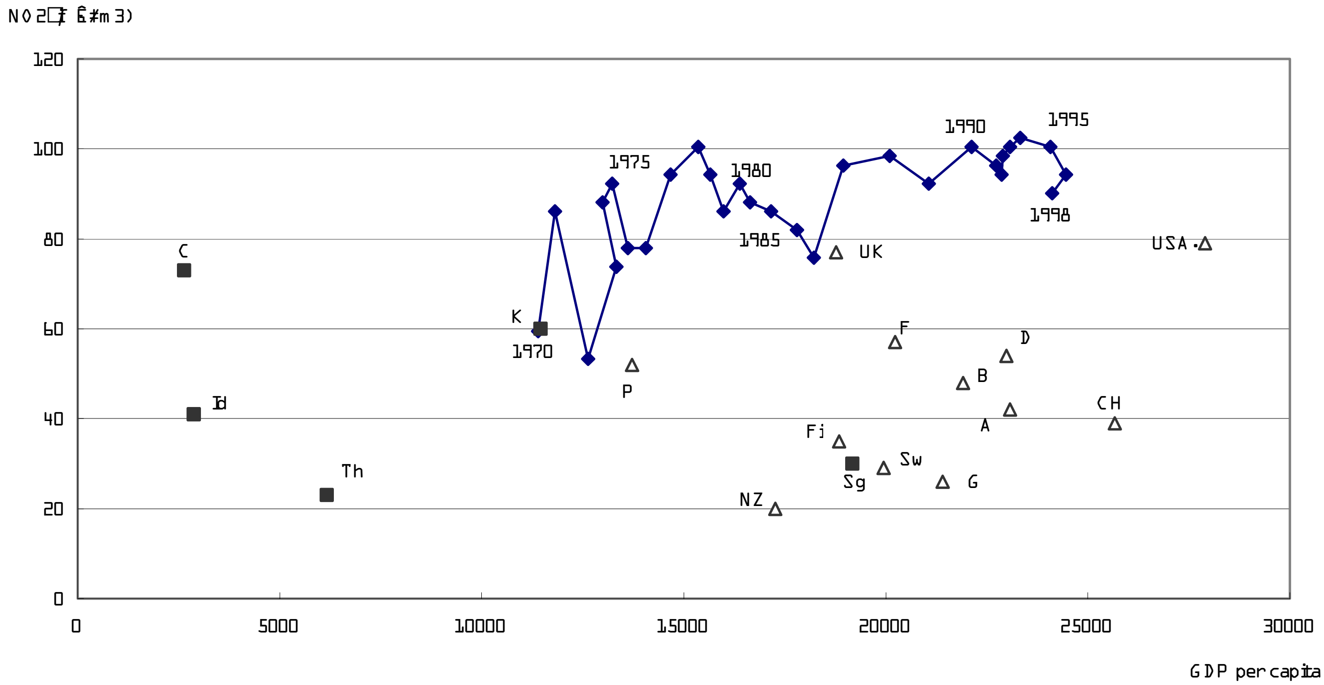
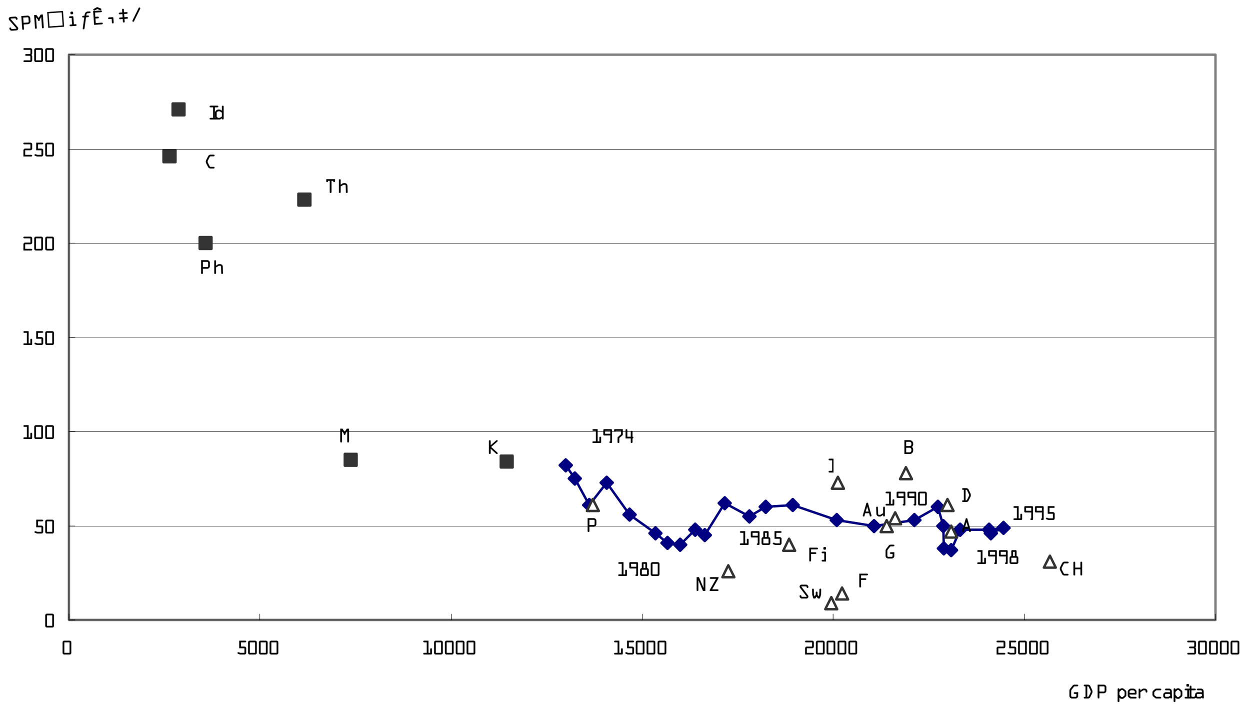


Figure 4. TSP Concentration and Income Level



Note: Income data are taken from the International Energy Agency, *Energy Balances of OECD Countries 1999-2000*, and *Energy Balances of Non-OECD Countries 1999-2000*. Environmental data are from the Environment Agency of Japan, *Air-pollution in Japan, Abstract of Environmental Statistics,* various issues. Annual averages of Chiyoda and Shinjuku wards, Tokyo. Environmental Standards of SPM were introduced in 1972, before which data do not exist. SO_2 is calculated as 1ppm=2860μg/m^3, NO_2 as 1ppm=2054μg/m^3. Data for the other countries are as of 1995 from the World Bank, *World Development Indicators 1999*. Indonesian data for SO□ and NO_2 are the annual averages from *Environmental Statistics of Indonesia 1998*.

The abbreviations stand for observation spots as follows: China (C): Shanghai, Philippines (Ph): Manila, Malaysia (M): Kuala Lumpur, Thailand (Th): Bangkok, Korea (K): Seoul, Singapore (Sg): Singapore, New Zealand (NZ): Oakland, Australia (Au): Sidney, Austria (A): Vienna, Denmark (D): Copenhagen, Portugal (P): Lisbon, Sweden (Sw): Stockholm, Switzerland (CH): Zurich, Belgium (B): Brussels, Finland (Fi): Helsinki, United States of America (USA): New York, United Kingdom (UK): London, France (F): Paris, Italy (I): Rome, Germany (G): Berlin.

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