Energy Futures and Acid Rain Problems in Northeast Asia – Perspective of the Republic of Korea

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I. Introduction

There is a growing concern over transboundary air pollution problems such as acid precipitation and global warming in Northeast Asia. Acid rain has ecological consequences in that it affects the soil, vegetation, and especially forests and lakes. It causes economic damage to man-made structures and it also affects human health. While Europe and the US found ways to control transboundary transportation of sulfur dioxides, Northeast Asia, surrounded by the fast growing, most populous countries, confronts a growing risk from acid rain.

There are basically two positions in dealing with regional acid rain control proposals. One is a cost-sharing principle and the other is a strict "polluter pays" principle. The cost-sharing position stems from the view that acid rain is a regional problem, the solution to which can be found through cooperation among countries within the same atmospheric region. The "polluter pays" position sees the problem as simple externality and insists that the polluter should compensate for the loss inflicted upon the polluted countries.

Northeast Asia is in an infant stage in establishing a regional cooperative institution comparable to that of Europe. So the first task is to establish a permanent cooperative body, which would deal with transboundary problems in Northeast Asia. Then a proper convention and protocols would be proposed to set a total emission level of SO_2 in the region. Based on this overall target, each country's reduction level would be negotiated. Perhaps an integrated approach toward all transboundary pollutants including SO_2, NOx, and CO_2 could be more cost-effective since all the transboundary problems have not yet been properly dealt with in this region.

In this paper we will first evaluate the US sulfur emission trading program and the cooperative mechanism developed in Europe. Then energy consumption and sulfur emission trends in Northeast Asia will be reviewed. Lastly the possibilities of applying the experiences of US and Europe to the Northeast Asian acid rain problem will be studied.

II. Cooperative Mechanism to Control Sulfur Deposition in Western Countries

1. US Sulfur Emission Trading Program

(1) Background and Objective

On November 15, 1990, the US Clean Air Act Amendments became law. Title IV of this eleven-title Act contains the acid rain control program, which directly addresses the problems of long-range transport and transformation of air pollutants. The objectives of the acid rain program are to reduce the adverse impacts of acid deposition through a 10-million-ton reduction in annual SO_2 emissions and a NOx reduction of around 2 million tons from the 1980 levels; and to achieve these reductions at the lowest costs by employing traditional methods and an emission allowance trading system (Klaassen, 1996, p.145). The outstanding features of the acid rain control program are its relative stringency and its market-based implementation scheme. The acid rain control program and its emissions allowance trading system provide an interesting case study in public policy development and offer useful lessons for the greenhouse gas debate. The emission trading scheme allows utilities to choose the most cost-efficient way to reduce emissions. Each allowance permits an emission unit to emit one ton of SO_2 during or after a specific year. An allowance is defined as a limited authorization to emit SO_2. However, it does not constitute a property right and does not limit the authority of the US to terminate or limit such authorization (US Congress, 1990, pp. 2591-2592). The environmental community's support for emissions trading depends on the integrity of both the reduction targets and the trading system itself. The most important provision uniting the government with the environmentalists was the cap on total SO_2 emissions. The "cap-cum-trading" deal forged an alliance that effectively disarmed acid rain control opponents and paved the way to the first acid rain control legislation and the first extensive market-based provisions in US environmental law (Kete, 1992, p. 83).

Although SO_2 emissions in the United States had declined from their peak of 33 million tons in 1973 to 25.9 million tons in 1980, the 1990 Clean Air Act Amendments set a goal of further reducing SO_2 by 10 million tons below the 1980 level to protect public health and the environment. Total SO_2 emissions were around 23 million tons in 1985. In the same year, electric utilities emitted 16 million tons. The acid rain program establishes a national cap on the SO_2 emissions of all utilities of 8.95 million tons/year. This is a reduction of around 10 million tons, comparable to the 1980 level of the electric utility emissions. This cap is to be implemented in two phases. Phase I started in 1995 and required the 110 highest emitting electric utility plants in 21 eastern and midwestern states to meet an interim ceiling of 5.7 million tons. Phase II began in 2000 and includes not only these 110 units but also smaller, cleaner plants throughout the US. With Phase II, a national cap of 8.95 million tons of SO_2 was placed on the number of allowances. Initial allowances are allocated for each year beginning in 1995. At the end of each year, each unit must hold allowances at least equal to its annual emissions. Furthermore, regardless of the number of allowances a unit holds, it is never entitled to exceed the ambient air quality standards for public health. The unit is free to buy the allowances, but it might not be able to use them to increase emissions if this threatens to violate ambient standards (Klaassen, 1996, p. 146).

(2) Evaluation

It is too early to evaluate the success of the sulfur trading scheme in the US, because Phase I only started in 1995. However, it is possible to study the expected cost savings, to compare expected market activity and prices with reality, and to analyze the circumstances that have influenced the market so far. <Table 1> shows that the sulfur trading program has the potential to cut costs by US $9.4 to $13.4 billion over the lifetime of the program. This is a reduction in costs of 40% to 45%. Here, costs consist of direct pollution control cost measures and the administrative implementation costs. The pollution control cost estimates are based on a linear programming model and assume a perfect permit market. Implementation costs consist of allowance system, monitoring, and permit costs.(Klaassen, 1996, p.148)

<Table 1> Expected Cost Savings of Sulfur Trading (1995-2010)

(million US$, 1990 value)

Type of costs		Traditional control	National trading program	Cost savings
Pollution control		19.000 to 30,900	9,500 to 17,100	9,600 to 13,800
Implementation	Allowance system	0	207 to 416	-207 to -416
	Monitoring	2,512	2,395	117
	Permits	0	68	-68
Total costs		21,612 to 33,412	12,170 to 19,979	9,442 to 13,433

Sources: ICF (1991, 1992).

Quoted from Ger Klaassen (1996), p.149.

The evidence thus far indicates that the program has been largely successful. However, actual allowance trading has not been as active as expected. There are various ways to achieve compliance under Title IV in addition to allowance trading. Those are intra-firm reallocation of emission allowances, fuel switching and/or blending, installing scrubbers (flue gas desulfurization), retiring plants, repowering plants, energy conservation, reduced utilization, and substitution among facilities. In principle an active allowance market is neither a necessary nor sufficient condition for cost effectiveness. However, under Title IV allowances are allocated on the basis of historic emissions without reference to cost, so one might anticipate ample trading. In fact not much allowance trading has occurred, but the prices of abatement options available to utilities have undergone dramatic changes since 1990. These changes stem from changes in the prices of rail transport of low sulfur coal and increased productivity in mining as well as from innovations in the use of fuel blending and in the design and use of scrubbers. However, we can hypothesize that changes in compliance costs are to a significant degree attributable to regulatory innovation embodied in Title IV. Even in the absence of robust allowance trading, the program has empowered utilities with the flexibility to take advantage of exogenous changes in input markets, such as a decline in the cost and an increase in the availability of low sulfur coal. Moreover this flexibility has promoted competition between input markets, which in turn has encouraged innovation and amplified cost savings. Hence, success to date is the result of fundamental regulatory reform of environmental regulation that has promoted efficient implementation through economic competition. Nonetheless, future performance standards may not be sufficient if low sulfur coal markets become constrained, especially after the year 2000 when Phase II of Title IV will greatly expand the program's coverage. Firms then may face widely disparate marginal costs for compliance, and allowance trading may become essential to the program's success (Burtraw, 1996, p. 81).

The next question is why the price of allowances has been far below the forecast price. <Table 2>

presents the range of price forecasts and realizations over the last few years. Before passage of the Clean Air Act, estimates of marginal abatement costs were as high as $1,500 per ton, which is the figure stipulated in the Act for direct allowance sales by the EPA. In debates surrounding the 1990 amendments, the EPA cited estimates of marginal abatement costs about half as high, and these costs became the basis for estimates of allowance prices. Since passage, estimates have fallen further. Through the first half of 1995, the price of allowances traded privately was about $179 and fell to the low $100s by year's end. The marginal price of 1995 allowances in the EPA auction administered by the Chicago Board of Trade (CBOT) has ranged from $122 to $140 (Burtraw, 1996, p. 83).

<Table 2> Marginal Cost Estimates and Realizations for Compliance Options

Industry Estimates Pre-1989	EPA 1990 Estimate	Early Allowance Trades	Early 1995 Allowance Trades*	1993 CBOT Allowance Auction	1994 CBOT Allowance Auction	1995 CBOT Allowance Auction
$1500	$750	$250	$170	$122	$140	$126

Source: Rico (1995).
Quoted from Burtraw (1996), p.84.

<Table 3> presents three estimates of the Phase I compliance activities of utilities. Over half of the plants affected by Phase I are fuel switching and/or blending. The next most common strategy is intra-utility offsets among facilities and pre-Phase I actions. Compliance is achieved by either over-compliance in one facility (accompanied by under-compliance in another facility) and/or reaching compliance criteria prior to Phase I in order to earn bonus allowances. Scrubber installations have been less common. Inter-utility allowance trading also has been less common. As of 1995, only 12 utilities have bought more than 5,000 emission allowances from other companies. From March 1994 through March 1995, the first year of the EPA's Allowance Tracking Program, about 28.9 million allowances were transferred between utilities or from brokers or fuel companies to utilities (USEPA, 1995).

<Table 3> Comparison of Compliance Strategies Estimates

Compliance Strategy	**GAO (94)**	**Rico (95)**	**EIA (94)**
Switch and/or Blend Coal	55%	63%	59%
Purchase Allowances [a]	3%	9%	15%
Install Scrubbers	16%	11%	10%
Pre-Phase I Compliance [b]	18%	15%	10%
Switch to Natural Gas/Oil	5%	1%	3%
Retire Plants/Repowering	3%	1%	2%
Total	100%	100%	99%

a. The EIA finds that 15% of utilities are using allowances in combination with other strategies.
b. For Rico (1995) and GAO (1994), this includes reduced utilization and substitution of Phase II sources.
Source: Burtraw (1996), p.90.

2. Regional Cooperation to Control Sulfur Emissions in Europe

(1) Acidification in Europe

The European Monitoring and Evaluation Program (EMEP) was set up in 1978 to monitor the movement of pollutants and to determine where the deposition of pollutants released from each source occurs. The surface of Europe is divided into squares with grid lines 150 km apart. There are about 100 monitoring sites which are used in the EMEP model and these are termed arrival points (Newbery, 1990, p. 302). The information generated by EMEP is remarkably useful, not only in quantifying the level of pollution, but also in identifying efficient and feasible abatement policies. The information on deposition can be used to draw maps showing the average acidity of precipitation over Europe using contour lines of increasing levels of acidity. The EMEP tables can also be used to throw light on the political economy of pollution control.

The next question one can ask of the EMEP data is whether there are significant opportunities for bilateral bargaining between pairs of countries over pollution levels. One way to identify such opportunities is to look for instances where the volume of bilateral pollution exchange is large relative to total depositions, and where trade is bilateral rather than unilateral. Bilateralism can be measured by the difference between exports and imports. Another possible question to ask is which pairs of countries have large net trade balances in pollution which might lead to financial negotiations over pollution levels. The following countries have net imports from another country which are greater than 5% of total depositions: Poland from Germany (19%); Demark from Germany (12%); Scandinavia from Germany (10%); Scandinavia from Poland (9%); Russia from Poland (9%) and so on (Newbery, 1990, p.306).

(2) Regional Cooperation

A. The Convention on Long-range Transboundary Air Pollution (CLRTAP)

It was not until the 1972 United Nations Conference on the Human Environment that the threat posed by acid rain was put on the international agenda. The UN conference accepted the principle that states must ensure that activities within their jurisdiction do not cause damage to the environments of other states. A Swedish case study in 1972 confirmed the damaging impact of sulfur and acid precipitation on materials and ecosystems. The OECD (Organization for Economic Cooperation and Development) conducted an international study to estimate the local and foreign contribution to each country's deposition of sulfur in 1977 and 1979. This study came to the conclusion that long-range transport of sulfur compounds was indeed occurring. It showed, among other things, that more than 50% of the atmospheric sulfur deposition in Austria, Finland, Norway, Sweden, and Switzerland came from foreign sources. Although not all countries agreed with the result, the OECD study provided a strong impetus to call for international policies to control transboundary sulfur pollution. The UN/ECE based in Geneva, provided a unique forum where both West and East could meet on equal footing to find solutions to control acid deposition in Europe, and a meeting of the ministerial level was held in Geneva in November 1979. This meeting resulted in the signing of the Convention on Long-range Transboundary Air Pollution (CLRTAP). This convention constitutes a framework within which contracting parties identify the problems posed by transboundary air pollution and accept the responsibility for taking appropriate steps. The convention was signed by 35 parties, including all the countries in Europe and two republics of the Soviet Union, Belarus and Ukraine. It was put into force in March 1983 after it had been ratified by 24 parties. The convention establishes an Executive Body as the supreme policy-making assembly. The second institutional layer consists of intergovernmental working groups as well as the Steering Body to EMEP (Klaassen, 1996, p. 188).

B. The First Sulfur Protocol

In March 1984, ten countries agreed to reduce emissions by 30%. Because at that time there was limited knowledge on abatement options, 30% was taken as a percentage that was feasible. This 30% club was extended in June 1984 to a group of 18 at the conference in Munich. The First Sulfur Protocol was opened for signatures in Helsinki in 1985 and has been signed by 20 parties. The basic provision of the Protocol was that parties were to reduce their annual sulfur emissions or their transboundary fluxes by at least 30% as soon as possible, or at the latest by 1993, using 1980 as a basis for calculating reductions.

C. The Second Sulfur Protocol

Negotiations on the Second Sulfur Protocol started in 1991. They came to a close in June 1994, when the Protocol was signed by 26 parties in Oslo. At the end of 1994, 27 parties signed. A major new element in the Second Sulfur Protocol is the application of an effect-oriented approach by basing the extent of emission reductions on the susceptibility of natural ecosystems to acid deposition. The ultimate goal is to reduce emissions so that critical loads and levels are not exceeded. Critical loads are defined as the maximum level of deposition below which no damage to sensitive ecosystems occurs. Critical levels refer to the concentrations of pollutants above which adverse effects on receptors may occur.

Economic, technical, and other constraints may make it difficult to achieve the necessary reduction everywhere and immediately, so interim steps might be needed. An accepted step in this approach is the generation of target loads that not only take into account environmental sensitivity (critical loads) but also technical, social, economic, and political considerations. Critical loads remain a long-term objective toward which the Second Sulfur Protocol makes a gradual move. As an interim target, the difference between the sulfur deposition in 1990 and the 5% critical loads must be reduced by at least 60% (Amann et al., 1993). The resulting targets for the deposition of sulfur have to be attained in a cost-efficient way, minimizing total European costs subject to the condition that countries carry out at least those reductions that they were planning to undertake anyway. The scenario, called A5, formed the basis for further negotiations. The A5 scenario would require an average reduction of 59% over 1980 levels. Although A5 served as the reference point, further negotiations led to a slightly different schedule for emission ceilings. The A5 scenario intends to reduce sulfur deposition to protect 95% of all ecosystems in each singular grid. Several countries did not agree to carry out the required reductions in the year 2000 as scenario A5 proposed. The reductions of several countries were therefore postponed until 2005 or 2010 (Klaassen, 1996, p. 197). The sulfur emission ceilings and percentage emission reductions in the second sulfur protocols are shown in <Table 4>.

The differentiated national emission ceilings are one of the two tiers of the Second Sulfur Protocol. In principle, these ceilings were based on an effect-oriented (critical-loads-based) approach combined with political horse trading. Broadly speaking, the critical load refers to the amount of acidic deposition which can fall on a given area before harmful environmental impacts occur (for a summary of European studies on estimates for the costs of different types of damages, see pp. 311-313 of Newbery, 1996).

The relationships between emissions and depositions are calculated by the EMEP program as part of the CLRTAP. Emissions are accumulated within national geographical boundaries. Deposition d_j is mapped onto each 100-by-100-kilometer square according to the formula:

$$d_j = b_j + \sum_i e_i t_{ij}$$

where b_j is the background deposition on the jth square, e_i is the emission from the ith country and t_{ij} is the "transfer coefficient" from the ith country to the jth square. For the most part, actual deposition levels in Europe considerably exceed critical loads. The Oslo Protocol set national emission ceilings -- i.e. limits to e_i for each country i -- with the declared aim of reducing the gap between existing deposition levels and agreed critical loads. So, for example, these deliberations resulted in emission ceilings for the UK which require a 50% reduction in sulfur emissions by the year 2000, a 70% reduction by the year 2005, and an 80% reduction by the year 2010, relative to 1980 emission levels (Jackson and Bailey, 1996, p.71).

The second tier of the Oslo Protocol is a source-based approach consisting of emission standards for new large combustion plants and fuel standards specifying the maximum sulfur content in gas oil. The fuel standards require parties to lower the sulfur content in gas oil to 0.05% for on-road vehicles (diesel oil) and 0.2% otherwise, no later than two years after the Protocol enters into force. In the case of limited supply, the lowering of the sulfur content may be postponed for 10 years.(Klaassen, 1996, p. 198)

<Table 4> Sulfur Emission Ceilings and Percentage Emission Reductions in the Second Sulfur Protocol

	Emission levels (kt SO_2/year)		Sulfur emission ceiling (kt SO_2/year)			Percentage emission reductions (base year :1980)		
	1980	1990	2000	2005	2010	2000	2005	2010
Austria	397	90	78			80		
Belarus	740		456	400	370	38	46	50
Belgium	828	443	248	232	215	70	72	74
Bulgaria	2 050	2 020	1 374	1 230	1 127	33	40	45
Canada								
- national	4 614	3 700	3 200			30		
- SOMA	3 245		1 750			46		
Croatia	150	160	133	125	117	11	17	22
Czech Republic	2 257	1 876	1 128	902	632	50	60	72
Denmark	451	180	90			80		
Finland	584	260	116			80		
France	3 348	1 202	868	770	737	74	77	78
Germany	7 494	5 803	1 300	990		83	87	
Greece	400	510	595	580	570	0	3	4
Hungary	1 632	1 010	898	816	653	45	50	60
Ireland	222	168	155			30		
Italy	3 800		1 330	1 042		65	73	
Liechtenstein	0.4	0.1	0.1			75		
Luxembourg	24		10			58		
Netherlands	466	207	106			77		
Norway	142	54	34			76		
Poland	4 100	3 210	2 583	2 173	1 397	37	47	66
Portugal	266	284	304	294		0	3	
Russian Federation c/	7 161	4 460	4 440	4 297	4 297	38	40	40
Slovakia	843	539	337	295	240	60	65	72
Slovenia	235	195	130	94	71	45	60	70
Spain	3 319	2 316	2 143			35		
Sweden	507	130	100			80		
Switzerland	126	62	60			52		
Ukraine	3 850		2 310			40		
United Kingdom	4 898	3 780	2 449	1 470	980	50	70	80
European Community	25 518		9 598			62		

* The sulfur emission ceilings listed in the table show the obligations referred to in the Oslo protocol. The 1980 and 1990 emission levels and the percentage emission reductions listed are given for information purposes only.

a: If, in a given year before 2005, a party cannot comply with its obligations under this annex, it may fulfill those obligations by averaging its national annual sulfur emissions for the year in question, the year preceding that year and the year following it, provided that the emission level in any single year is not more than 20% above the sulfur emission ceiling.

b: For Greece and Portugal, percentage emission reductions given are based on the sulfur emission ceilings indicated for the year 2000.

c: European part within the EMEP area.

Source: United Nations, “Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions,” 1994. 6

III. Acid Deposition and Source-Receptor Relationship in NEA

1. Energy Consumption and Sulfur Emission in NEA

Total energy consumption in Northeast Asia (NEA) was 43 EJ (exajoules or 10^{18} joules) in 1990. This represents 51% of total primary energy consumption of Asia and 12% of the world. As shown in <Table 5>, Northeast China comprises 45%, Japan 42% , South Korea 8%, and the North Korea 4%. It is expected that the share of Northeast China will increase to 55% by 2020.

<Table 5> Total Energy Consumption by Country

(10^{18} joule/year)

Country	1990	2010		2020	
		Base	Low	Base	Low
N.E. China (China)	19.4 (30.3)	44.5 (73.5)	35.6 (59.1)	61.0 (101.0)	45.0 (75.4)
Japan	17.9	25.7	20.9	28.8	21.5
South Korea	3.6	9.5	7.8	13.4	9.7
North Korea	1.8	5.0	3.9	7.9	5.5
Total	42.7 (53.6)	84.7 (113.7)	68.2 (91.7)	111.2 (151.1)	81.7 (112.1)
Total in Asia	(83.6)	(188.5)	(154.5)	(274.1)	(207.4)

* Figures in parentheses are calculated using the energy consumption of China as a whole instead of Northeast China.

Source: Wes Foell, Markus Amann, Greg Carmichael, Michael Chadwick, Jean-Paul Hettelingh, Leen Hordijik, Zhao Dianwu eds., *RAINS-ASIA: An Assessment Model for Air Pollution in Asia*, A report on the World Bank sponsored project ‘Acid Rain Emission Reduction in Asia,’ December 1995.

For the analysis of the acid rain problem in Northeast Asia, we need to estimate the region’s future energy consumption. Major factors which determine energy consumption are economic growth and energy intensity, which shows how efficiently the energy is used. In many of the Asian countries, energy is used inefficiently now. We can slow down the energy consumption with the improvement of energy efficiency without undermining the sustained growth in the region. <Table 6> shows the energy intensity of the industrial sector in each country.

<Table 6> Industrial Energy Intensity Assumptions for the Base Case

(Gigajoules per US $1,000 (1990) Industrial GDP)

Country	1990	2000	2010	2020
China	109.9	81	60	44.2
Japan	4.78	4	3.37	2.85
South Korea	11.5	9.5	8	6.7
North Korea	85.5	120.7	139.9	158
Asia Average	17.1	17.1	15.9	14.6

Source: Wes Foell et al. op. cit., Table 3.7.

<Table 7> shows the pattern of final energy use by end-use sector. In Northeast Asia, 45% of energy was used in the industrial sector, 19% in the power generation sector, 16% in the domestic and commercial sector, and 10% in the transportation sector. It is expected that the share of the industrial sector will decrease to 40% by 2020.

<Table 7> Energy Consumption in Northeast Asia by End-Use Sector

(10^{18} joule/year)

Use	1990	2010		2020	
		BAS	HEF	BAS	HEF
Industrial Fuel Combustion	19.3 (45%)	36.0	28.7	45.0 (40%)	33.9
Domestic/Commercial	6.9 (16%)	12.8	11.1	16.1	12.8
Transportation	4.1 (10%)	10.3	8.0	15.5	9.9
Power Generation	8.2 (19%)	17.5	13.7	24.4	17.3
Non-energy Uses	1.8	3.4	3.0	4.2	3.8
Other (Conversion and Loss)	2.3	4.7	3.6	5.9	4.1
Total	42.7 (100%)	84.7	68.2	111.1 (100%)	81.7

Source: David G. Streets, “Energy and Acid Rain Projections for Northeast Asia,” Mimeo, 1997, p. 7.

<Table 8> shows the energy consumption in Northeast Asia by fuel type. Coal was the principal fuel with 48% of primary energy use, heavy and medium oil followed with 20%, and light fuel oil with 15%. The shares of natural gas and nuclear were about the same -- around 7%. The high reliance on fossil fuels such as coal and oil contributes the main reason for the high levels of sulfur dioxide and nitrogen oxidesemissions that lead to acid rain. It is expected that the energy consumption in Northeast Asia will increase from 43 EJ in 1990 to 111 EJ in 2020, and coal is expected to increase more than twice from the 1990 level of 21 EJ to 59 EJ in 2020. If the increased energy use is satisfied by nuclear or renewable energy sources, there will be no danger of air pollution in this region. However, coal will remain the dominant energy source because it is abundant in this region, cheap, and easy to exploit and use.

<Table 8> Energy Consumption in Northeast Asia by Primary Fuel Type

(10^{18} joule/year)

Fuel Type	1990	2010		2020	
		BAS	HEF	BAS	HEF
Coal	20.6 (48%)	44.8	34.1	58.8 (53%)	39.8
Heavy and Medium Oil	8.7 (20%)	15.1	11.8	19.3	13.3
Light Fuel Oil	6.6 (15%)	10.6	8.8	12.6	9.2
Natural Gas	3.0 (7%)	6.1	5.3	8.8	7.5
Renewables	0.1	0.2	0.2	0.3	0.3
Hydroelectric	0.8	2.7	2.7	3.8	3.8
Nuclear	2.8 (7%)	5.2	5.2	7.6	7.6
Total	42.7 (100%)	84.7	68.2	111.1 (100%)	81.7

Source: David G. Streets, ibid.

The estimate of total sulfur dioxide emissions in Northeast Asia in 1990 was 14.7 million metric tons.(or 14.7 megatons (Mt)). Northeast China was responsible for 81% with 11.9 Mt, South Korea 12% with 1.7 Mt, Japan 5% with 0.8 Mt, and North Korea 2% with 0.3 Mt. Major areas of heavy sulfur dioxide emissions in China are China's industrial centers: Hebei-Anhui-Henan areas with 3.1 million tons, Northeast Plain with 2.5 million tons, and Jiangsu province with 2.1 million tons. Under the Business-As-Usual (BAS) energy scenario, sulfur dioxide emissions will rise to 31.3 Mt in 2010 and 40.5 Mt in 2020. While there would be a slight increase in sulfur dioxide emissions in Japan, significant increase was projected to occur in Northeast China and South and North Koreas until 2020. Under the High-Efficiency (HEF) scenario, which assumes improved energy efficiency and fuel substitution away from fossil fuels, sulfur dioxide emissions would grow to 24.7 Mt in 2010 and 28.8 Mt in 2020.

It is expected that sulfur dioxide emissions would decline from 24 Mt in 1990 to about 17 Mt in 2020 in North America and from 37 Mt in 1990 to about 16 Mt in 2020 in Europe. These two regions realized the importance of regional acid rain problems and have taken necessary and arduous measures to reduce sulfur dioxide emissions. This signifies that it is not sufficient to just improve the energy efficiency in Northeast Asia to significantly reduce the emissions of sulfur dioxides. It is necessary also to utilize various emission control technologies. Otherwise the Northeast Asia will sooner or later become the major emitter of sulfur dioxide in the world.

<Table 9> Emissions of Acidic Air Pollutants in Northeast Asia by Country under Base Case Scenario

(10^6ton/year)

Country	SO_2			NO_x		
	1990	2010	2020	1990	2010	2020
Northeast China	11.9 (81%)	25.3	32.5	6.9	N/A	26.8
Japan	0.8 (5%)	1.0	1.1	2.6	N/A	4.6
South Korea	1.7 (12%)	4.1	5.6	1.1	N/A	5.1
North Korea	0.3 (2%)	0.9	1.3	0.5	N/A	2.4
Total	14.7	31.3	40.5	11.1	N/A	38.9

N/A = Values not calculated.

Source: David G. Streets, op. cit., p. 12.

In Asia, very little research has been conducted to investigate the levels and impacts of acid deposition. However, available monitoring data confirms that the acid rain is in fact increasing in many parts of Asia. Some of the ecosystems of the Asia region are similar to those in the US and Europe, where a significant number of economic as well as scientific studies have been performed to bring a noticeable change in acid deposition. Thus, in some cases, it is possible to extrapolate the potential effects found in these western nations to the corresponding ecosystems of Asia (Wes Foell et al., 1995, p.I-5). The RAINS-Asia project was performed to analyze and assess the relative vulnerability of anthropogenic and natural environments to acid deposition. According to the summary report of the RAINS-Asia project, Northeast China, Japan, and Korea are highly vulnerable to acid deposition and are expected to be at greater risk in the future.

<Table 10> Vulnerability of Various Asian Regions to Acid Deposition Risk Factor

	High emission		High deposition		Sensitive soils	Sensitive Vegetation and materials	High risk
Region	Current	Future	Current	Future			
NE China	×	×		×		×	
Japan Korea			×(winter	×(winter	×	×	×
S China		×	×(winter	×(winter	×	×	×
SE Asia	×	×	×(local area summer mostly)	×(local area summer mostly)	×(mountain area)	×(mountain area)	×(mountain area)
SE Asian islands	×	×	×(isolated, local)	×(isolated, local)	×(mountain area)		
N India	×	×		×(summer)		×(Himalayan	
SW India			(borderline acidity)	×(winter)	×	×(mountain area)	(borderline acidity in mountain area)
NE India		×		×(summer)	×		
Sri Lanka, Maldives			(borderline acidity)	×(winter)			
Siberia, N Mongolia				×(summer)		×	

Source: Wes Foell et al., op. cit., Table 1.2.

2 Source-Receptor Relationship in NEA

Columns in <Table 11> show the source countries of sulfur dioxide emissions, and the rows show the receiving countries. For example, China received 5,990 thousand tons of its own SO_2 and received 21.6 thousand tons from North Korea. South Korea received 175 thousand tons of its own sulfur and 28 thousand tons from China.

<Table 11> Country-to-Country Source-Receptor Matrix for Sulfur

(10^3 sulfur ton/year)

Source / Receptor	China	Japan	S. Korea	N. Korea	Total	Asia Total
China	5,990.0 (83%)	0.2	4.6	21.6	6,016.4	6,140.0
Japan	38.8 (0.5%)	149.0	28.8	2.5	219.1	405.0
S. Korea	28.0 (0.4%)	1.2	175.0	2.6	206.7	211.0
N. Korea	59.6 (0.8%)	0.1	62.8	49.3	171.8	172.0
Total	6,116.4	150.4	271.2	76.0	6,614.0	6,928.0
Asia Total	7,220.0 (100%)	291.0	513.0	111.0	8,135.0	12,300.0

Source: Constructed by the author based on Wes Foell et al., op. cit., Table 5.3a.

<Table 12> shows the percentages of sulfur deposition within Northeast Asian countries which originate from China. China emitted 7,220 thousand tons, 83% (or 5,990 thousand tons) of which fell on China, 0.4% fell on South Korea, 0.5% fell on Japan, and 0.8% fell on North Korea. Even if only a small portion of the sulfur emitted by China reaches neighboring countries, it contributes a significant share of the total sulfur deposition in those countries. For example, North Korea receives only 0.8% of China's total sulfur emissions, but this constitutes 35% of the total sulfur deposition in North Korea.

<Table 12> China's Contribution to NEA Countries

Receptor	% of China's Deposition in Asia	% of Receptor's Total Deposition
China	83	98
South Korea	0.4	13
Japan	0.5	10
North Korea	0.8	35

Source: Wes Foell et al., op. cit., Table 5.3.b.

<Table 13> shows the country-to-country, source-receptor relationship among Northeast Asian countries. South Korea is responsible for 7.1% of Japan's sulfur deposition and 3.7% of North Korea's sulfur deposition. In case of Japan, anthropogenic emissions from Japan accounts for only 37% while volcanoes are responsible for 46% of sulfur deposition. North Korea's own contribution is 29%, while China is responsible for 35% of the total sulfur deposition in North Korea.

<Table 13> Country-to-Country Source-Receptor Relationship

Receptor / Source	% of Receptor's Total Annual Sulfur Deposition			
	South Korea	Japan	North Korea	Mongolia
China	13	9.6	35	48
South Korea	83	7.1	3.7	0.01
Japan	0.5	36.8	0.05	0
North Korea	1.2	0.6	29	0.01

* Volcanoes are responsible for 46% of the total annual sulfur deposition in Japan.

Source: Constructed by the author based on Wes Foell et al., op. cit., Table 5.3.a.

IV. Optimal Framework Toward Acid Rain Problem in NEA

1. Environmental Cooperation in NEA

Regional environmental cooperation became one of the top priorities in every region of the world recently. In the Asia-Pacific region, there are several sub-regional environmental cooperative bodies at the intergovernmental level. These include the ASEAN Senior Officials on the Environment (ASOEN), South Asia Cooperative Environment Program (SACEP), South Pacific Regional Environment Program (SPREP), and Lower Mekong Basin Development Environment Program (LMBDEP). In Northeast Asia, however, it was not until 1993 that an intergovernmental forum on environmental cooperation was established. The main hindrance to the establishment of such a forum came from the military and political confrontation which had dominated international affairs in Northeast Asia. However, the end of Cold War made the formation of a forum for regional environmental cooperation possible.

Cooperative mechanisms to deal with environmental problems in Northeast Asia can be broadly classified into multilateral cooperation and bilateral cooperation as shown in <Table 14>. The multilateral cooperation is operated through the regional cooperative bodies such as ESCAP and APEC; or through intergovernmental meetings such as Northeast Asia Sub-regional Program for Environment Cooperation (NEASPEC), Northwest Pacific Action Plan (NOWPAP), and Tuman River Area Development Plan (TRADP); or through other cooperative bodies such as Environment Congress for Asia and the Pacific (ECO-Asia) and Northeast Asian Conference on Environmental Cooperation (NEACEC). Bilateral cooperation is operated between the two interested countries such as Korea-China, Korea-Japan, and Korea-Russia.

<Table 14> Northeast Asian Environmental Cooperation Structure

Multilateral Cooperation	Through Existing Regional Cooperation Bodies	ESCAP	· Asia-Pacific Environment Ministers' Meeting (Every 5 years) · Asia-Pacific Environment and Sustainable Development Commission · Regional Action Program for Environmentally Sound & Sustainable
		APEC	· APEC Environment Ministers' Meeting · APEC Marine Preservation Meeting
	Inter-Governmental	NEASPEC	· Members: China, Japan, S. Korea, N. Korea, Mongolia, Russia · First Meeting; Seoul (1993) · ESCAP functions as temporary secretariat
		NOWPAP	Members: China, Japan, S. Korea, N. Korea, Russia First Meeting; Seoul (1994)
		TRADP	Members: China, S. Korea, N. Korea, Mongolia, Russia Initiative: UNDP
	Inter-Agency or Non-Governmental	ECO-ASIA	Initiative: Japan · Met 5 times during 1991-96
		Northeast Asia Acid Rain Specialists Meeting	· Initiative: Japan EPA · Met 3 times during 1993-95
		Workshop on Trans -boundary Air Pollution	· Initiative: Korea Environmental Research Institute
		NEACEC	· Members: China, Japan, S. Korea, Mongolia, Russia · Meet annually since 1992
Bilateral Cooperation	Japan-Korea		· Agreement: 1993. 6
	China-Korea		· Agreement: 1993. 10
	Korea-Russia		· Agreement: 1994. 6

Source: Eui-Soon Shin, "Acid-Rain Problem and Environmental Cooperation in Northeast Asia," *Korea Journal of Resource Economics*, September 1997, p.136.

2. Market-based and Cooperative Approach

(1) Economic Rationale

Acid rain differs from greenhouse gases like carbon dioxide and CFCs in that it is not a pure public good (or bad) in the Samuelson sense. Acid rain causes damage where it is deposited, and there appears to be a reasonably linear relationship between emissions and depositions. It is possible to predict a stable relationship between the location of the source and the deposition, at least averaged over a year. A large fraction of SO_2 can be accounted for by individually identified large stationary sources, predominantly power stations. Technically, acid rain appears to be a depletable or rival good in consumption, in that if one ton of sulfur falls on a given local area, then that cannot fall elsewhere, and reduces the amount which will harm others by that amount. It might appear to be a simple bilateral externality of the kind considered by Coase. But there are two important differences from the simple case of bilateral externality. If one country emits sulfur into the air, then more than one country will be affected. If the recipients are to bargain over reductions in acid rain, they will have to agree among themselves how to coordinate their bargaining, and how to share any costs involved.

Let us consider the efficacy of bilateral or multilateral bargaining over pollution abatement, in the spirit of Coase. One can imagine two possible allocations of property rights. The status quo is one in which each country is free to pollute its neighbors. The alternative is one in which each country agrees to a certain annual level of emissions -- e.g. 70% of the 1980 measured level. In the second case, the polluter would have to pay for increased emissions, and a natural offer would be an amount between the marginal cost of abatement and the marginal damage done to the recipients. This principle is termed the Polluter Pays Principle, or PPP. In the status quo situation, new polluting sources could set up and pollute at no apparent cost. The costs of damage would be borne by the recipients (the Victim Pays Principle, or VPP). In this case, the first task would be to agree on a reference path of pollution in the absence of any cleanup -- presumably based on a forecast of energy demand and emissions per unit of energy used. In the second case, the recipient would pay the polluting country the damage cost of the difference between 70% of 1980 levels and the reference emission path (Newbery, 1990, p. 328).

Licenses to pollute which are tradable and are auctioned off have several attractions. The first is that they are the natural instrument to meet international agreements which constrain total emission levels. Second, they can overcome organized resistance from the industry affected, since firms can be allocated licenses proportional to current emission levels. The costs of abatement fall on consumers and on new entrants, who have to buy licenses from incumbents. Third, other countries can negotiate further reductions by buying up licenses. Licenses work well for large stationary sources, which are the main source of SO_2, but are not immediately applicable to small mobile sources. An important experiment with the license system was the US Environmental Protection Agency's sulfur emissions trading policy, with its various components allowing firms to meet firm level or area level standards by either internal reorganization or by external trading or bargaining. The resulting cost-savings has been substantial, as analyzed above.

(2) A Possible Strategy

Inter-governmental negotiations so far have been guided by the principles of uniform reduction in emissions from a benchmark level or uniform standards. However, there are two serious problems with this approach. The first is political, and may be sufficient to derail the negotiations -- some countries are net losers from such negotiations. The second objection is economic -- the reduction in aggregate pollution damage is done at higher than least cost. Both problems can be solved by the natural solution which allows beneficial and efficient bargaining. This would involve first agreeing to a benchmark trajectory of allowable emissions (not necessarily equal for all countries), and then facilitating bargaining over deviations from this level. This might be done by first estimating the marginal damage costs (or willingness to pay for abatement, if higher) by each cell or square, then calculating the appropriate cost sharing formula for the group of countries affected by polluter j. Thus for country i its share of the payments to polluter j would be

$$a_i = MD_i \cdot t_{ij} \Big/ \sum_k MD_k t_{kj}$$

The recipients would then appoint a negotiator with power to levy charges on recipients proportional to these cost fractions, up to the total damage level. The negotiator could then bribe the polluting country to make additional reductions.(Newbery, 1990, p.334). The current tax rate would be the amount offered by the recipient negotiator. The main problem is that flue gas desulfurization (FGD) requires a large fixed investment to amortize over up to 40 years and thus requires the investor to calculate the future benefits of installation. If these future benefits are uncertain, then abatement may be deferred. It would pay the recipient negotiator to offer formal contracts, possibly indexed to recipient GNP, in order to reduce uncertainty and thus induce greater abatement for the same cost.

V. Summary and Conclusion

Even though not enough time has passed since its enactment, the SO_2 allowance program of the US provides useful lessons and serves as a benchmark against which other pollution control and market-based programs can be compared (McLean, 1996, p.149). Following are the lessons learned from the experience of US SO_2 allowance trading program:

First, actions prior to program design are important. Market-based instruments are tools to solve problems, but first the problem must be defined, goals set, and the economic, social, and environmental implications of alternative solutions should be evaluated. The public's acceptance of and support for proposed solutions should also be assessed.

Second, the design of the program is critical because it determines whether effective and efficient implementation is possible. The goals and responsibilities should be clearly stated, and there should be unequivocal consequences for not complying or for delaying implementations. From the beginning of the program the emissions from all potentially affected sources should be accounted for and a maximum allowable emissions level, the cap, should be established and sustained. Accurate measurement of emissions is the key to environmental accountability, market credibility, and operational flexibility. Allowance allocation is primarily a political process, not an environmental one. Overall, the design should be simple.

Third, in implementing the program, the government should stay focused on achieving the goals in the legislation, resolving issues promptly, and improving operational efficiency. The government should refrain from trying to participate in, control, or fine tune the market, particularly since many changes, such as restructuring, may occur outside the regulator's domain.

It is hard to imagine any politically acceptable policy that assigns varying reduction requirements to specific countries based on the results of large scale source-receptor modeling in Northeast Asia at this time. It is even harder to imagine the political acceptability of ambient-based trading which theoretically would be more efficient than the emissions trading program adopted in the US. Thus, emissions trading, while only a crude substitute for ambient trading, is more politically feasible and is at least as effective as ambient targeting. The question is how to devise a mechanism to introduce a cost-effective market-based emission trading mechanism in

Northeast Asia.

The concept of joint implementation (JI) -- or activities implemented jointly -- now appears within the policy frameworks of a number of international conventions. These include the Framework Convention on Climate Change (FCCC), the Biodiversity Convention, the Montreal Protocol, and the Convention on Long-range Transboundary Air Pollution (CLRTAP). The general intention under each of these initiatives is to develop mechanisms which allow two or more parties to meet their obligations to the conventions through activities implemented jointly. The main argument for such a procedure has been from economic efficiency: the costs of transboundary pollutants abatement might be lowered by seeking out the least cost options first, irrespective of geographical boundaries. Climate change is a problem that may be even more amenable to market-based solutions than acid rain, mainly because greenhouse gas emissions do not cause local and regional “hot spots” which need to be guarded against. To slow the overall greenhouse effect, it may be better to concentrate on the total set of greenhouse gases and to identify the strategies that would reduce total global warming potential the soonest, rather than focusing on individual greenhouse gases.

While Europe and the US found ways to control transboundary transportation of sulfur dioxide, they are struggling to cope with the global warming problem, which is technically and politically more difficult and problematic than the acid rain problem. Northeast Asia is in an infant stage in establishing a regional cooperative institution comparable to that of Europe now. So the first task to the Northeast Asian countries is to establish a permanent cooperative body which would deal with transboundary problems in Northeast Asia or in the Asia-Pacific region, if it is a more proper geographical boundary. Then some kind of conventions and protocols will be derived based on the agreed total emission limit in the region, and specific ’countries’ reduction targets will be negotiated. Perhaps an integrated approach to all transboundary pollutants including SO_2, NOx, and CO_2 could be more cost-effective because all the transboundary problems are not properly dealt with in this region yet..

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