POLICY OPTIONS FOR REFORMATION OF THE POLLUTION LEVY SYSTEM IN CHINA

BY
MIKIKO KAWAI

COURSE: PIA
INSTRUCTOR: DR. STEVE FABER
DATE: APRIL 25, 2000

1. Introduction

The world's environment is gaining more importance, now more than ever. Nowadays, people have a much higher awareness about issues concerning environmental problems. Two years ago, in 1997, people gathered at the Kyoto Conference, which convened to discuss human survival in the next decade in relation to environmental problems. In this conference, we discussed how developed and developing countries should share responsibilities for environmental destruction caused primarily by civilized lifestyles supported in developed countries, and efforts to attain a better standard of living for developing countries.

For developing countries, development activities have been in conflict with environment protection. Development can hardly be accomplished without exploiting natural resources, and once these natural resources are depleted, they cannot be feasibly restored. Exploitation of natural resources brings out numerous additional problems. For example, in Indonesia, slash-and-burn agriculture practices cause massive mountain fires, burning entire precious tropical forests, and creating smog, In China, a waterpower project, which reacquires the construction of a dam and reservoir, has changed some of the characteristics of the physical environment of the river basin and the river itself. However, for peoples' betterment or civilized lives, generating electricity is necessary (Gupta & Asher, 1998, pp.3, 4).

Without high technology to implement environmental-friendly development projects and the government's skill to enact appropriate policies, developing countries have been struggling to find a happy medium between the two. How to go about developing a nation without harming its natural environment and deteriorating peoples' lives has been a key issue. In order to realize environmentally sustainable development, governments of developing countries incorporate environmental management in their nation's priority policies. However, this is not an easy task because accomplishing development and environment management at the same time is costly. Keeping this price as low as possible is another dilemma that developing countries currently face.

In China, as well as other developing countries, economic expansion has transformed the peoples' lives over the last two decades. Such economic advances have made most Chinese citizens' lives much better off. Growth has elevated China into the ranks of the world's economic and political powers, and further growth is expected. China's economy is likely to continue to grow at a swiftly even into the next century because its population, 1.2 billion, eclipses that on the United States four-fold.

Over this course of development, China has been facing several environmental problems such as water pollution, soil erosion, hazardous waste and so on. It seems impossible to prioritize these problems; however, air pollution caused by consuming energy should be ranked at or near the top.

In order to confront these problems, China has gradually enacted environmental management legislation, and has created a system of multilevel environmental protection agencies to implement and enforce it. China has employed conventional instruments of environmental management, especially economic instruments, more creatively in comparison to measures enacted by other developing countries (Panayotou, 1995-1998, p. 434). This paper will discuss several of China's novel economic instruments, particularly the efficiency of a present pollution levy system.

2. Nature of the Problem

Nowadays, developing countries seeking economic modernization and a higher quality of life generally cannot realize their goals without considerably higher energy inputs and by improving energy conversions. China has been able to endow itself with energy resources, and recent economic growth has outstripped the energy consumption. Although China has reduced the energy intensity of its economy (energy consumption per unit of GDP) by around 50 percent, it is still one of the most energy intensive economies in the world (See Table 1). Energy conversions are major cause of injury to the local global environment.

Table 1: Trends of TSP and SO2 Emissions with Economic Growth

Year	GDP (Billion Yuan)	Energy Consumption Mtce	Energy/GDP (tce/MY)	TSP Emissions (Mt)	TSP/GDP (VMY)	SO2 Emissions (Mt)	SO2/GDP (t/MY)
1981	442.5	594	1342	15.20	34.3	8.80	19.9
1982	446.1	621	1392	14.13	31.7	9.60	21.5
1983	534.9	660	1224	13.34	24.9	10.37	19.4
1984	616.1	709	1151	14.32	23.2	10.49	17.0
1985	699.1	767	1097	12.95	18.5	12.58	18.0
1986	761.1	808	1062	13.84	18.2	12.92	17.0
1987	849.1	866	1020	14.45	17.0	13.13	15.5
1988	944.8	930	984	14.36	15.2	14.14	15.0
1989	983.2	969	985	13.98	14.2	15.32	15.6
1990	1020.9	987	967	13.24	13.0	15.60	15.3
1991	1114.8	1038	931	13.14	11.8	16.22	14.5
1992	1273.5	1092	857	14.14	11.1	16.85	13.2
1993	1445.3	1118	773	14.16	9.8	17.85	12.4

Notes: *In real terms, 1978 base., "Primary commercial energy consumption.
Mtce = Million tons of coal equivalent; Mt = Million tons; MY = Million yuan; t = tons
Source: Hanchen & Bingjiang 1995-1998.

In China, severe local and regional air pollution resulting from uncontrolled combustion of coal has been recognized (Smil, 1993, p.100). Much of China's urban citizenry suffers from particulate pollution in ambient outdoor air; essentially the smoke from fossil fuels combustion is visible and irritating to the eyes, throat, and lungs. One study of airborne particulates in five major Chinese cities showed that their concentrations ranged from two to five times the maximum deemed acceptable by the World Health Organization [WHO]. Breathing this material can induce a variety of acute and chronic respiratory problems. Particulate pollution may also pose a serious health threat in indoor settings, where people spend much of their time. Indoor air pollution is especially severe in hundreds of millions of rural households that burn coal, crop wastes, or wood in inefficient and poorly ventilated stoves for cooking and sometimes heating. Such stoves are also used in urban settings, but their health impact is diminishing; especially in large cities, due to improved stove designs and technologies, and the increased availability of alternative fuels, such as natural gas and other technologies.

Emissions of sulfur dioxide (SO2) from coal combustion are another threatening local pollutant to human health. Inhalation of SO2 has been demonstrated to have a direct though lesser effect on acute and chronic health problems, including loss of pulmonary function. SO2 also contributes to another environmental threats; it combines with nitrogen oxides (NOx, also products of combustion) and they are oxidized into the atmosphere to form sulfuric and nitric acids, which are deposited onto the Earth's surface as acid precipitation, more popularly known as acid rain. Acidification is a serious problem expanding in scope, especially in southern China where local coal deposits have a high sulfur content, and where the chemistry of dust and soils cannot buffer its acidity. Acid precipitation is considered a regional hazard because its effects are often felt far from emission sources, even across provincial or national boundaries. It is known to severely damage crops, forests, fisheries, and structures in China. While the focus in this section has been on health effects of such energy-derived pollution, non-health impacts on agricultural productivity are also significant. (Nielsen & McElroy, 1995-1998, pp. 11-13).

Coal combustion brings about not only air pollution but also other environmental disasters. Ash produced by combustion of raw coal by households and in small boilers is another pervading issue. The Ash is disposed in millions of dispersed waste dumping sites, but the disposal of bottom and fly-ash generated by coal-fired power plants and large industrial boilers requires extensive areas for adjacent piling or pounding.

One way to reduce the disposal of mining wastes would be to use them for electricity generation. But the energy content of these wastes is only relatively lower than what good steam coal does, and the plants would become a major source of local air pollution. Hydrocarbon industries demand much less space than coal extraction. However, construction of hydro stations claims flooding and resettlement of millions of people (Smil, 1993, pp. 113,114).

Moreover, elephantine water pollution in China that has resulted from

1. dumping solid wastes into rivers
2. uncontrolled acid drainage from thousands of small and large mines,
3. small leakages of wastes from oilfields, pipelines, refineries, storage tanks translating into spreading contamination of soils, underground and surface waters, and food supplies

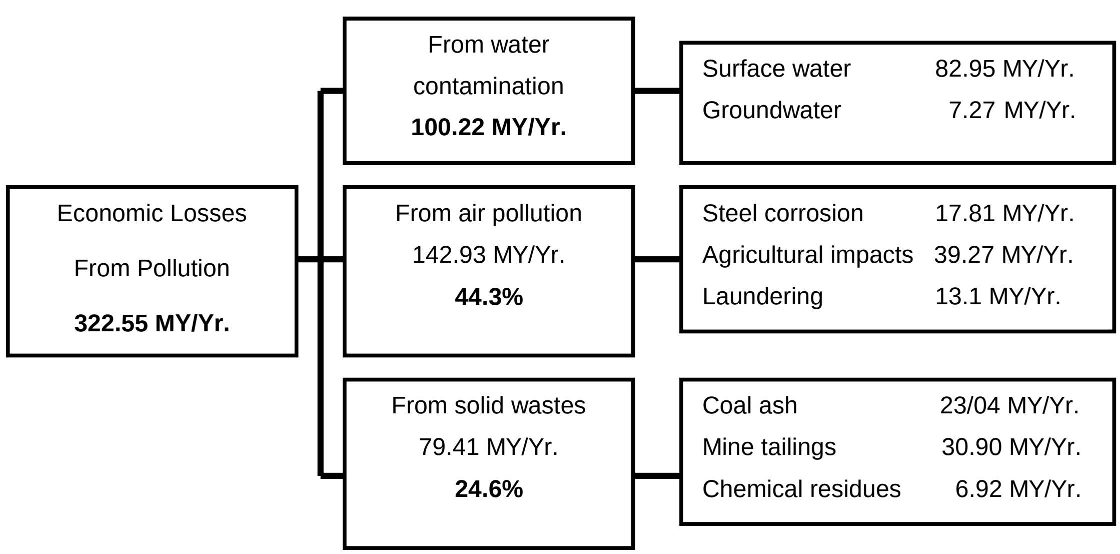
has caused immeasurable damages simply from using coal as en energy resource.

In the World Bank's comprehensive study of air and water pollution in China, a cost approximation of general environmental damage is introduced. According to the study, a projection of 178,000 annual premature deaths could be avoided if China met its mid-range set of ambient standards for a number of air pollutants. The study also estimates the total mortality impacts of indoor air pollution caused by particulate pollution each year in rural China account for 111,000 premature deaths (Nielsen & McElroy 1995-1998, p.14).

This World Bank study also estimates that urban air pollution costs the Chinese economy US$32.3 billion annually in premature deaths, morbidity, restricted activity, chronic bronchitis, and other health effects. Damages from indoor rural air pollution, including premature deaths and morbidity, are estimated at US$10.6 billion annually. The costs of acid rain are total US$5 billion in crop, forest, material, and ecosystem damage. Add in a minor component for lead exposure to children, and the total cost for air pollution is estimated at RS$50 billion per year, or 7.12 % of the GDP (Nielsen & McElroy, 1995-1998, p. 14). The following two cases show two typical examples of losses from Environmental Pollution in two Chinese cities.

CASE 1: Shenyang is old, heavily industrial, and one of the most polluted cities in China suffering from outdated and aging technologies, equipment, high consumption of resources, and energy. Following figure explains details of economic losses in Shenyang.

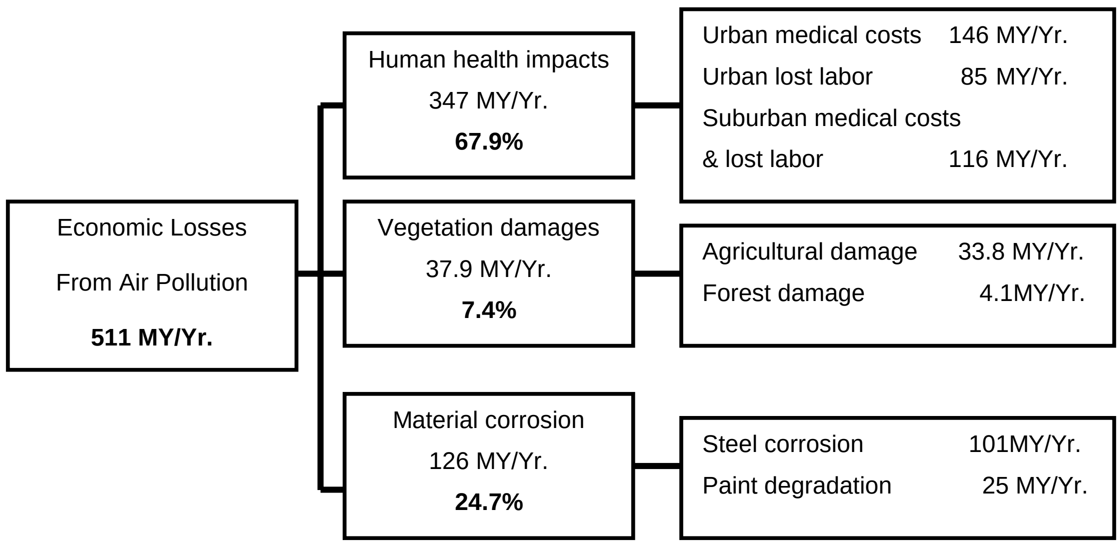
Figure 1: Economic Losses from Environmental Pollution in Shenyang.



Source: Hanchen & Bingjiang 1995-1998.

CASE 2: Chongqing is located in an area where the sulfur content of coal is high, around 4%. This causes heavy SO2 emissions, leading to the worst acid rain deposition in China. It affects the ecosystem's agriculture, the condition of buildings and structures, as well as transportation services and infrastructure. SO2 and particulates also affect the health of people in both urban and suburban areas. The economic losses are heavy, as shown in Figure 2.

Figure 1: Economic Losses from Environmental Pollution in Shenyang.



Source: Hanchen & Bingjiang 1995-1998.

Implementing well-designed policies to reduce air pollution will immediately bring about economic benefits.

3. Past and Present Policies

During the pre-reform era in China before 1978, industrialization focused on heavy industry, an energy-intensive process that left large point sources of pollution – yet it was the main policy of central government. Generally environmental policies were neglected. However, China has been gradually making efforts to implement environmental programs. China's environment is not deteriorating as fast as would be expected for a rapidly developing economy. China's energy use intensity in pollution has been reduced from 13.4 tons of coal equivalent (tce) per 10,000 yuan of GNP in 1980 to 9.4 tce by 1990 (Financial Times, 1992 in Hanchen & Bingjiang, 1995-1998, p.43 1). However, problems still remain. With low levels of economic and technological development, China has limited funds for environmental protection, and their capacity for policy reformation for environmental management remains poor. Hence, the overall situation of environmental pollution in China remains unsatisfactory.

3.1 History and Present of Environmental Policies in China

China amended its constitution in 1978 to include environmental protection. This was followed by framework environmental legislation and a series of environmental regulations.

Environmental objectives at a national level in China have long-run goals dictated by the magnitude of the pollution problem. To attain these goals, the national government considers framing countermeasures against urban and industrial pollution as a priority matter within its environmental policy. Their first goal is to arrest the rising trend of environmental degradation by the year 2000. The second is that the trend should be reversed by the year 2030. These long-term goals have been translated into an environmental policy governed by four overriding principles, often referred to as the “environmental management principles." Forming the basis for detailed regulation, they include "prevention first," "polluter pays,” “beneficiary pays," and "primacy of local level participation and responsibility" (Hanchen & Bingjiang, 1995-1998, p.435).

Environmental policy in China has been formed by two historical legislation changes: the Environmental Protection Laws (EPL) in 1979 and 1989. EPL 1979 introduced a system of regulations, monitoring activities, and enforcement based on two principles: “64 pollution prevention" and "polluter pays." The first principle uses "command-and-control" and includes: (1) the requirement for environmental impact assessment for all new projects and industrial facilities; (2) the requirement that all facilities include pollution prevention measures in their design, construction, and operation (the "three simultaneities" policy); (3) industrial siting restrictions; (4) effluent and emission standards; and (5) the formation of environmental protection units at state, provincial, city, and county levels. The polluter pays principle was embodied in a system of levies or charges on pollutants exceeding the standards (Hanchen & Bingjiang, 1995-1998, p.435).

In the meantime, EPLA 1989, structured upon the earlier law, added further regulatory and incentive elements: (1) an environmental responsibility system to reward (or punish) managers and government officials for meeting (or failing to meet) specified environmental targets; (2) a discharge permit system, first implemented on a trial basis in thirty-two cities; (3) fines for failing to meet environmental targets within a specified period; (4) ranking and publicizing of the environmental performance of major cities based on quantitative indicators of environmental infrastructure and environmental quality; and (5) formation of environmental units in individual enterprises to collect and report effluent and emissions data to monitor standards (Hanchen & Bingjiang, 1995-1998, p.435).

Chinese environmental policies with these objectives are aimed at the protection and eventual improvement of the environment without adverse effects on economic growth and, not necessarily, maximization of social welfare. These are often referred to as 'win-win policies'. However, when conflicts between environmental protection and economic growth occur, the latter priority tends to prevail.

Table 2 introduces the environmental instruments, which are actually used to accomplish the objectives of the Chinese environmental policies.

TABLE 2: Reaulatorv. Economic, and Voluntarv Instruments in China

Regulatory Instruments	Economic Instruments	Voluntary/Suasive Instruments
Ambient air & water quality standards	Pollution levy system emissions (air) effluents (water)	Clean-up campaigns
Effluent & emissions standards for industries & vehicles	Non-compliance penalties ("four small pieces")	Educational programs
Mandated minimum environmental investments (7% of new project funds)	Compensatory & punitive fines (EI & RI)	Environmental awareness campaigns
"Three simultaneities" (design, construction, operation)	Discharge permit system (experimental)	Annual nationwide check-up measured by environmental indices (ranking 37 cities)
Mandatory changes in production technology	Responsibility system (mixed EI & RI)	Positive and negative publicity
Discharge license systems	Sulfur tax (experimental)	Voluntary compliance
Compliance schedules	Emissions trading (experimental)	Environmental awards
Mandatory waste treatment facilities	Grants for pollution control to firms that paid pollution fees	Voluntary fundraising from enterprises
Environmental impact assessment	Competitive grant & loan system for environmental investments	Voluntary labor from the public
Compulsory transfer of funds from bank accounts to pay levies (mixed EI & RI)	Low-interest loans for energy-saving investments	Firms in financial difficulty can negotiate exemptions
Environmental compensation fee (EI & RI)	Subsidies for energy-saving products	
Use of credit policy to implement Environmental Impact Assessments (EIAs) (mixed RI & EI)	Tax breaks & other incentives for recycling	

Source: Hanchen & Bingiiang 1995-1998.

3.2 Use of Economic Instruments in China and Other Countries

As mentioned in the Introduction, to this paper, the efficiency and effectiveness of the pollution levy system is considered. At present, the pollution levy system is widely used in most countries throughout the world as one of the most famous economic instruments in environmental policies. Until the early 1980s, the very few instruments involved the use licenses, standards or bans. Rudimentary major environmental policies originally served as “regulatory’ or ‘command and control’ instruments involving licenses, standards and bans. The practice of using economic instruments is varied depending on which country the regulation is being applied.

Market economy countries, especially OECD member countries, have actively promoted the application of economic instruments to environmental policies and many successful experiences have been noted since the 1970s. The "Declaration on Environment and Development” of the United Nation, adopted in June 1992 at the UNCED Conference in Rio de Janeiro, encouraged a wider use of economic instruments in the formulation of environmental policies by governments in order to internalize environmental costs associated with production and consumption (Barde, 1997, p.34). According to an OECD survey reflecting on the situation in 1987, fourteen OECD countries possessed 150 cases of economic instrument investigations (including subsidies) out of which 80 were environmental charges and taxes. Since then, the situation has continued to evolve and a number of countries have implemented or are intending to introduce new economic instruments. In some countries the number of economic instruments has increased by 50% between 1987 and 1993 (Barde, 1997, p.34).

The application of emission taxes and charges, in the 1970s and 1980s, constituted the first "wave" of economic instruments, which were related mainly to water effluent and solid waste charges. There has been a marked increase in the use of deposit-refund systems (35 to 100% increase depending on the country), due to the steep increase in packaging waste (140 million tons per annum in OECD countries). Since then, the situation has evolved into an increase in the use of environmental taxes. This is particularly true for the Nordic countries (Denmark, Finland, Norway, Sweden) and the Netherlands; Belgium and Austria have also introduced a number of new environmental taxes as well. The great number of new product taxes, in particular "green" energy taxes, is a key feature of this evolution. Carbon taxes have been introduced in Denmark, Finland, Norway, Sweden and the Netherlands; Switzerland is considering the introduction of a Carbon tax. Sulphur taxes are applied in Denmark, France, Norway and Sweden. Tax differentiation between leaded and unleaded gasoline has significantly contributed to the increased use of unleaded gasoline in several countries. A variety of polluting products are also subject to “ecotaxes,” e.g., pesticides, fertilizers, lubricant, and packaging (Barde, 1997, pp.34,35).

The Chinese government stated that every level of the government should make full use of economic instruments and market incentives to promote sustainable development and protect the environment, such that market prices completely reflect the environmental costs of economic activities. China is presently developing a market economy, and the fundamental role of its market mechanisms are increasingly apparent. It is crucial that China accelerates the use of economic instruments in environmental policy and applies such instruments more widely to environmental protection (Jinnan & Xinyuan, 1997, p. 15).

China began applying a pollution levy system across the country in 1982. It now covers five fields: waste water discharge, waste gas emissions, solid waste disposal, noise low-level radioactive waste discharge, [and 113 items.] The charges are levied only when emissions exceed national standards; in effect, the system operates in the form of non-compliance charges. In 1995, the levy was implemented over 368,200 enterprises and the revenues arising out of the levy reached 3.713 billion yuan, which is 0.6% of national financial income in 1995 (Jinnan & Xinyuan, 1997, p.18).

The overall performance of China's environmental economic policy, however, is varied. While provinces, which have tightened enforcement, have witnessed a substantial decline in the water pollution intensity, or pollution per unit of output, for factories which are under regulatory supervision, some regulatory incentives for air pollution control have actually weakened since 1987. Industrial discharges continue at very high levels, seriously contaminating the atmosphere of many cities. If levies are not adjusted to give enough incentives, industrial pollution intensities, pollution loads and the contamination of China's ambient environment will increase. An alternative mode of though suggests that China's current industrial growth could be good enough to offset projecting damages for the future by bringing benefits to people. In order to determine the effectiveness of tighter regulation in coming operations, alternative choices for China's policy future will be discussed.

4. Policy Options

1. The 'win-win' scenario – based on the idea that pollutants are better off by present ineffective levy levels without any cost explicitly incurred for abatement cost. In this scenario, economic development is already presumed to be beneficial on other grounds and can offset damage of pollution overall. Air pollution levies in this scenario are hold at 1993 level.
2. The stricter-regulation scenario – provides explicit incentives to reduce pollution intensity, which will complement the impact of economic reform. In order to verify the degree of strictness affecting pollution reduction, two scenarios are set:

One is air pollution levies are increased by 5% annually. The second is 10% annually.

5. Criteria

In order to compare future effects of the 'win-win' policy and the stricter regulations, I refer to the econometric study done by the World Bank (1997), in which two criterions are applied into the both scenarios.

1. Projected Health Damage – number of deaths from SO2 pollution is estimated using the following factors: (1) industrial air pollution loads, (2) atmospheric pollutant concentrations, (3) risk of individual daily mortality.
2. Projected Abatement Cost and benefit – if tightening regulation should be pursued, what is the cost-effectiveness of tightening regulation, and to what degree should regulation be tightened? To answer this questions, abatement costs and benefit of pollution control will be projected in the two scenarios.

6. Analysis of Options

6.1 Criteria 1: Health Damage

6.1.1 Analysis Method

1. Health Damage - Number of deaths is projected by the following procedure.

1. **TOTAL PROJECTED SO2 LOAD** is calculated based on the econometric study of variations in pollution intensity for SO2, which reflects significant intensity factors: The effective pollution levy: large plant share of output; SOE share of output; and the shares of exceptionally clean and dirty sectors. The log

equation used for the econometric study to estimate projected SO2 loads for three scenarios is referred as follows:

$$\text{Log } AIRIr = \alpha 0 + \Sigma\alpha 1k \bullet skr + \alpha L \bullet LARGEr + \alpha G \bullet STATEr + \alpha p \bullet \log PLWr + Er$$

Prior expectations: $\alpha L < 0$, $\alpha G > 0$, $\alpha p < 0$

Where *AIRIr* = Air pollution intensity (discharge / industrial output)
skr = The industrial output share of the kth sector
LARGEr = The industrial output share of large plants
STATEr = The industrial output share of state-owned plants
PLWr = Effective air pollution levy per unit of pollutant discharge
Er = A stchastic error term incorporating provincial components

2. **PROJECTING SO2 CONCENTRATION IN ATMOSPHERE** - According to the study of the World Bank, there is an elasticity linkage of loads to ambient concentrations of SO2. Using this relationship, ambient SO2 concentration is projected. If SO2 emissions density or emissions per unit area (loads) increases by 1% in a particular city in a year, the year's atmospheric concentration increases by **0.51%.** Using this elasticity, future concentrations of SO2 is estimated as follows:

Previous year's concentration x (1.51 x Rates of change of estimated pollution load) = This year's concentration

3. **PROBABILITY OF INDIVIDUAL MORTALITY FROM SO2 POLLUTION -** The empirical study done by Xu, et.al. (1994) finds a strong relationship between atmospheric concentrations of SO2 and mortality rates. The statistical method, which Xu uses for the study, is a regression analysis of the daily deaths counts. The regression model is referred as follows;

$$\text{Log } E(yt) = \alpha xt + \beta zt + \Sigma\gamma j yt\text{-}j$$

Where $t = 1, 2\ldots, 365$ (day of the year)
$j = 1, 2 \ldots, 5$ (log day for mortality)
yt = the number of deaths on days

x_t = the vector of controlling indicator variables on day t for quintiles of temperature, quintiles of humidity, and an indicator for Sunday (the only day of the week significantly different)
z_t = the vector of air pollution variables on day *t*

The regression coefficients are estimated from the calculation. The result shows highly significant associations were found between SO2 and daily mortality. The risk of total mortality was estimated to increase by 11% with each doubling in SO2 concentration.

4. **ESTIMATED # OF DEATHS FROM SO2 POLLUTION -** Multiplying the individual mortality probability from SO2 by city's projected population, the number of deaths from SO2 pollution is estimated.

6.1.2 Analysis Result

1. Total SO2 loads in China

Figure 3

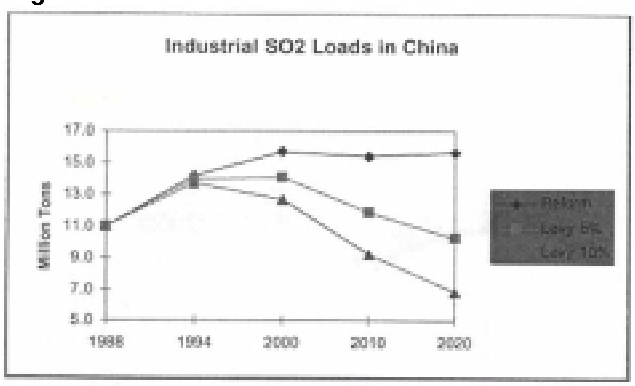


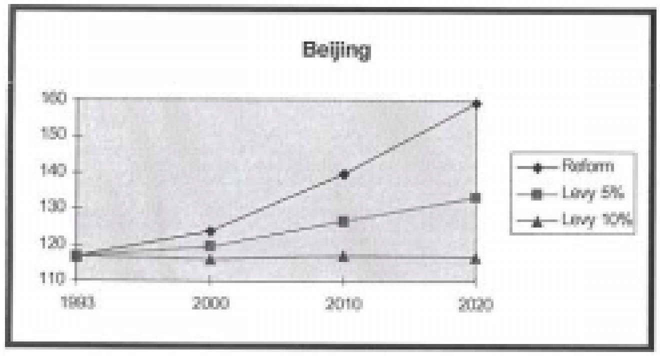
Table 3

	1994	2020
'win-win' scenario	14.2 millions tons	15.7 million tons
5% stricter levy	14.2 millions tons	10.3 million tons
10% stricter levy	14.2 millions tons	6.9 million tons

In the 'win-win' scenario, contributions made by the air pollution intensity of industrial productions to reduce SO2 emissions is not enough to offset the total amount of SO2 emissions at 1994 level. However, the stricter levy scenarios at both levels show improvements.

2. SO2 Ambient Concentration in Beijing

Figure 3



Comparing rising levels of SO2 concentration of the 'win-win' scenario, [117µg/m^3 in 1993 to 159µg/m^3 in 2020], the stricter levy scenario with a 5% annual increase in the effective air pollution levy shows significant effects to slow the deterioration of air quality, and a 10% annual increase in the levy helps to maintain the 1993 level.

3. As seen in the figure 4, for the 10% levy increase, projected deaths in 2020 are 67% less than in the 'win-win' scenario.

Table 4

	'win-win' scenario	Levy 5%	Levy 10%	% Decrease for Levy 10%
Annual Death	4500	3200	2400	47

4. In order to see overall results of stricter regulation, the cumulative projected annual deaths from 1997 to 2020 are calculated in the three scenarios. According to the calculation, 14,000 lives and 24,000 lives are saved by a 5% annual increase and 10% annual increase, respectively.

According to the health damage criteria, the stricter regulation can bring enormous differences in pollution abatement. Although stricter regulation is applied, a heavy loss of life still exists. In view of these projected losses, further abatement could possibly be too costly to justify the loss of so many lives. In order to answer the question, how much air pollution would be socially worthwhile to abate, economic efficiencies of stricter regulations will be assessed.

6.2 Criteria 1: Abatement Cost & Benefit

Characteristics

Results of the econometric analysis by the World Bank show two significant characteristics of the MAC of SO2 in China. First, the abatement cost of SO2 increases steadily at the margin of degree of abatement. Second, the MAC of SO2 varies with the industrial sector, the size of firms, firm ownership, and degree of abatement. These characteristics affect China's policy making in regards to the optimal level of regulation for air pollution reduction.

Cost-Effectiveness of Stricter Regulation

Increasing marginal abatement costs of SO2 suggests that air pollution abatement may no longer be cost-effective beyond the certain level, because in such situation, the same financial resources can be used for other investments with greater lifesaving potential. Alternatives include: investment in health facilities, public health education and direct investment in productive capital to improve health by increasing income levels. The cost/benefit analysis predicts that the expected marginal benefit from further SO2 abatement is greater than its marginal abatement cost. If so, Chinese government should implement a stricter regulation policy. Taking Beijing's case as an example, cost-effectiveness of a stricter policy in a city is analyzed.

Marginal Benefits of Abatement (MB)

Population of Beijing = approximately 11,120,000 (1993);
Mortality rate = 0.611%;
Total deaths = 0.00611*11,120,000 = 68,000;
Annual SO2 emissions = about 366,000 tons

If Beijing decreases 1,000 tons of SO2 emissions by abatement, Beijing's SO2 concentration in atmosphere decreases by 0.139% (0.139 = 0.51*1000/366000*100; 0.51 Elasticity of SO2 emission to concentrations). By applying the Beijing dose-response results by Xu, et. al., to this concentration change, from the calculation in the proceeding section of health damage [6.1 Criteria 1: Health Damage], an annual saving of 10.4 lives per 1,000 tons can be estimated; that is, 1 life saved per 100 tons abated annually. Because the average annual wage of a worker in Beijing was $800 in 1993, the annual benefit of lifesaving by 100 tons of SO2 abatement is $8,000 at a 10% of discount rate. This $8,000 is the marginal benefit from 100 tons of SO2 additionally abated.

Computation of Marginal Costs of Abatement (MCA)

The MAC for large plants (SOE and non-SOE) varies from $2,860 at 15% of abatement to $27,000 at 85% abatement. When the MB from 100 tons of SO2 abatement is $8,000, the optimum level of abatement is achieved at 60%, where MAC and MB cross (Figure 4). On the other hand, MAC for smaller plants (SOE and non-SOE) varies from $8,000 at 15% of abatement to $40,000 at 75% of abatement, because small plants are less cost-effective in abating SO2. When MB is $8,000, the level of abatement can be balanced at 15%.

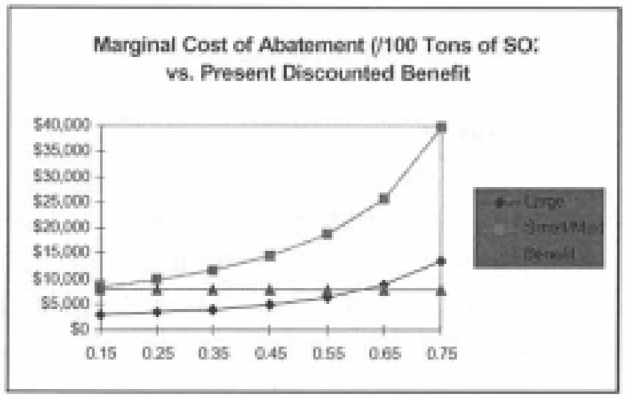


Figure 4

According to China's National Environmental Protection Agency, Beijing's current abatement rate for industrial SO2 is only 2.5%. Considering the cost-effectiveness of SO2 abatement, Beijing needs to adopt stricter regulations to reduce SO2 concentrations in atmosphere. Even by adopting the lowest abatement rate among possible choices, **15%**, the incremental cost for 100 tons of SO2 abatement by large plants (main polluters) is estimated to be only $2,860, when the incremental benefit of lifesaving is $8,000. In this case, estimated social rate of return to additional 100 tons of abatement is approximately 180%. This Social rate of return of stricter regulation is sufficiently attractive over other investments in China's urban health sector. Therefore, Beijing should make its regulation of the SO2 abatement level stricter up to, at least, 15%.

7. Keys to The Future and Conclusion

In spite of the commonly held belief that pollution abatement is very costly, the analysis above concludes that stricter regulations of air emissions in heavily polluted areas serve as very cost-effective options for public health improvement. Therefore, it is strongly recommended that China implement stricter regulations for air pollution.

Some factors are identified as keys to effective policies for air pollution abatement. They are:

1. continued economic reform
2. cost-effectiveness of pollution levy
3. targeting on low cost sources, and
4. rapid socio-economic development.

In considering these factors, which affect the level of pollution abatement in a direct or indirect way, the Chinese government can substantially improve their urban environment with well-designed and well-implemented policies.

References

1. Barde, J. (1997). Economic instruments for environmental protection: Experience in OECD countries. In OECD, *Applying market-based instruments to environmental policies (pp.* 31-58). Paris, France: OECD.

2. Chung, C. (1997). Introduction. In OECD, *Applying market-based instruments to environmental policies (pp.* 7-11). Paris, France: OECD.

3. Curbing pollution an urgent task. (1996, August 5). *Beijing Review, p.4.*

4. Dasqupta, S., Wang, H., & Wheeler, D. (1997). *Surviving Success: Policy Reform and the Future of Industrial Pollution in China.* Available at www.worldbank.org

5. Economy, E. (1999, March). Painting China green: China needs to work on environmental policy. *Foreign Affairs, p.* 14.

6. Elvin, M., & Ts'ui-jung. (Eds.). (1998). *Sediments of time: Environment and society in Chinese history.* Cambridge, England: Cambridge University Press.

7. Environmental measures. *World Development*, *p.* 1227.

8. Environmental protection focuses. (1999, July 12). *Beijing Review, pp.* 18-20.

9. Folmer, H., & Tietenberg, T. H. (Eds.). (1997). *The International yearbook of environmental and resource economics 199711998: A survey of current issues.* Chellenham, Glos, UK: E. Elgar.

10. Gan, L. (1999, Spring). Implementation of agenda 21 in China: Institutions and obstacles. *Environmental Politics,* pp.318-326.

11. Gupta, A., & Asher, M. G. (1998). *Environment and the developing world. Principles, policies and management.* New York, NY. John Wiley & Sons Ltd.

12. Hanchen, W., & Bingjiang, L. (1995-1998). Policyrnaking for environmental protection in China. In McElroy, Michael B., Nielsen, Chris P., & Lydon, Peter (Eds.), *Energizing China: Reconciling environmental protection and economic growth.* (pp.371-403). Newton, MA: Harvard University Press.

13. International Energy Agency, Chinese State Planning Commission, & Chinese 11rNational People's Congress (Environment and Resources Protection Committee). *(1997). Energy efficiency improvements in China: Policy measures, innovative finance, and technology deployment.* Paris, France: OECD.

14. Jahiel, A. R. *(1998,* Dec.). The organization of environmental protection in China: Special issue; Chin's environment. *The China Quarterly, pp.757-759.*

15. Jinnan, W., & Xinyuan, L. *(1997).* Economic policies for environmental protection in China: Practice and perspective. In OECD, *Applying market-based instruments to environmental policies (pp. 15-29).* Paris, France: OECD.

16. Marks, R. *B. (1997). Tigers, rice, silk, and silt: Environment and economy in late imperial south China.* Cambridge, England: Cambridge University Press.

17. Miller, K. A. *(1997).* The use of mathematical models in policy evaluation: comments. In Martin, Wade E., & McDonald, Lisa A. (Eds.), *Modeling environmental policy (pp. 185-197).* Norwell, MA: Kluwer Academic Publishers.

18. Nielsen, C. P., & McElroy, M. B. *(1995-1998).* Introduction and overview. In McElroy, Michael B., Nielsen, Chris P., & Lydon, Peter (Eds.), *Energizing China: Reconciling environmental protection and economic growth (pp.371-403).* Newton, MA: Harvard University Press.

19. OECD. *(1996). Coherence in environmental assessment: Practical guidance on development co-operation projects; Practical guidance on development co-operation projects.* Paris, France: OECD Publications and Information Center.

20. (1996). Environmental Performance in OECD countries: Progress in the 1990s. Paris, France: OECD Publications and Information Center.

21. OECD Group on Environmental Performance. *(1997). OECD environmental performance reviews: A practical introduction.* Paris, France: OECD.

22. Panayotou, *T. (1995-1998).* The effectiveness and efficiency of environmental policy in China. In McElroy, Michael B., Nielsen, Chris P., & Lydon, Peter (Eds.), *Energizing China: Reconciling environmental protection and economic growth (pp.431-472).* Newton, MA: Harvard University Press.

23. Patton, C. V., & Sawicki, D. *S. (1993). Basic methods of policy analysis and planning.* Englewood Cliffs, NJ: Prentice Hall.

24. Peterson, K. J. *(1999,* May). Cleaning up China: Government planning new environmental measures. *World Press Review, p.22.*

25. Ross, L. *(1998,* Dec.). China: Environmental protection, domestic policy trends, patterns of participation in regimes and compliance with international norms. *The China Quarterly, pp.809-810.*

26. Qiuping, *C. (1998,* Sept. *7).* Environmental protection in action. *Beijing Review, pp.8-12.*

27. Smil, V. *(1993). China's environmental crisis: An inquiry into the limits of national development.* New York, NY. An East Gate Book.

28. Tietenberg, T. H. *(1998). Environmental economics and policy*. Reading, Mass.: Addison-Wesley.

29. *(1996). Environmental and natural resource economics.* New York, NY. HarperCollins College.

30. *.(1994). Economics and environmental policy.* Aldershot, Hants, England: E. Elgar.

31. Zhang, W., Vertinsky, 1, Ursacki, T., & Nemetz, P. *(1999,* Spring).Can China be a clean tiger?: Growth strategies and environmental realities. *Pacific Affairs, p.23.*

32. Zhou, F. *(1997).* Economic development, energy, and the environment in the People's Republic of China. In Kaya, Yoichi, & Yokobori, Keiichi. (Eds.), *Environment, energy, and economy (pp.367-37 1).* Tokyo, Japan: United Nations University Press.

33. Xu, X., & Dockery, D. W. (1994). *Air Pollution and Daily Mortality in Residential Areas of Beijing, China,* "Archives of Environmental Health", 49(4), 216-222.