Cost Benefit Analysis of the Sulfur Dioxide Emissions Control Policy in Japan

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Abstract

This research study attempts to examine the economic efficiency of sulfur dioxide (SO_2) emissions control policy in Japan by using cost benefit analysis (CBA). The SO_2 emissions control policy is divided over 3 stages by epochal policy reinforcement. Reducing the incidence of chronic bronchitis and asthma are the two main policy benefits, estimated by using cost of illness (COI) approach. Policy costs have been derived from the private sector investments for pollution control to meet the pollution standards under command and control (CAC) regulations. The estimated results, at a social discount rate of 2.5%, indicates cost benefit ratio as 3.32 in stage 1 (1968-1973), 0.80 in stage 2 (1974-1983) and 0.28 in stage 3 (1984-1993). This result indicates that our hypothesis about the efficiency of CAC under certain circumstances is valid, as were the situation during stage 1. However, the results covering stage 2 and 3 for a policy period after mid 1970s supports the previous studies to indicate that CAC regulations do not remain economically efficient. This suggests that Japan needs to reconsider its SO_2 emissions control policy from economic perspective.

1. Introduction

OECD (1977) describes Japan's environmental policy for 1970s as dramatically successful attempt to combat the pollution, especially sulfur emissions reduction and heavy metal pollution control. However, this report also mentioned Japan's pollution abatement policy as ineffective and inefficient to check the pollution. Furthermore, O'Connor (1994) mentioned that Japanese environmental management had achieved impressive results mainly for technological arena but less progress was made for behavioral changes as command and control (CAC) did not provide any incentive for that; thus, there may be a scope for market based instruments (MBIs) to provide economic incentives for behavioral change.

These major previous studies mainly appraised Japan's pollution control policy as inefficient policy due to CAC. However, CAC policy varies as per socioeconomic and historical situation of the country. Therefore, we have to analyze more thoroughly with a realistic approach to find out the success and failure of the policy. Our hypothesis is that under the certain situations CAC can provide efficient and effective results. We test our hypothesis for sulfur dioxide emissions control policy in Japan. For this purpose, we use cost benefit analysis (CBA) and especially use cost of illness (COI) for benefit assessment.

Cost benefit analysis (CBA) is a technique intended to evaluate the economic efficiency of public policy, using as a metric a monetary measure of the policy cost and benefit. Although there are many criticisms of CBA when applied to environmental decision-making, CBA, when properly applied, has concrete advantages including 1) improving the transparency of government action, 2) raising environmental knowledge and 3) enabling the comparison of alternative policies (Kopp et al, 1997). Moreover, the recent General Accounting Office and Morgenstern studies suggest that CBA has some impacts on regulatory development (GAO 1998, Morgenstern 1997).

For example, in the United States, this policy decision tool has been authorized by Executive Order 12291 in 1981 and Executive Order 12866 in 1993, which required all major federal regulations to pass a cost benefit test before implementation. The field of air quality management is also required to conduct CBA based on the Clean Air Act Amendments of 1990, section 812. To support that policy in USA, various studies were conducted (Chestnut 1995, USEPA 1997, Ostro and Chestnut 1998, USEPA 1999). Based on those studies, we analyze Japan's policy for SO_2 emissions control.

2. SO_2 emissions control policy in Japan

Post-1967 data from nation-wide monitoring stations indicate that average annual concentrations of atmospheric SO_2 experienced a downward trend following their peak of 0.04 ppm in 1967 (Fig.1). This could be the result of the introduction of emissions controls called "K-value controls " in 1968. SO_2 environmental standard was reinforced in 1973 as daily average: 0.04ppm and hour maximum: 0.1ppm. Then, the SO_2 measure was reinforced in 1974 by introducing the "Total Emissions Control" for the areas where the regular emissions standards were insufficient to meet the SO_2 ambient standard.

With these new measures, the private sector also promoted various measures such as installation of tall chimneys, fuel desulfurization, fuel conversion to LNG (liquefied natural gas), and installation of fuel-gas desulfurization facilities (CJEBAP 1997). As a result, SO_2 concentration dramatically dropped and the environmental standard was attained at every monitoring station in 1983. The concentration level continued to decline after attainment of the environmental standard, because both K-value controls and Total emissions controls strictly regulated new pollutant emissions facilities.

This paper divides SO_2 emissions control policy into three stages based on history, and conducts CBA in each stage to determine the changes in efficiency of the policy. The first stage is from 1968 to 1973, when K-value controls played a prominent role. The second stage is from 1974 to 1983, when Total Emissions Control was the main control strategy. The third stage is from 1984 to 1993, when the new source regulation became effective.

3. Methodology

3.1 Cost and benefit items

The first step of a CBA is to determine the policy's costs and benefits. Table 1 summarizes the cost and benefit items of previous CBA studies for air pollution control policy conducted by the USEPA and OECD.

The USEPA study performed a CBA of the entire Clean Air Act (CAA) from 1970 to 1990, and assessed the benefits and costs related to all air pollutants. The direct benefits included reduced incidence of a number of adverse health effects (hereafter health benefits), improvements in visibility, and avoided damages to soil and agricultural crops. The direct costs of implementing policy included annual compliance expenditures in the private sector and program implementation costs in the public sector. The study suggested that there are indirect costs not readily quantified, such as the possible adverse effects of CAA implementation on capital formation and technological innovation (USEPA 1997).

The OECD study conducted a CBA of SO_2 emissions control in Europe. The direct benefits included avoided damage to materials, crops and aquatic ecosystems, and health benefits. The direct costs included capital investment for pollution control devices and operating costs of those devices in the private sector (OECD 1981).

To summarize these studies, the benefits of air control policy could be health benefits, avoided damages to materials, crops and ecosystems, and improvement of visibility. The costs associated with implementing environmental policies include costs in three social sectors: private, government and society.

Conceptually, the analysis should include all benefits and costs related to the policy at issue, but there is an inevitable data limitation. Moreover, the essence of CBA is covering large proportion of costs and benefits of that policy (OECD 1981). Thus, this analysis applies to health benefit; especially chronic bronchitis and asthma, a primary concern of SO_2 pollution control policy in Japan as a policy benefit. This paper focuses only on morbidity not on mortality because of the lack of reliable epidemiological studies. The cost for pollution control by the private sector is applied as a policy cost, because the proportion of the private sector's investment in air pollution measures have been large in Japan.

3.2 Discount rate (SDR)

Taking into account the argument that 'environmental' projects should be subjected to a lower discount rate (Winpenny 1991), SDR is set at 0%. 2.5% and 9% SDR are also set referred to extreme ranges of commercial interest between 1970 and 1990 in Japan. In the analysis, r stands for SDR and is applied for both cost and benefit estimations.

4. Benefit analysis

This section first examines the human health effects of reducing SO_2 concentration. Then, the economic value of those human health effects is determined. Finally, results of the economic benefits analysis are presented. All Japanese yen values are rounded and are in 1993 yen.

4.1 Human health effect of SO_2 emissions control

The number of human health damage reduced by SO_2 emissions control is calculated by following function.

$$\Delta Cases = b \times \Delta SO_2 \times POP \quad (1)$$

Table 2 shows the health damages (cases), exposed population group (POP) and coefficient of does-response function (b) in this study.

In this study, chronic bronchitis and asthma are considered as major health damages caused by SO_2. A pollution victim compensation system was introduced in Japan in 1973, which was established to compensate the air- pollution especially SO_2 related health damages. That health damage included chronic bronchitis, bronchial asthma and pulmonary emphysema (CJEBAP 1997).

The dose-response functions of these health damages come from macroepidemiology study conducted by Environmental Agency from 1980 to 1985 (EAJ 1986). This study examined the relationship between respiratory health status of 51 cities' population group, a sample of 98,695 children and 167,165 adults, and the concentration of criteria air pollutants. In particular, children studies have advantages in examining human health effect of air pollution, because of children's; 1) close life style to local area, 2) no effect of occupational exposure, 3) no effect of direct smoking, 4) relatively uniform past exposure, and 5) relatively uniform life style (Tsunetoshi et al. 1987). Therefore, children studies are applied in this analysis.

EAJ study on Chronic bronchitis shows 4 different dose-response functions according to the different population groups (girl; boy; allergic girl; allergic boy). In the same manner, asthma studies shows two different dose-response functions with respect to girls and boys. Based on Ostro and Chestnut (1998), we categorize those population groups with respect to their sensitivity to get ill under the same ambient levels. Hence, we assume, in case of chronic bronchitis, one third of population is less sensitive, one third is normal , one sixth is sensitive, and one sixth is very sensitive. For asthma, we assume that half of the population is relatively less sensitive and other half is relatively more sensitive.

Furthermore, Tsunetoshi et al. (1987) pointed out that 50 percentage of total patients of chronic bronchitis also have asthma. Therefore, the number of the patients of asthma is calculated as the total number of estimated asthma patients minus 50 percentage of the total estimated chronic bronchitis patients.

The nation-wide annual average SO_2 concentration is available from Japan's national air monitoring record (EAJ 1998). Although nation-wide annual average concentrations may not relate to real health damage, they serve to evaluate the macro trend of policy impacts. Thus, by applying that data, estimated number of patients is shown in Table 2.

4.2 Cost of illness (COI) estimations for SO2 emissions

Freeman (1993) has suggested an equation to estimate willingness to pay (WTP) for avoiding air pollution related health effects. The equation is as follows:

$$w_c = p_w \cdot \frac{ds}{dc} + p_b \cdot \frac{\partial b^*}{\partial c} + p_a \cdot \frac{\partial a^*}{\partial c} - \frac{\partial u / \partial s}{\lambda} \cdot \frac{ds}{dc} \quad (2)$$

where pw is the wage rate; pb is the price of mitigating (medical) activities; pa is the price of averting (defensive) activities; and l is Lagrangian multiplier (the marginal utility of income).

According equation (2), WTP of health damages consists of medical expenditures, lost earnings, defensive expenditures and disutility of income. COI covers medical expenditure and lost earnings. Therefore, COI estimates are likely to substantially understate total WTP. Some of the studies attempted to adjust COI to estimate WTP (Rowe et al. 1995). However, this paper does not modify the results of COI estimation because of the high uncertainty of the relationship between WTP estimates and COI estimates in Japan.

Moreover, there are two ways to calculate COI; individual COI only covers private payments. On the other hand, social COI includes the costs to society and national subsidy. We use social COI in this study, because CBA should be based on social cost and social benefit estimations.

Chronic bronchitis and asthma are the morbidity effects that may be expected to last from the initial onset of the illness throughout the rest of the individual's life. The full COI could be estimated using the average annual lost earnings and the average annual medical expenditures with the assumption that 1) lost earnings continue until age 65, 2) medical expenditures are incurred until death, and 3) life expectancy is unchanged by chronic bronchitis (Cropper et al. 1990).

Values derived from these assumptions depend crucially on the age of the population at risk. Cropper et al. presented values for age populations of 30, 40, 50 and 60 years old (Cropper et al. 1990). Shin et al. (1997) used the average age for the population as a whole. In this analysis, the population at risk assumes the average age for the population as a whole at each policy-starting year.

4.3 Model for benefits analysis

Above benefit estimation model is shown in following equations.

$$\text{Benefit} = \sum_{t=0}^{e} BMt/(1+r)^t + \sum_{t=0}^{l} BLt/(1+r)^t \quad (3)$$

where BMt is social medical expense in year t; BLt is social labor loss in year t; e is remaining life time which refers life expectancy at average age of population; and l is years in labor force remaining which refers 65 average age of population.

$$BM_t = p_i \times M_f \quad (4)$$

$$Bl_t = \text{Hospital visit}\left[A \times P_i \times W_f \times B \times \frac{E_f}{2} \times C\right] + \text{Hospital admission}\left[E \times P_i \times W_f \times G \times E_f \times H\right] \quad (5)$$

where Pi is number of reducing incidence; Mf is annual average medical expenses per capita; Wf is working ratio above 15 years old at the end of policy period; Ff is average income per day at the end of policy period; A=0.83 is hospital visit ratio in all respiratory patients; B=0.44 is product population ratio in the hospital visit respiratory patients; C=52 is annual average hospital visit days of respiratory illness patients; E=0.17 is hospital admission ratio in all respiratory patients; G=0.31 is productive population ratio in the hospital admission respiratory patients; and H=15 is annual average hospital admission days of respiratory illness patients.

Benefit is the sum of social medical expenses (BMt) during the eth year and the social labor losses (BLt) during the lth year. Table 3 shows e and l data in each policy stage.

Medical expenses and labor losses in tth year can be calculated as follows (refer to equations (4) and (5)) . BMt is derived by multiplying the reduction in the expected numbers of respiratory patients and annual medical expenses per capita for the respiratory illness (Mf). Data on annual medical expenses for respiratory illness are calculated from medical statistics in Japan (MHW 1993, 1998)

Values of labor losses (BLt) consider only the population who are working. BLt should be divided into two parts: hospital visits and hospital admissions. Values of each case are derived by multiplying the reduction in number of workers due to morbidity, the daily average wage, and the days of work lost because of the illness.

The analysis assumes that 83% (A) of all respiratory patients are hospital outpatients, and the rest, of 17 % (E) are admitted into the hospital. The reduction in number of workers due to morbidity is a proportion both of above 15 years (Wf), and productive workers, which is 44% of all hospital visit (B) and 31% of all hospital admission (G) in the expected numbers of respiratory patients. Duration of hospital visit is assumed to be 52 days (C) per year and duration of hospital admission is assumed to be 15 days (H) per year. These assumptions are based on the medical statistics of respiratory illness patients in 1993 (MHW 1993). Workers are assumed to lose the whole daily wage during the hospital stay (Ff) and half of the daily wage per hospital visit (Shin et al. 1997). Annual medical expenses per capita, the portion of the whole population that is above 15 years old (Wf) and the average income per day (Ff) in each policy stage are shown in Table 4.

4.4 Benefit estimations

As a result, the policy benefit in each policy stage is determined (Table 5). It appears that, where the discounting rate is 2.5%, the policy benefit of stage 1 is 20,428 billion yen; at stage 2, it is 12,829 billion yen and at stage 3, it dramatically falls to 2,531 billion yen.

5. Cost analysis

Cost estimation method is shown as the following equation.

$$\mathrm{Cost} = \sum_{t=0}^{e} Ct/(1+r)^t \quad (6)$$

where Ct is cost at tth year; and e is remaining life time.

To balance the cost cycle with the benefit cycle, it is hypothesized that the cost rose during the eth year continuously. This cost cycle is shown in Fig. 2, and consists of fuel conversion costs, capital costs, and running costs. All the costs are assumed to rise constantly during the eth year after the end of the policy period.

Table 6 shows the calculation methods and data sources of each cost stream. Fuel conversion includes changing to low-sulfur crude oil, low-sulfur heavy oil, and LNG. Those costs are calculated by multiplying a price difference between high-sulfur fuel, which had been used until the policy implementation, and low-sulfur fuel. Capital costs are calculated based on the production record of tall chimneys, fuel-gas desulfurization facilities and fuel desulfurization facilities. Moreover, our assumption based on capital costs of stage 2 and stage 3 have been calculated for investment made during that stage and remaining stock from previous stage. Because of data limitations, running cost is calculated only for fuel-gas desulfurization facilities. These basic data are shown in Table 7.

Table 8 shows the following cost estimate results. Where SDR is 2.5%, the policy cost is 6,152 billion yen in stage 1, it increases to 16,043 billion yen at stage 2, and in stage 3 falls to 8,451 billion yen.

6. Cost-Benefit Ratio

Our research study presents a cost benefit analysis of SO2 emissions control policy in Japan. Table 9 summarizes the result of the cost benefit ratio. Where the SDR is 2.5%, the cost benefit ratio is 3.32 at stage 1. It dramatically decreases to 0.80 at stage 2, then further drops to 0.28 at stage 3.

The OECD conducted a CBA of sulfur oxide control in Europe, and reported cost benefit ratios between 0.6 and 5.8 (OECD 1981). In 1997, USEPA showed the cost benefit ratio of overall air pollution control policy from 11.0 to 94.0 with a mean 42.0. USEPA revised this study in 1999, and predicted cost benefit ratio from 0.8 to 8.4 with mean 3.7.

7. Conclusion

Comparing the various studies, our study results for cost benefit analysis we can get the concluding remarks as follows:

1) Cost benefit ratio of stage 1 is comparatively higher showing efficiency and almost same as the one calculated in other previous studies. This indicates that CAC in early stage was efficient in Japan. This is a contrary result with other same type of studies.

2) However, cost benefit ratio of stage 2 and 3 is comparatively lower showing inefficiency, especially during stage 3 it is 0.28, which is very low. This indicates that institutionalized CAC in Japan looses the flexibility of implementation and rationality. Therefore, at this stage OECD (1977) and O'Connor (1994) comments for Japan's policy after the mid of 1970s are valid

3) The study results approve our hypothesis that CAC policy under the certain situations could be implemented efficiently.

This study only considers the probability of dose-response and its effect on the various population groups. Therefore, we need to study CBA under the various uncertainties by using various probability weights. Further studies may be conducted to get more specific results, since the benefits could be underestimated as a result of using the COI. However it can be assumed that Japan needs to reconsider its SO_2 emissions control policy from the economic perspective.

References

Chestnut L (1995) Human Health Benefits from Sulfate Reductions under Title IV of 1990 Clean Air Act Amendments, United States Environmental Protection Agency (USEPA)

CJEBAP (Committee on Japan's Experience in the Battle against Air Pollution) (1997) Japan's Experience in the Battle against Air Pollution: Working toward Sustainable Development, The Pollution-Related Health Damage Compensation and Prevention Association

Cropper ML, Krupnick AJ (1990) The Social Costs of Chronic Heart and Lung Disease, Discussion Paper QE 89-16-REV, Resources for the Future, Washington, D.C.

EAJ (Environmental Agency in Japan) (1986) Taiki Osen Kenkou Eikyou Chosa Houkokusho (showa 55-59)(Report of Air Pollution and Health Impact)(in Japanese), EPA Taiki-Hozen-Kyoku (EAJ Air Pollution Control Department)

EAJ (1998) Nihon no Taiki Osen Jokyo: Heisei Junen Ban (Situation of Air Pollution, FY1998)(in Japanese), EAJ

EDMC (Nihon Energy Keizai Kenkyu-jo: Energy Keiryou Bunseki Center) (The Energy Data and Modelling Center)(1997) Energy Keizai Tokei Yoran (Energy Economic Statistics)(in Japanese), EDMC

Freeman AM (1983) Air and Water Pollution Control, John Wiley & Sons, New York

GAO (General Accounting Office) (1998) Regulatory Reform: Agencies could Improve Development, Documentation, and Clarity of Regulatory Economic Analysis, GAO/RCED-98-142. 26

Government of Japan (1971) Kogai Hakusho Shouwa 46 Nendo Ban (Whitepaper of Environmental Pollution, FY1971)(in Japanese), Government of Japan

Japan Society of Industrial Machinery Manufactures (1986) Baien Taisaku Gijutsu Chosa Houkokusho (Report of Control Technology for Point Source Air Pollution)(in Japanese), Japan Society of Industrial Machinery Manufactures

Kopp RJ, Krupnick AJ, and Toman M (1997) Cost- Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art, Discussion Paper 97-19, Resources for the Future, Washington, D.C.

MCA (Management Coordination Agency in Japan) (1973) Population Statistics 1973(in Japanese), MCA

MCA (1983) Population Statistics 1983(in Japanese), MCA

MCA (1993) Population Statistics 1993(in Japanese), MCA

MCA (1997) Annual Statistics Report 1997(in Japanese), MCA

Matsuno Y (1997) Tekkogyo ni okeru Iousankabutsuhaishutsusakugen heno Kakushu Kankyou-taisaku-shudan no Kiyo (2) (Pollution Control Technologies Effect for Reduction of Sulfate from Steel Industry), Keizaironsou (Kyoto University Economic Journal)(in Japanese) 160.3, Kyoto University

Morgernstern R(ed) (1997)Economic Analysis at EPA: Assessing Regulatory Impact, Resources for the Future, Washington D.C.

MHW (Ministry of Health and Welfare in Japan) (1998) Kokumin-Iryohi Heisei 8nendo (FY 1996 National Medical Expense)

MHW (1993) Kanja-Chosa (Zenkoku-ban) (Report of Patient, Nation Wide)(in Japanese), Kosei-Tokei-Kyokai (Association of Public Welfare Statistics)

OECD (Organization for Economic Co-operation and Development) (1977) Environmental Policies in Japan, OECD, Paris

OECD (1981) The Costs and Benefits of Sulfur Oxide Control: A Methodological Study, OECD, Paris

O' Connor (1994) Managing the Environment with Rapid Industrialization: Lessons from the East Asian Experience, OECD, Paris

Oil Association (1985) Naigai Sekiyu Shiryou 1985 (in Japanese), Oil Association

Oil Association (1992) Naiagai Sekiyu Shiryou 1992 (in Japanese), Oil Association

Ostro B, Chestnut L (1998) Assessing the Health Benefits of Reducing Particulate Matter Air Pollution in the United States, Environmental Research, Section A, 7:94-106

Rowe R, Lang C, Chestnut L, Latimer D, Rae D, Bernow S, White D (1995) New York State Environmental Externalities Cost Study, Oceana Publications Inc.

Sawamura R, Hamada A, Hayatsu H (1992) Kankyo-Eiseigaku (Environmental Hygienic Sciences)(in Japanese), Nankodo, Tokyo

Sekitu (1984) Oil Price Statistics 1984 (in Japanese), Sekitu

Sekitu (1994) Oil Price Statistics 1994 (in Japanese), Sekitu

Shin E, Hufschmidt M, Lee J, Nickum JE, Umetsu C (1997) Valuating the Economic Impacts of Urban Environmental Problems: Asian Cities, UNDP/ UNCHS (Habitat)/ World Bank Urban Management Program Working Paper Series 13

Tsunetoshi Y, Fukutomi K, Yoshida K, Doi M (1987) Epidemiological Study of Respiratory Symptoms in School-Children with Special Reference to Effect of Air Pollution (in Japanese), Journal of Japan Society of Air Pollution, 22(6):431-459

USEPA (1997) The Benefit and Cost of the Clean Air Act. 1970 to 1990, USEPA

USEPA (1999) The Benefit and Cost of the Clean Air Act. 1990 to 2010, USEPA

Winpenny JT (1991) Values for the Environment, HMSO, London

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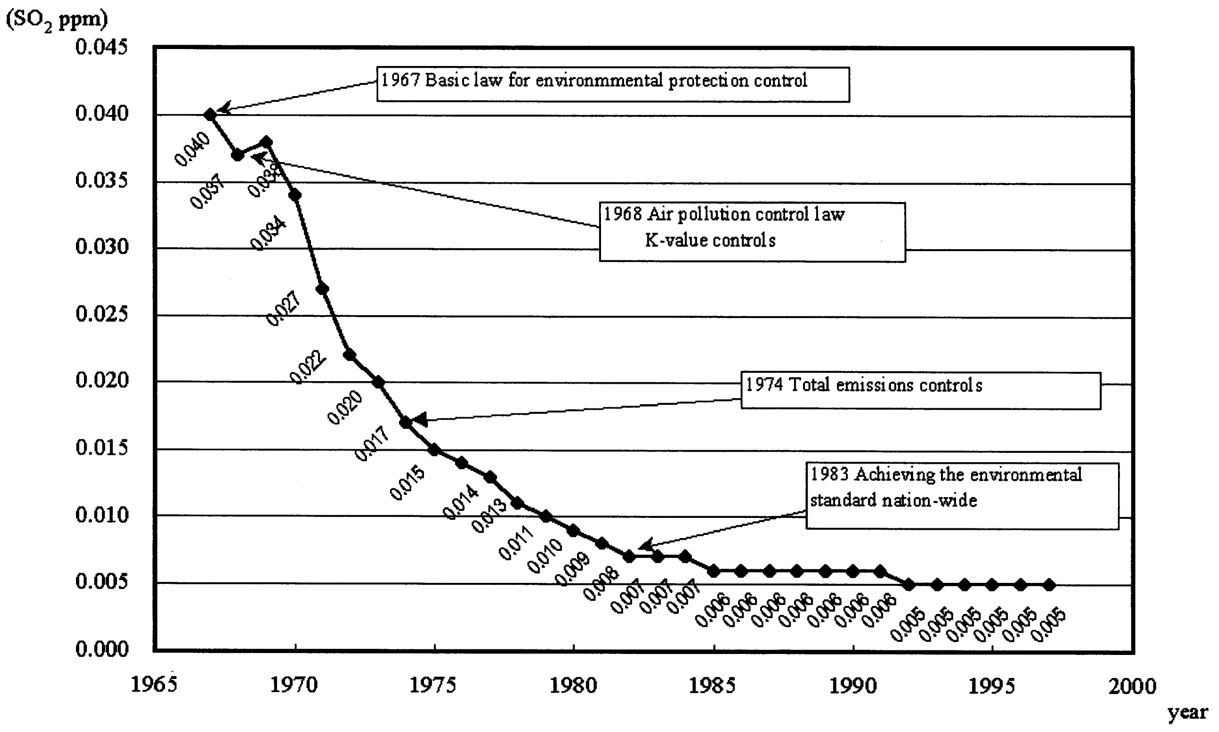

Fig. 1. Change in average annual SO_2 concentration and SO_2 emission control policy in Japan (1967-1997)
Source: Government of Japan (1971), EAJ (1998)
The concentration data is average from nation-wide environment monitoring stations. The number of station increased from 113 to 1,375 through 1967 to 1997.

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Table 1. Benefits items and cost items of air quality management

Control policy targets		USEPA (1999) All air pollutants	USEPA (1997) All air pollutants	OECD (1981) SO_2
Benefits	Human health			
	Mortality	v	v	
	Morbidity	v	v	v
	Materials			v
	Agriculture	v (Including soil)	v (Including soil)	v
	Ecosystem	v		v (Only aquatic)
	Visibility	v	v	
Costs	Private	v	v	v
	Government	v	v	
	Society	(v)*	(v)*	

* **suggested, but not readily quantified**

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Table2. Human health effect of SO_2 emission control

Health damage	b : coefficient of does response function (): weight	ΔSO_2 (ppm)			POP : population (thousand)			ΔCases : # reducing incidence (thousand)		
		Stage 1	Stage2	Stage3	Stage 1	Stage 2	Stage3	Stage 1	Stage2	Stage3
Chronic bronchitis [a]		0.0200	0.0115	0.0020	109,104	119,536	124,764	895	564	102
Low	0.014 (33%)									
Central	0.027 (33%)									
High	0.072 (17%) 0.092 (17%)									
Asthma								1,047	660	120
Low	0.065 (50%)									
High	0.072 (50%)									

Source: EAJ (1986, 1998), MCA (1973, 1983, 1993)

Table 3. The benefit arising in each policy stage

	Stage 1	Stage 2	Stage 3
Policy starting year	1968	1974	1983
Average age	32	34	38
Life expectancy at average age (*e*)	44	44	41
65 years old – average age (*l*)	33	31	27

Source: MCA (1973, 1983 and 1993)

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Table 5. Benefit stream

billion yen (1993 year price)

SDR=0.0%

	Stage 1	Stage 2	Stage 3
Medical expenses	29,241	17,554	3,395
Labor losses	3,731	3,001	537
Total	32,972	20,555	3,931

SDR=2.5%

	Stage 1	Stage 2	Stage 3
Medical expenses	17,872	10,729	2,139
Labor losses	2,556	2,100	300
Total	20,428	12,829	2,531

SDR=9.0%

	Stage 1	Stage 2	Stage 3
Medical expense	7,707	4,627	953
Labor loss	1,258	1,064	211
Total	8,965	5,690	1,164

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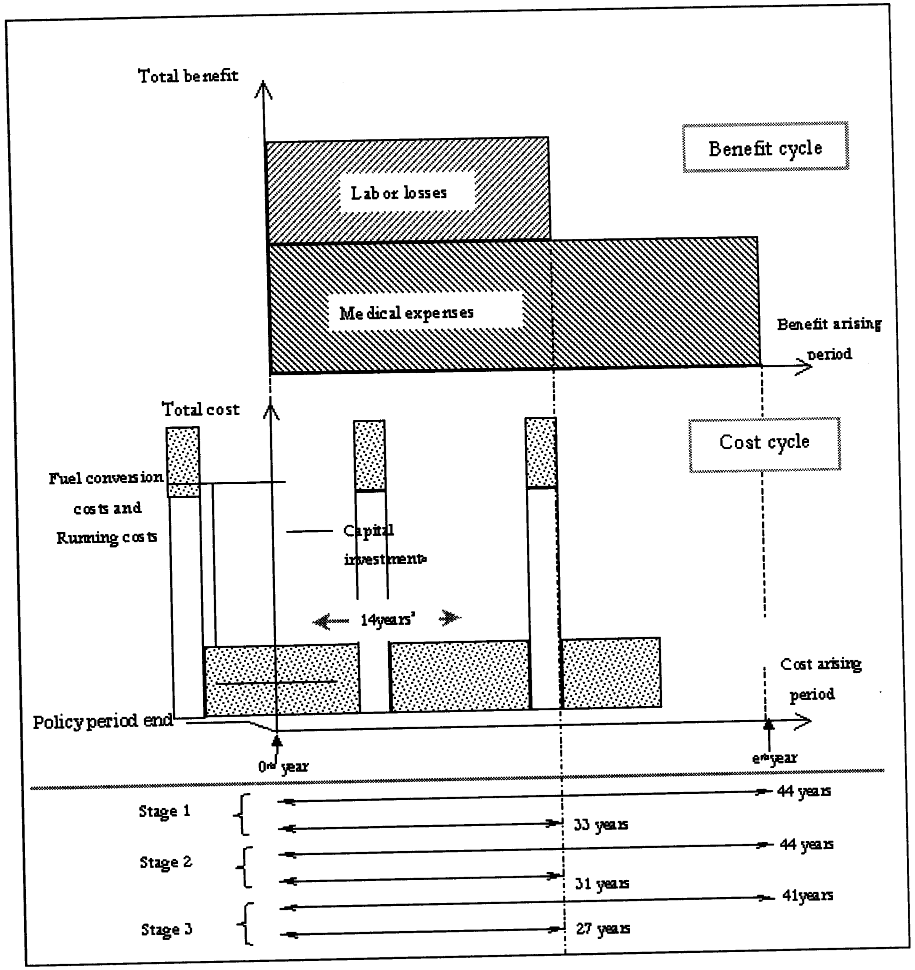

Fig. 2. Benefit cycle & cost cycle

[a]Depreciation period based on Matsuno (1997)

[b]Capital investment divided by 14 years is annual capital cost.

Table 6. Cost calculation method and data source

Cost items		Calculation method	Data source
Fuel conversion	Low-sulfur crude oil	(Low-sulfur crude oil price − high-sulfur crude oil price) × amount of low-sulfur crude oil import	Oil association (1985, 1992)
	LNG	(LNG price- heavy oil price) × amount of LNG import	EDMC(1997)
	Low-sulfur heavy oil	(Low-sulfur heavy oil price − high-sulfur heavy oil price) × amount of low-sulfur heavy oil production	Sekitsuu(1984, 1994)
Capital investment	Tall chimney	Production record	Japan society of industrial machinery manufactures, "Kankyo sochi no seisan jisseki (annual report)
	Fuel-gas desulfurization facility		
	Fuel desulfurization facility		
Running cost	Fuel-gas desulfurization facility	Running cost (hundred million yen) = 0.3136 × capacity of dealing with fuel gas (10000Nm3/h) +0.4	Japan society of industrial machinery manufactures (1986)

Basic data for cost estimation

billion yen(1993 year price)

Capital cost

	Total 1968-1973	Total 1974-1983	Total 1984-1993
Fuel-gas desulfurization facility	153.9	826.3	363.2
Fuel desulfurization facility	326.9	291.7	191.4
Tall chimney	210.3	103.7	83.2
Total	691.1	1,221.6	637.8

Fuel conversion and running cost

	Average 1968-1973	Average 1974-1983	Average 1984-1993
Low-sulfur crude oil	0.2	0.2	0.1
LNG	0.0	117.4	131.4
Low-sulfur heavy oil	121.2	315.8	107.5
Runnning cost for fuel-gas desulfurization facility	52.9	48.5	28.7
Total	174.3	481.9	267.7

Table 9. Cost benefit ratio

SDR	Stage 1	Stage 2	Stage 3
0.0%	3.28	0.78	0.28
2.5%	3.32	0.80	0.28
9.0%	3.38	0.82	0.29

Table 8. Cost stream

billion yen (1993 year price)

	Stage 1	Stage 2	Stage 3
SDR=0.0%	10,065	26,248	14,205
SDR=2.5%	6,152	16,043	8,951
SDR=9.0%	2,653	6,918	3,986

Table 3.1.1 Evaluation method

1. CBA (Cost-Benefit Analysis)	Comparing the social costs with the social benefits of the project in monetary terms
2. CEA (Cost-Effectiveness Analysis)	Comparing the social costs with the social benefits of the project in technical terms
3. MCA (Multi Criteria Analysis)	Comparing the project with some criteria

Table 3.1.2 Cost effective analysis

Technology	Installation Cost (million $)	Emission Level (PPM)
A	50	98
B	15	135
C	25	105

*Target level is an emission standard of no more than 100 ppm
Source: John A Dixon et al. (1994)

Table 3.1.3 Some general guidelines of CEA

- Examine targets in a mix of countries, both developed and developing. Find out what levels the World Health Organization (WHO) recommends and how they are determined.

- Evaluate the seriousness of the environmental impact which is to be controlled. Discover if it life-threatening (for example mercury poisoning), a health hazard (for example dust and particulates) or merely a nuisance (for example certain noise levels)

- Evaluate the effect of the most cost-effective method of control on the financial and economic return from the project. If the cost of the preferred choice is so great that the project will not be profitable, then the decision must be either not to go ahead or to reconsider the issue of pollution control. Determine the implications of canceling the project. Consider the probable effects of reducing the levels of pollution control. Establish what lessons can be learned from other countries which have faced the same problems.

- Discover whether there is some compromise which will minimize environmental damage while still allowing the project at issue, or another project, to be built.

Source: John A Dixon et al. (1994)

Table 3.1.4 Example of effectiveness measures

Program Objective	Measure of Effectiveness
Program completions	Number of students completing program
Reducing dropouts	Number of potential dropouts who graduate
Employment of graduates	Number of graduates placed in appropriate jobs
Student learning	Test scores in appropriate domains utilizing appropriate test instruments
Student satisfaction	Student assessment of program on appropriate instrument to measure satisfaction
Physical performance	Evaluation of student physical condition and physical skills
College placement	Number of students placed in colleges of particular types
Advance college placement	Number of courses and units received by students in advance placement, by subject

Source: Levin (1983)

Table 3.1.5 5steps of CBA

1. Draw up a list of all alternative project.
2. List all the social(private + external)costs and benefits associated with each project.
3. Quantify, in technical terms, the costs and benefits associated with each project.
4. Calculate a money valuation of the costs and benefits.
5. Evaluate the cost-benefits ratio.

Source: Timothy O'Riordan and R. Kerry Turner (1983)

Table 3.1.6 Hypothetical cost and benefits of adult literacy projects

Strategy	Costs	Benefits	C/B	Net Benefits
Group instruction	$200,000	$250,000	0.80	$50,000
Self-instruction with educational technology	$150,000	$125,000	1.20	-$25,000
Group instruction with individualized session	$350,000	$420,000	0.83	$70,000

Source: Levin (1983)