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International Bargaining and the EC Large Combustion Plant Directive

Roger Fouquet

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Enquiries about SEEC may be made to:

Director of SEEC: Peter Pearson **Secretary**: Isobel Hildyard

SEEC, Economics Department, University of Surrey,
Guildford GU2 5XH, UK.

Telephone: +44-483-509379 Fax: +44-483-303775

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INTERNATIONAL BARGAINING AND THE LARGE COMBUSTION PLANT DIRECTIVE[1]

1 INTRODUCTION

Since the beginning of the industrial revolution, air pollution, caused partly from the burning of fuels to power machines, has harmed the environment and its inhabitants. One of the most recently publicised forms of air pollution is acid rain which results from sulphur dioxide (SO_2) released in the burning of some fossil fuels (see figure 1) and nitrogen oxide (NO_x) escaping from car exhausts. Scientific progress has revealed the connection between sulphur dioxide and environmental damage. As damage becomes more apparent the need to identify appropriate levels of control mounts.

Regional differences in the amount of 'acid' gases emitted and received, coupled with the fact that acid rain travels across political boundaries creates national differences in attitudes towards its reduction (see table 1). Curbing acid rain requires international agreements and cooperation. Agreements about the speed and level of reductions in 'acid' gases appear hard to attain and have led to long rounds of negotiations.

In this paper, I highlight and analyze the mid-1980s talks dealing with the European Community (EC) legislations on levels of sulphur dioxide emissions, known as the Large Combustion Plant Directive (LCPD). I examine, in particular, disputes over the UK's requirements of sulphur

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1 This discussion paper arises out an M.Sc. Dissertation in Energy Economics at Surrey University (Fouquet 1991). I am indebted to David Hawdon, as my dissertation supervisor, and Peter Pearson, as editor, for their invaluable comments, and Isobel Hildyard and Ian McQueen for their assistance.

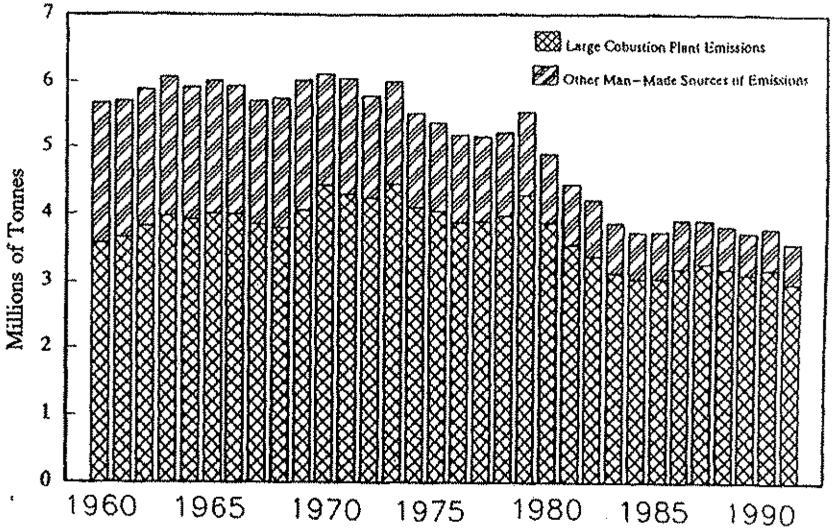

Figure 1 **UK Sulphur Dioxide Emissions 1960–91**

Source: Digest of Environmental Protection and Water Statistics (1992) Table 2.2 p.12

dioxide, as Europe's largest emitter of the substance, seeing whether a Rubinstein-type bargaining model can help explain and predict the outcome of the negotiations and the means of reaching an end[1].

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1 Other studies on international cooperative behaviour to reduce acid rain include Newbery (1990), Maler (1990), Tahvonen, Kaitala, Pohjola (1993). See also Newbery (1993) on repercussions of the LCPD for electricity supply and coal industries.

Table 1: Emitters and Receivers of Sulphur Dioxide (in 1987)

	FR	GDR	FRG	BNL	IT	SP	SC	USSR	UK	TOT
FR	332	41	40	28	21	65	0	0	43	760
GDR	14	725	61	11	2	1	1	1	15	979
FRG	69	163	330	44	13	6	1	1	45	821
BNL	32	15	51	102	0	2	0	0	31	267
IT	21	15	8	2	353	10	1	1	4	562
SP	11	5	3	1	2	523	0	0	6	674
SC	5	48	18	6	2	0	59	33	32	501
USSR	10	167	36	8	13	1	8	2204	16	3584
UK	14	15	11	8	1	2	0	1	571	702
N.A.	136	253	131	71	182	210	28	196	437	3087
TOT	721	2005	823	322	759	856	107	2558	1271	16695

(FR - France; GDR - East Germany; BNL - Benelux; IT - Italy; SP - Spain; SC - Scandinavia; N.A. - North Africa)

Source: Newbery (1990) p.303

The next section, introduces the forces which generated the European acid rain conflict: sulphur dioxide emissions, their causes and effects, potential methods of abatement, and their economic consequences. Section three defines the parties involved, their preferences, interactions and final agreement on the Large Combustion Plant Directive (LCPD). I, then, 'test' the accuracy of the Rubinstein bargaining model to predict the outcome of negotiations surrounding the directive. Section four, also discusses reasons why negotiations failed, in an attempt to explain the delayed agreement. The final section draws conclusions and offers some insights into the possible conduct of future negotiating rounds on global environmental management.

2 THE INTERNATIONAL ACID RAIN GAME

2.1 Acid Rain

Acid rain is the product of a two step process: initially, sulphur or nitrogen is oxidised; then, these oxides dissolve in rainwater to form dilute acid. Sulphur is present in all fossil fuels. When these are burnt at high temperatures, to generate power, oxides form (such as steam and carbon and sulphur dioxide), which are released into the atmosphere. The amount of oxides produced depends on the sulphur content of the fuel and the temperature of combustion.[1]

Once oxides are formed, they may travel long distances (up to 2000 kilometres) before being deposited and causing damage. Oxides travel either as particles, landing within 25 kilometres of emission source, or as water droplets in clouds, transforming into weak acids, and dispersing for hundreds of kilometres before precipitating. The rain's dispersion depends on weather conditions, and wind strength and direction. Air temperature and turbulence are factors that determine the rain's recipients. With knowledge of prevailing winds meteorologists produce forecasts of emissions' destinations. (See Table 1).

Once the acid lands, it reacts with its surrounding environment. Most of the damage attributed to acid rain is caused to lakes, forests and buildings. As a stock pollutant, acid rain accumulates over time. A hundred years of industrial pollution has damaged the European environment, and any resolution to abate sulphur emissions will only limit further accumulation but will not make the problem disappear.[2]

Sulphur dioxide dispersion epitomises the problem of externalities.

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1 See Appendix 1 for sources of Acid Rain.

2 Additional information on acid rain can be found in Park (1987).

Acid rain may seriously damage a nation's environment, yet, much of the sulphur dioxide responsible for it may have blown over from another country. Accusations fly in the reverse direction. Demands for emission reductions follow. The emitters' government may refuse to react, claiming that it would damage their economy and that insufficient evidence exists to cast blame anyway. Trans-boundary disputes, and pollution, grow; entrenched positions deepen.

While it is clear that sulphur and nitrogen emission cause acid rain, many uncertainties remain. Acid rain harms fish and buildings; although it is less clear about its effect on trees. It is also difficult to measure the consequences of the damage caused, as it requires putting values on imponderables or partial damage.

The rain's course is determined by weather, a variable notoriously difficult to predict. Furthermore, it is sometimes difficult to link environmental damage to acid rain, and, if the damage has been so attributed, tracing back the source of the emissions is a painstaking operation. Much doubt, therefore, exists and many further questions must be raised about the cause and effects of acid rain.

Efforts to abate acid rain to appropriate levels must come from all sides. Scientists should research the causes and effects in order to reduce the doubts and uncertainties, while policy-makers must propose initiatives to prevent further deposition. Recent policies to reduce deposition have targeted sources of oxide emissions. Though there are many sources, both natural and man-made, certain heavy polluters, such as electricity generators, are blamed for much of the damage (see Appendix I). Policies to reduce their emissions stand as the first step towards abating acid rain.

2.2 Policies To Reduce Acid Rain

It can be argued that policy-makers should represent the public's 'best interest'. According to this view, the government should introduce the measures that most improve social welfare. In theory, maximising social welfare might be achieved with the aid of cost-benefit analyses, which evaluate policies with the highest net benefit. In practice, government normally listens to powerful industries and lobby groups, which guide it towards appropriate policies.

With such advice, Government decides what stance it takes towards a particular problem. The strategy includes whether the problem is considered important or not, whether to take proactive or reactive measures, what sectors of the economy will be affected, and by how much.

Government has several possible approaches to ensuring desired reductions. It may decide proactive measures are necessary. One approach is the command-and-control method which imposes a legally-binding quota of emissions. For polluters to emit beyond this level leads to fines. Such a method continues to be followed by policy-makers for its clarity. Economists prefer the use of market-based instruments, such as pollutant taxes, subsidies for low emissions, or tradable permits.[1] Their benefits reside in the flexibility they allow polluters, limiting the economic consequences of abatement. Polluters, theoretically, abate emissions up to the level at which marginal costs of abatement equal marginal benefits; this level is optimal for emitters - as it becomes cheaper to pay taxes or buy permits than to abate emissions. Furthermore, taxes and permits continually pressurise polluters into reducing emissions or introducing coal-cleaning technology, if possible.[2]

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1 Sulphur dioxide emissions permits have just been introduced in the US, and are bought and sold at the Chicago Mercantile Exchange.

2 For more details on the policy debate see, for example, Pearce, Markandya and Barbier (1989).

Alternatively, governments can take a reactive stance. Reactive policies propose cleaning-up any damage after it has been caused. Such a position suggests that the government feels the present costs of abatement are too high to take further action and it is often said that more information and evidence needs to be accumulated to convince government that the economic (and political) benefits of acid rain abatement outweigh the costs.

A government's stance on acid rain is affected by the two groups directly concerned with the problem, and their power to influence decision-making. These two groups are, on the one side, those who want proactive measures to limit destructive effects of acid rain and, on the other, those who want to avoid any proactive measures because it will harm their interests. The environmentalists and downwind nations are concerned about the state of lakes, forests and buildings caused by acidification. Electricity generators worry about high investment costs which would result from abatement policies. Businesses, trade unions, and the Treasury (or Central Bank) know that high costs will lead to a rise in electricity prices, which may cause inflation, hinder the economy's competitiveness abroad, and in turn lead to unemployment. The side with most influence has the most impact on a government's position.

2.3 The Energy Sector and its Response to Policies

Decisions relating to sulphur dioxide emissions directly affect electricity companies' profits. Their initial response will be to put pressure on their government not to introduce such policies. If this fails, they will try to influence the nature of the policies. Then, generators will reluctantly comply with emission requirements. Compliance can lead to radical and expensive changes in generating processes. The change to each power station depends on the cost-effectiveness of the available options: switching fuel or removing present fuel's sulphur.

One possible change to a power station is a switch out of high-sulphur coal. Such a response means using either low-sulphur coal or another fuel, probably natural gas, maybe nuclear or renewable energy. For old power stations, electricity companies have tended to replace them with natural gas generators - combined cycle gas turbines (CCGT); the fixed costs associated with natural gas power stations are lower than coal ones (Skea 1990). For recently built coal power stations, the costs of switching to other fuels becomes an unlikely option. If this is the case, generators may start using low-sulphur coal. To do so, however, may be either politically unsound, as in many European countries the coal industry is still powerful, or just impossible, due to long-term contracts with suppliers. The response to abatement policy will depend on the age of existing power stations, fuel prices and the costs of importing coal or investing in cleaning technology.

The alternative to switching out of high sulphur coal is to invest in equipment which extracts sulphur dioxide from emissions. Installed in power stations, Flue Gas Desulphurisation (FGD) removes most of the sulphur gasses produced in combustion before they are released into the atmosphere. The most common technique used involves 'scrubbing' the flue gas with limestone to remove sulphur dioxide. This technique, introduced in three-quarters of FGD power stations, regularly removes 90 percent of the sulphur and has the advantage of being easily added-on or retrofitted to existing power stations - so new, cleaner power stations do not need to be purpose-built. However, this technique adds around 10 to 15 percent to the costs of generating electricity in new, modern power stations, and up to 20 percent on retrofitted plants (Newbery 1990). It also leaves behind a wet sludge with no commercial use. Thus, as well as the important cost increments involved with FGD, the disposal of this sludge and the mining of limestone provide new environmental concerns.

Pressurised Fluidised Bed Combustion (PFBC) is another 'cleaning' method. It seeks to remove the sulphur from coal during the combustion process using limestone. Park (1987) believes this to be the best alternative to low-sulphur coal. PFBC, though, is still not perfected to a commercial level and is not expected to be until the end of the century. The whole problem could well be resolved by the time PFBC is fully developed.

Electricity companies in Europe carry considerable political weight. They will use their weight to delay restrictions on emission restrictions. If restrictions are imposed, they will use their weight to pressurise the government into forcing trading partners to follow suit. The electricity companies' ability to influence their government is fundamental to understanding national strategies in the 'acid rain' disputes.

2.4 International Repercussions of Responses

The effects on trade from policies to reduce sulphur dioxide, as well as initial views on trans-boundary pollution and electricity company concerns, heighten international disagreements about acid rain. Government stances tend to become even more clearly-defined through pressure from domestic businesses, firms and trade unions.

Power generator adjustments tend to affect the balance of trade in several ways. First, since only a few economies produce more than one energy source on a scale necessary to generate large amounts of electricity, switching fuel is likely to significantly alter an economy's patterns of trade, particularly relating to energy markets. This may increase or decrease a trade balance deficit, depending on the nation's natural resources. Secondly, when power generators choose to buy cleaning equipment, they are unlikely to find the necessary know-how in a country with little experience of sulphur dioxide abatement. The main producers of cleaning equipment are in countries which have had to meet high emission standards. Large amounts of trade will result, but only in one direction: from nations with (sulphur-cleaning) technological know-how to those with recently-implemented sulphur dioxide abatement policies.

Furthermore, since such adjustments force power generators into large investments, electricity production costs will rise. These costs will be passed on to consumers as higher electricity prices. Individual nations introducing 'acid rain' policies, forcing power generators into large investments, will increase domestic firms' and businesses' production costs which in turn results in inflation, a reduction in their competitiveness relative to firms in countries without such policies, and unemployment. A competitive advantage, as well as a more healthy economy, emerges from not imposing restrictive policies, especially where trading partners have.

On the other hand, international pressures are important in government decision-making. If fellow governments - especially within the European Community - put pressure on a government to take a particular position on an issue like the acid rain debate it cannot completely ignore them. The danger of ignoring such pressure is to risk being ignored in future negotiations. And, since members of the EC are incessantly discussing, negotiating and conceding matters of national interest, the price of being ignored by fellow member states is very high. A government's stance on acid rain is further shifted by foreign interests. The acid rain problem becomes an international 'game' where governments which have introduced sulphur dioxide legislations try to put pressure on decision-makers in polluting countries to adopt similar policies and reduce their emissions by as much as possible.

A government, in choosing the most appropriate position, tries to incorporate both domestic and international pressure groups. Its choice, though, may only represent one group, if it is very influential or the evidence (e.g. scientific information or cost-benefit analysis) overwhelmingly supports its case. On the other hand, equally influential pressure groups will lead a government to search for compromises. As circumstances and roles in an economic system change, the power of pressure groups to influence government may vary. Thus, it may not be surprising to see players in negotiations initially refuse opponents' proposals, then, suddenly concede their position and seek compromises.

3 NEGOTIATORS AND NEGOTIATIONS

The following section examines European governments' stances on the acid rain debate. These positions - influenced by major pressure groups, like environmentalist, electricity companies, and foreign governments - form the basis of EC member states' strategies on negotiations surrounding the Large Combustion Plant (LCP) Directive to reduce sulphur dioxide emissions. In conclusion to this section, there is a brief outline of the negotiations and the final agreement.

3.1 The FRG

In the early 1980's, a sweeping political campaign to save decaying forests in the Federal Republic of Germany (FRG), 'Waldsterben', forced the government to introduce measures to reduce acid rain. With little scientific evidence to link acid deposition with the decay, parliament voted in a proposal to reduce sulphur dioxide emissions by 75 percent of the 1980 level by 1993.

Large reserves of lignite (brown coal), a powerful coal industry and the fear of a trade balance deficit meant electricity generators could not switch out of high sulphur coal. Forced to use lignite, substantial flue gas desulphurisation retrofitting was necessary for many power stations to meet the emission targets.

By 1987, the cost of the technology response to abatement policy was set at £9 billion - DM21 billion (Boehmer-Christiansen and Skea 1990). Inevitably, electricity prices rose in FRG, placing firms at a comparative disadvantage with respect to foreign competitors. "The BDI [FRG's equivalent of the CBI] and other bodies argue[d] that the German Federal Government should attempt to 'spread the misery' of stringent environmental controls to other European partners in order to protect German industry against a potential loss of competitiveness" (Boehmer-Christiansen and Skea p.203).

Furthermore, 60 percent of acid deposition on German soil was not from domestic polluters (see Table 2). In 1983, the German government began to pressurise the European Commission to put forward a proposal regarding Community legislation on sulphur dioxide, nitrogen oxide and particulate emissions from large combustion plants.

3.2 Minor Negotiators

The response to such proposals was mixed. Belgian and French governments, both having reduced sulphur emissions considerably in the 1980's through the development of a nuclear energy policy, welcomed the proposals. Along with the Netherlands, a supporter of environmental legislations, they sided with the German government.

Denmark, on the other hand, supported UK's initial scepticism about the requirements. The Danish government, under pressure from its energy sector and realising its economy had little to gain from such measures (See Table 3), conceded only small reductions.

Spain, Greece, Ireland, Italy and Portugal, all, resented the Commission's proposals to limit sulphur dioxide emissions. Spain and Italy would both incur negative net benefits from large reductions (see Table 3). Spain, in particular, had planned an expansion of coal-generated power stations. Greece, Ireland and Portugal can be considered non-industrialised nations compared to FRG, UK or France, and, therefore, it could be argued, should be allowed to expand their industrial sector without stringent environmental demands. Furthermore, the damage per tonne of sulphur dioxide for these four countries is the lowest in the EC (Newbery 1990). Thus, their abatement would provide little benefit for its high costs.

Table 2: Sulphur Emissions (in thousand tonnes or Percent)

	Emissions: 1980	1987	Change	Ratio of Contributions / Tot. Dep.	Ratio of Imports / Exports
USSR	6400	5100	-20%	0.61	2.1
ex-GDR	2500	2500	0	0.74	7.0
UK	2335	1840	-21%	0.81	9.7
Spain	1625	1581	-3%	0.74	7.0
Italy	1900	1252	-34%	0.63	4.3
FRG	1600	1022	-36%	0.40	1.4
France	1779	923	-48%	0.44	1.4
Belgium	400	244	-39%	0.41	2.7
Greece	200	180	-10%	0.38	1.8
Denmark	219	155	-13%	0.37	2.4
Netherlands	244	141	-42%	0.23	1.0
Sweden	232	116	-50%	0.12	0.3
Ireland	110	84	-24%	0.31	1.3
Norway	70	50	-29%	0.07	0.2

Source: Newbery (1990) p.304

Table 3: Net Benefits from Abatement

	Maler's Proposed Abatement (based on 1980 level)	Net Benefits (Million DM)
Netherlands	80%	565
UK	81%	-365
Belgium	36%	91
Italy	86%	-81
FRG	86%	328
Denmark	86%	119
France	10%	879
Ireland	38%	71
Spain	14%	-29
Greece	86%	53
USSR	2%	1505
Portugal	19%	10
Norway	6%	272
Sweden	4%	606

Source: Newbery (1990) p.326

Beyond the EC, Scandinavian governments - excluding the Danish one - demanded overall emission reductions as they tended to be downwind from major polluters, like USSR, FRG and UK. They incessantly pressurised polluters to reduce emissions; and, finally, succeeded. Many see Swedish and Norwegian governments' pressure as instrumental in Britain's change of stance.

3.3 The UK

The mid 1980s saw the UK government shift its position on acid rain abatement. Initially, it had refused to impose restrictions on its electricity companies. Later, it conceded that sulphur dioxide emissions should be reduced.

In 1983, the European Commission, FRG and Scandinavian nations' proposals for all European electricity generators to reduce sulphur dioxide emissions were flatly rejected by the British government. Its decision was based on evidence put forward by various domestic pressure groups. The electricity generators, represented by the Central Electricity Generating Board (CEGB), argued that, because of their present dependence on high sulphur coal, FGD retrofitting would be required in the short and medium term (see figure 2). Forced to pass on to the consumer the high costs of such adjustments, inflation would rise and British competitiveness abroad would decline. The Treasury, businesses and trade unions, all felt the burden on British economy was unacceptable. Mrs Thatcher thought so too.

Mrs Thatcher claimed that FGD was a technological dead-end and that insufficient evidence linked sulphur dioxide emissions with dead foreign fish. Three years later, she visited Norway - along with Lord Marshall, the head of the CEGB. The pair, possibly distressed by the overall health of Norwegian fish, returned to Britain accepting some responsibility for the damage done and promising to take action to reduce acid rain. The CEGB proposed retrofitting two major power stations (Skea 1990).

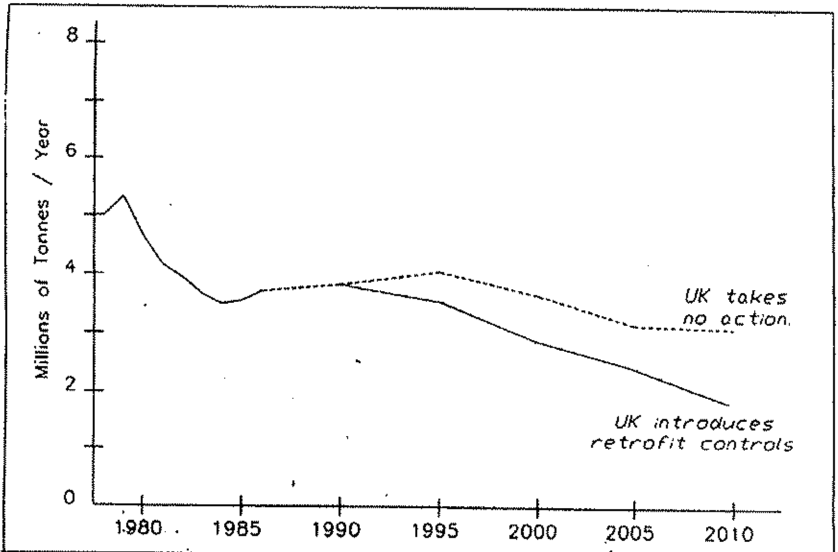

Figure 2 **UK Sulphur Dioxide Emissions 1980 - 1985. Projections 1986 - 2010.** Source [illegible]

This new stance on an old problem can be explained by anticipated changes in the structure of the energy sector. Two influential groups, the CEGB and the National Coal Board (NCB), were losing their power. During the coal miners' strike, in 1984/5, government needed a strong coal board to fight off the miners' rebellion. It could, therefore, not inflict a damaging blow to the NCB like sulphur dioxide emission restrictions which risked shifting electricity production out of coal. Once the strike was over, and NCB had served its purpose, government no longer needed a strong coal industry. Its power and influence dwindled.[1]

CEGB's plight was similar. Through the 1970s and early 1980s, it strongly influenced government on policies relating to energy matters. But, with the impending privatisation and break-up of the electricity supply industry, CEGB carried little weight. Its fears were no longer the government's concerns.

Furthermore, partly due to privatisation, electricity generators were expected to shift out of using coal towards natural gas and nuclear power. One of the expected consequences of this was a dramatic reduction in sulphur dioxide emissions. Emission projections suggested a gradual rise until the early 1990s followed by a sharp drop.

It appeared the government could now accept a foreign proposal which required the UK's large combustion plants to moderately and gradually reduce sulphur dioxide emissions. Any proposal that imposed a too large or immediate reduction would require, instead of a natural shift out of coal, direct action, such as FGD retrofitting. Direct action was to be avoided because it increased the costs of acid rain abatement and decreased the net benefits (see Table 3). The UK government's position on LCP Directive negotiations was no longer to completely oppose reductions but to agree on a level that came closest to maximising the UK's net benefits of acid rain abatement.

3.4 The Bargaining Rounds

Prior to 1983, Scandinavian governments formed, and invited others to join, the Thirty Percent Club, which proposed that members should

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1 Newbery (1993) suggests the decline of the coal industry was considerably affected by the outcome of these LCPD negotiations.

agree to reduce sulphur dioxide emissions by 30 percent of their 1980 level before 1993. The convention, supported by the United Nations Economic Commission on Europe (UNECE), was rejected by certain major polluters like US, UK and FRG, and eventually lost its inertia.

FRG's decision to introduce severe legislation gave the international effort to reduce acid rain a new impetus. By the end of 1983, the German government felt it was time, for environmental reasons, and necessary, for competitive reasons, for other EC members to assist in the effort. This view was supported by the European Commission, which had a supra-national legislative power to effectively pressurise reluctant members to reduce emissions in the reduction and, once they agreed, to ensure they fulfilled their promises.

Hastily drawn up, in March 1983, a European Commission Framework Directive proposed that, along with nitrogen oxide and particulates reductions, sulphur dioxide emissions from all European large combustion plants should decline by 60 percent of the 1980 level before 1996. The position taken by certain governments - especially the UK's - was to immediately reject the proposal.

The first effort to harmonise European power stations' emissions was thwarted. The debate continued through 1984 and 1985 but no substantial ground was covered in those years. During this period, the Commission realised that without the UK's cooperation a harmonised legislation would be useless, because of its size as a sulphur dioxide emitter. The Commission tried to isolate the UK by giving concessions - or derogations - to other reluctant nations. But, the entry of Spain and Portugal into the EC spelt the end of that strategy by the Commission, as these two nations expected to increase coal consumption in the following years.

In the first half of 1986, it took the Dutch Presidency, one of the main protagonists of the Directive, to highlight the importance of the proposed legislation and get all members back to the negotiating table.

This return coincided with British government's change of position on acid rain abatement. A new sense of optimism emerged from the negotiations. Reduction proposals were no longer unilateral, and tended to be based not on objective criteria but on what nations might accept. Even this approach, used by most governments making proposals, took a long series of offers and counter-offers before an agreement was reached.

The offers and counter-offers followed the presidency of the European Commission. Every six months, another country took over the presidency. During the six month period, its responsibility was to propose legislations, like the LCP Directive. Considerable prestige was bestowed upon the president which ensured particularly difficult legislations were fully accepted by all member states.

The LCP Directive was a difficult piece of legislation to get ratified, because of the greatly conflicting interests. Therefore, all governments, which considered the directive important - including the UK, by 1986, but not Spain or Greece - would propose target reductions. The targets reflected the president's position on acid rain abatement, while still trying to be acceptable to the opposition.

Just like the European Commission, initially, the Dutch, British, Belgian, Danish and German governments (in that order) failed to propose acceptable reductions. The proposals were too un-compromising for the opposition and were consistently rejected.

Finally, the UK government, in 1988, having changed its position on acid rain two years earlier, felt that an agreement on levels of sulphur dioxide emission reductions was becoming urgent. It held a bilateral meeting with the German delegation. At the meeting, thanks to previous offers and counter-offers, the British representative could make a proposal that the Germans could not refuse.

It broke the deadlock. The two sides agreed on a proposal for UK large combustion plants to reduce their sulphur dioxide emissions by 20, 40 and 60 percent by 1993, 1998 and 2003, respectively. The anticipated lull in proposals through 1989 as two non-cooperators held the EC presidency next, Spain and Greece, meant that the agreement had come on the brink of an eighteen month 'stale mate'.[1]

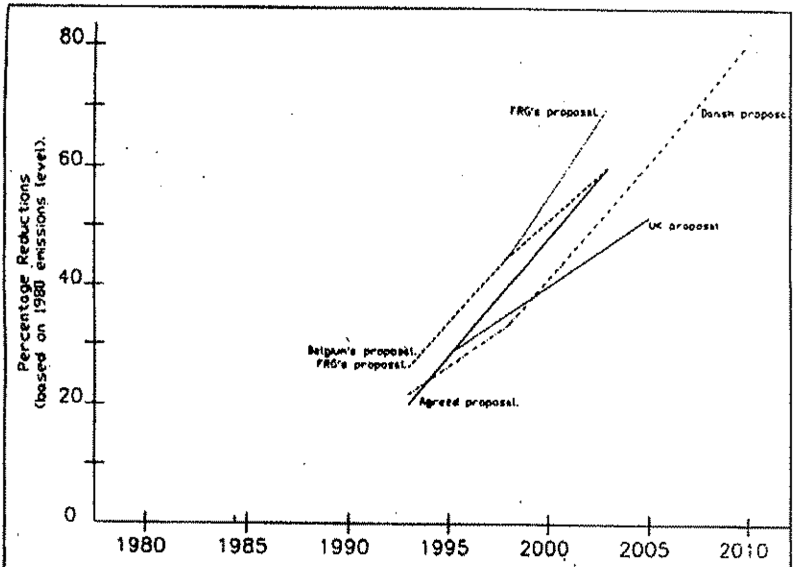

Figure 3 **LCP Directive Proposals on UK Sulphur Dioxide Emissions.**

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1 See Appendix II for a table of the complete LCP Directive and figure 3 for the proposals made during the negotiations.

4 THE MODEL

4.1 Introduction

The negotiations surrounding the Large Combustion Plant Directive are investigated using Rubinstein's sequential non-cooperative bargaining model (Rubinstein 1982). Between 1986 and 1988, a well-ordered series of offers and counter-offers characterised negotiations. The two prominent parties, British and German governments, had a common interest - a signed directive - and a conflicting interest - UK's level of reductions.

The dangers of not coming to a mutual agreement were political and environmental. As offers and counter-offers ensued without an agreement in sight, cooperation between the two nations on other joint projects became less likely and acid deposition caused by sulphur dioxide dispersion accumulated in European lakes, forests, and cities. The more proposals, and time, required to reach an agreement the more damaging would be such a wait on international relations and environmental well-being. Thus, cooperation was required as soon as possible.

Each nation had much interest in the level, or rate, of reduction from British power stations. Unfortunately, here, the interests were diametrically opposed. A low rate of reduction would benefit the UK at Germany's expense, and vice versa. The British government - once it realised reductions were required - wanted a rate that would maximise its net benefits.[1] This was a low rate of reduction. Far too low for German politicians, in view of the huge retrofitting bill their power stations had previously covered. The bill had penalised German industry through higher electricity prices and a loss of competitiveness and it was about time "they spread the misery around".

Germany and Britain tried to agree on UK reduction levels; several rounds of negotiations followed. Each party made a series of offers, based on its knowledge of opposition's willingness-to-concede. Unfortunately, each proposal tended to overestimate the opponent's willingness-to-concede, or underestimate its reluctance to capitulate. Frustrating as each rejected proposal might have been, it provided invaluable additional information about the opponent's position. Gradually, each proposal moved closer to the opponent's position. After several years of observing each others' position through this 'tatonement' process of offers and counter-offers, British and German governments came to a solution.

4.2 Choice of Model

In game theory, various approaches attempt to explain the process through which players go to reach a mutually acceptable solution. The cooperative approach, first developed by Nash (1953), assumes that players communicate with one another to maximise their joint utility. A solution is found which satisfies these conditions. If one player fares better than the other - for example, player I's share is greater than player II's - then a side payment will be made to compensate the less well-off player (here, player II). This approach would be appropriate to model negotiations where players were expected to work together to reach an agreement.[1]

A non-cooperative approach makes the opposite assumption: that players are calculatively rational and self-interested and try to maximise their own welfare irrespective of the other player's. From a non-cooperative perspective, bargaining is the meeting of parties, whose interests may be partially common and partially different, in an attempt

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1 For more details on cooperative bargaining models see Binmore and Dasgupta (1987).

to secure an agreement on one or several issues of discord. Negotiations are assumed to proceed in a certain sequence. The first player proposes a value (V_a) for her share of an imaginary pie. A second player, then, states how much he requires (V_b). Any value of V_b such that

$$V_a + V_b > 1 \quad (1)$$

means that the payoff to both players is zero and that the proposal is effectively rejected. Any value of V_b such that

$$V_a + V_b =< 1 \quad (2)$$

means that the offer is accepted and bargaining ends.

An alternative model, initially developed by Schelling (1960), suggests that players use focal points to generate proposals. Focal points - such as "drive on the left hand side", "meet under the clocktower" or "let's pay fifty-fifty" - are proposals that have been acceptable in the past, or are intuitively or aesthetically appealing to players. In suggesting such values, individuals do away with the effort of calculating an optimal proposal. Though focal points appear more immediately related to sociology, economists have, increasingly, been incorporating the concept into bargaining models (see, for example, Binmore, Swierzbinski, Hsu and Proulx 1993).

Several rival models compete to explain bargaining behaviour. I have chosen the non-cooperative approach because of its assumptions about players' rationality and I believe it best describes the behaviour of governments involved in the acid rain disputes.

As members of a 'common market', both German and British governments may have been seeking to maximise a pan-European utility function. However, Newbery (1990) pointed out that, in relation to the LCPD negotiations, "..the governments of Europe were rational, selfish and non-cooperative." (p.325). Furthermore, Newbery's conclusion, and the discussion following his paper by Siebert (1990), suggests that an inter-governmental strategy to reduce acid rain would have tried to minimise the net costs of abatement for all countries together. Each country's abatement, however, was considered individually; and, from the way each government made its proposals, it becomes clear that emission reductions were based on national interests, and not pan EC-welfare.

This supports the view that a non-cooperative model to explain the LCPD negotiations would be most appropriate. It is possible, though, that focal points did determine or, at least, influence government proposals. But because of simplicity and, especially, similarity between the model and features of the LCPD negotiations, the final LCPD agreement will be initially explained using Rubinstein's non-cooperative bargaining model.

4.3 The Rubinstein Model

Rubinstein's non-cooperative bargaining model suggests that players enter negotiations with the intention of receiving as large a 'split of the pie' as possible. Since both players intend to maximise their own interests and some of them clash, disagreement ensues. Rubinstein (1982) proposes an explanation on how they come to an agreement. He states the agreement depends on players' urgency to agree, and opponents' knowledge of the urgency, as well as the order of proposals.

The model assumes that there are costs associated with the duration of negotiations. Thus, speed (in coming to an agreement) is of the essence. These are represented by a discount factor, which makes payoffs today worth more than payoffs tomorrow. The discount factor is appropriate to the acid rain debate because all nations suffer - to differing degrees - by not having a European agreement on emission reductions. These unevenly-distributed costs - and, therefore, unequal discount factors - grew as international pressure and environmental damage mounted. The discount factor, therefore, has an important role to play in explaining LCPD negotiation's final agreement.

Unfortunately, the value of governments' urgency to finalise such a directive (and discount factor) is unknown. To incorporate this feature into the model, I have chosen to use a proxy for environmental damage based on acid rain imports, as this is directly related to the externality problem and the costs associated with an unsigned directive. The annual discount factor for each government is measured as the ratio of indigenously produced acid deposited in its country to total acid deposited in its country (see Table 2). The UK, an upwind sulphur emitter, has a ratio of 0.81 (i.e. a six monthly discount factor, S_{UK}, of 0.9), whereas the FRG, in the middle of Europe, has a lowly 0.4 (i.e. a bi-annual discount factor, S_{FRG}, of 0.63). These values suggest that international cooperation and a solution to acid rain disputes is more urgent for Germany than for Britain.[1]

In the model, perfect information is assumed. In particular, each player knows how urgently the opponent wants to finalise negotiations. A player, aware of her own and opponents' discount factor, will make a proposal, $V_{a1,}$ that is just too low for the second player to reject. This initial proposal, the lowest player II will accept, is the highest player I can receive. Such a 'split of the pie' favours the first player to make an offer. The benefits of being first mover are considerable, and much of the game's outcome revolves around a pre-game race between players to be the first to offer. If both players have perfect information, they come to equilibrium and an agreement immediately, the solution depending on players' discount factor and who proposes first.

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1 A more accurate discount factor would incorporate political costs, as well as environmental ones, resulting from disagreements about levels of reductions. Due to the qualitative nature of political costs, I was unable to find a proxy.

Formally, the solution to a bargaining game is

$$V_a = \frac{1 - S_b}{1 - S_b . S_a}$$

$$V_b = 1 - V_a$$

(where V_a is player one's proposed accepted 'share of the pie', and S_a and S_b are player I and player II's discount factors - See Appendix IV for a proof).

There is no doubt that for the 1983 and 1986 proposals, governments involved in EC acid rain abatement negotiations, were far from perfectly informed about opponent's urgency to conclude. However, by 1988, through a series of offers and counter-offers governments may have been much closer to certainty about opponents' discount factors. Under the circumstances, I believe that the UK government's final proposal may be modelled as an individual bargaining game with perfectly informed players.

To estimate the predicted solution to the UK's sulphur dioxide emission reductions based on a Rubinstein sequential bargaining model I simply include Germany and Britain's discount factors. However, these discount factors must be altered to take account of the additional urgency that loomed over the final proposal. Spain and Greece, two countries reluctant to push for the directive's ratification, were to take over EC presidency in 1989. Estimates are based on discount factors which imply that if governments did not agree in 1988 eighteen months would pass before the next proposal. Thus, the discount factors for the final agreement become

$$S_{UK} = (0.9)^3 = 0.729$$

$$S_{FRG} = (0.63)^3 = 0.25.$$

The Rubinstein solution to the final agreement - based on the assumptions that there is perfect information, the rules of the game and order of proposals is understood by both parties, UK moves first, and discount factors are based on an eighteen month wait between proposals - is

$$V_{UK} = \frac{1 - S_{FRG}}{1 - S_{FRG}.S_{UK}}$$

$$= \frac{1 - 0.25}{1 - (0.25x0.729)}$$

$$= 0.917;$$

$$V_{FRG} = 1 - 0.917 = 0.083.$$

Clearly, the model suggests the UK government would come out net beneficiary of the negotiations and LCP Directive.

To translate the solution into a value corresponding with the LCP Directive, I, first, calculate an average annual rate of sulphur dioxide emission reduction corresponding with the estimated range of proposals (from appendix III). Thus,

$$AR_{UK} = 2.854\%;$$

(see Appendix V for calculations) and, then, into phased annual rates and total reductions (for 1993, 1998 and 2003) on the 1980 level,

AR_{UK93}	$= 2.2\%$		
AR_{UK98}	$= 2.8\%$		
AR_{UK03}	$= 3.6\%$;		
TR_{UK93}	$= 24.0\%$	ACTUAL AGREED 93	$= 20.0\%$
TR_{UK98}	$= 38.0\%$	ACTUAL AGREED 98	$= 40.0\%$
TR_{UK03}	$= 56.0\%$	ACTUAL AGREED 03	$= 60.0\%$;

(see figure 4).

It appears that, as phase reductions were based on a discount rate of five percent, and the spread for the first and third phase is only from 24.0 percent to 56.0 percent, based on their actual proposal, the UK government's discount rate is of considerably more than 5 percent. In other words, it was willing to compromise the long term to get a better deal in the short run.

This could be in part explained by the imminent privatisation of electricity generators, and that CEGB as a nationalised enterprise would not need to take action, and leave the cleaning-up job to privately-owned generators. Also, by pushing off the date when large reductions are required, the revenue from the electricity sell-off would be unchanged by a directive on emissions. Or, the short-run/long-run trade-off can be considered as part of Government belief that natural gas and nuclear power were to replace coal anyway and, therefore, if the energy markets were given time to adjust the invisible hand would reduce sulphur dioxide. Fortunately for UK electricity generators and businesses, there has been a considerable shift out of coal into natural gas after privatisation. British industries, unlike German ones, managed to reduce sulphur dioxide emissions without paying large bills for FGD retrofitting.

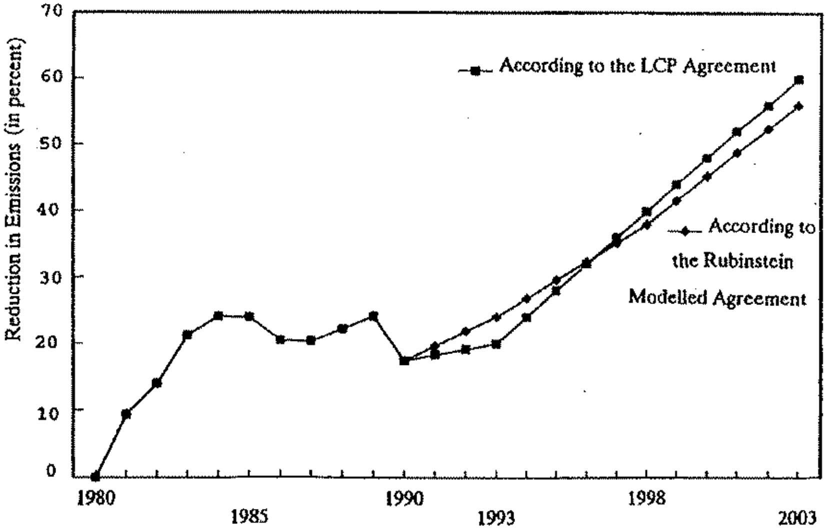

Figure 4 Reduction in the UK Sulphur Dioxide Emissions (from 1980 level)

4.4 Out-of-Equilibrium Behaviour

Predictions made using Rubinstein's model appear to simulate the final outcome of LCPD negotiations with realism. However, because of the assumption of perfect information, resulting in an immediate equilibrium solution, the model does not incorporate the possibility of rejected proposals. In other words, the perfect equilibrium Rubinstein model provides no explanation or prediction about the duration of the negotiations.

To incorporate out-of-equilibrium behaviour the model must anticipate periods of imperfect information. In the initial round of bargaining, players know little about opponents' intentions. If so, an impasse becomes possible. Rubinstein (1987) realising the shortcomings of his original model extended it to incorporate the possibility of imperfect information about opponents' discount factors. His extension suggests that player I knows player II to be one of two types: a person with a high discount factor (i.e. strong) or one with a low discount factor (i.e weak). Player I, seeking information about her opponent's type, offers player II a share so small that only a 'weak' person would accept (since the costs, in wasted time, of rejecting the proposal would be too great for a weak player, but not for a strong one). Player II's acceptance or rejection of the offer signals to player I her opponent's discount factor.

Such an extension to Rubinstein's perfect equilibrium model provides additional explanation about acid rain disputes only if both players have imperfect information and each side can have several possible discount factors. Under these circumstances, players would acquire information about discount factors by observing opponents' rejections. Eventually, through a 'tatonement' process, they would learn the correct discount factors and converge on a solution.

This adds a new dimension to negotiations. Each player wants to be the first to know perfectly an opponent's discount factor. Achieving perfect knowledge enables a player to find the minimum payoff his/her opponent will accept. Once one acquires sufficient information to evaluate the opponents' minimum acceptable payoff, bargaining is effectively over. Negotiations could be characterised as a race for perfect knowledge of the opponent's discount factor. In the LCPD negotiations, the UK government won the race and, thus, was the first mover in a bargaining game of perfect information.

An alternative explanation, introduced by Schelling (1960) and developed by Crawford (1987), still assumes imperfect information. This explanation uses players' willingness to commit themselves to a particular payoff. If they do commit themselves, their opponent need no longer know with certainty their discount factors but only their commitment levels. When a player knows his/her opponent's commitment level, a proposal can be made which maximises his/her own payoff by minimising opponent's payoff.[1]

Also, the likelihood of capitulating from the committed level is important. If a player 'burns all the bridges behind him', it will be impossible to turn back on a position. If so, it may be wise for his opponent to concede to that committed level otherwise an agreement will never be reached. Thus, a pre-game race begins between players to commit themselves and credibly show that turning back is impossible.

If threats are not credible, impasses may occur. In the face of uncertainty over the likelihood of an opponent committing or capitulating, it may be rational to be committed to a value, and to rejecting the opponent's offer in the hope of him (or her) capitulating. The level of certainty about the opponent's commitment determines the likelihood of a player capitulating.

During the acid rain abatement negotiations, it appears that in 1983 a race for 'commitment' began but that both players ended up committing themselves - the UK government's position was to agree only to low rates of reduction and the FRG government's stance was to make British electricity generators fall in line with German ones. Unfortunately, neither was aware or convinced of the others' commitment. Under these circumstances a player suspects the opponent is not fully committed to a position and may capitulate from it. If so, such a player consistently makes a proposal expecting the opponent to capitulate, but because neither the opponent's urgency to come to an agreement nor the value of such an agreement are great enough, it is rejected. From 1983 to 1988, British and German governments were entrenched in their

1 Schelling (1960) argued that it was irrational for players to commit, but because it appears they do and Crawford (1987) has developed a model based on such behaviour, it may partly lead to an explanation of the negotiations' duration.

positions unwilling to capitulate and unaware of each other's opponent's unwillingness to do so. Then, in 1988, additional urgency associated with the agreement led the UK to propose a 'split' which broke the deadlock. The decision may not have been a more informed one, but because discount factors had changed for that round, capitulation from a previously firm position was necessary. Under these circumstances, the FRG capitulated, and accepted an offer incompatible with its position.

Other explanations exist for such out-of-equilibrium behaviour. For example, as domestic pressures demanded governments to return from negotiations with a favourable agreement, representatives preferred to return empty-handed rather than face humiliation. Thus, both sides stood their ground, refusing to concede an 'inch'. Alternatively, Baumol and Benhabib (1989) have suggested players' non-linear response functions may generate 'chaotic' offers and counter-offers that could lead negotiations to ".. easily break down as each party, not understanding the source of the problem, suspect the other side of duplicity and sabotage." (p.7).

The forces that generated the acid rain disputes are numerous and complex. The many factors involved must be carefully examined to understand why no agreement was achieved for so long. This study finds, however, that two features are fundamental in explaining the duration of negotiations: the urgency to reach an agreement and players' imperfect information about their opponents' intentions or positions.[1]

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1 As part of an extension to this work, I intend to test Rubinstein's bargaining model under imperfect information to test its ability to accurately predict the outcome and duration of the LCP Directive negotiations.

5 CONCLUSIONS

The recent LCPD talks were long and painstaking. Five years after they began, and six proposals after the Commission's initial suggestion, the UK and the FRG agreed on a level of reduction for sulphur emissions from British power stations. The agreement made was for 20, 40 and 60 percent reduction from the 1980 level by 1993, 1998 and 2003, respectively.

I have highlighted several features of the acid rain conflict in order to explain the outcome and duration of negotiations surrounding the Large Combustion Plant Directive. The Rubinstein-model, used to predict the outcome, assumed, first, that players' urgency to conclude discussions were based on countries' relative amount of sulphur dioxide imported; second, that their information about their adversary's time preferences was perfect and symmetrical; and, third, that UK and FRG were the only players, making offers and counter-offers until one proposal was accepted by both. A further assumption concerning the nature of the UK government's preferences about the level of abatement determined the range of proposals. I assumed that Britain was aiming to maximise net benefits of abatement - so that, in the long run, emissions of sulphur dioxide would be lowered by 54.5 percent of the 1980 level; as a lower boundary, I suggested Britain would not conceivably lower emissions to a level which meant making a net loss (i.e. 74 percent; Appendix III explains the results). It was then possible to estimate an outcome for the Large Combustion Plant Directive.

The model yielded a reasonably accurate prediction of the equilibrium solution. Its inability to address the issue of negotiation length and the problem of out-of-equilibrium behaviour, which characterises real-life bargaining situations, is a particular weakness. Alternative approaches highlighted the many impasses which surrounded these negotiations. Principally, I have argued that, as well as a change in the urgency to agree, both players were insufficiently informed either about their opponent's discount factor or commitment to a position. Because of the uncertainty, both parties rejected their adversary's offers. But, in the long run, as more and more offers were proposed and rejected, players increased their understanding of the opponent's position and urgency. The accumulated information, and perhaps the higher urgency to reach an agreement in 1988, explained why a solution was finally found.

I believe that the model has provided some insight into the acid rain debate. But, more importantly, this study has suggested ways of understanding some of the recent and future international negotiation rounds. With a growing interest in global environmental management, negotiations, such as the UNCED conference on climate change in Rio de Janeiro in 1992 and future LCPD negotiations, become a more frequent occurrence. There is, therefore, a growing need to analyze the sides involved, and their reasons for disagreeing. As I have suggested, part of the problem stems from the parties' inability to understand and inform themselves about their opponent's objectives. Future negotiators should be aware of this problem, and strive to acquire sufficient information to prevent breakdowns.

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APPENDICES

APPENDIX I: Sources of Acid Rain

Man-made sulphur dioxide and nitrogen oxides form primarily from fossil fuel combustion. Other sources of emissions result from industrial processes, particularly smelting operations and acid manufactures, and vehicle exhausts.

Not all fossil fuels have the same sulphur content. Their content depends on the type of fuel and its source. Coal, responsible for 79 percent of fossil fuel combustion emissions, has the highest and widest range of sulphur content; varying from 0.5 percent to 5 percent. In the UK, only 15 percent of the coal has a low sulphur content. And, most of it originates from Scottish and Welsh mines (Park 1987), which are being shut down for profitability reasons. If more coal of this type was needed it would have to be imported.

Fuel oil's sulphur content is lower than coal's, ranging upwards from 0.1 percent; North Sea oil contains less sulphur than Middle East crude. Fuel oil produces 12 percent of sulphur dioxide emitted from power stations. Natural gas produces virtually no sulphur or carbon, the main cause of the greenhouse effect.

Table A1: Contributions to Sulphur Dioxide (Millions of tonnes per year)

SOURCES	AMOUNT
Natural Causes:	
Biogenic	
- Oceans	50
- Land	48
Non-Biogenic	
- Volcanoes	5
- Sea Spray	44
Total	147
Man-Made:	
Fossil Fuels	104
TOTAL	251

Source: Park (1987) p.33

APPENDIX II: Large Combustion Plant Directive Final Agreements

Table A2: Proposed Sulphur Dioxide Emission Reductions during the LCP Directive Negotiations

SO2 1980	799	437	3200	23	467	3560
LCP SO2 (1980)	530	323	2225	3	467	1910
	Belgium	Denmark	FRG	L'bourg	N'lands	France
CEC	60	60	60	60	60	60
NL (95)	50	50	70	0	60	60
UK (95)	57	37	58	0	77	91
UK (05)	57	51	58	0	77	91
BEL (93)	40	34	40	40	40	40
BEL (98)	60	56	60	50	60	60
BEL (03)	60	56	60	50	60	60
DK (93)	40	34	40	40	40	40
DK (98)	60	56	60	50	60	60
DK (10)	80	78	80	60	80	80
FRG (93)	40	34	40	40	40	40
FRG (98)	60	56	60	50	60	0
FRG (03)	70	67	70	60	70	70
LCP (93)	40	34	40	40	40	40
LCP (98)	60	56	60	50	60	60
LCP (03)	70	67	70	60	70	70

(Continued) **Table A2:** **Proposed Sulphur Dioxide Emission during the LCP Directive Negotiations**

SO2 1980	219	3800	3250	400	328	4670
LCP SO2 (1980)	99	2450	2290	303	115	3883
	Ireland	Italy	Spain	Greece	Portugal	UK
CEC	60	60	n.m.	60	n.m.	60
NL (95)	0	40	10	0	0	45
UK (95)	0	47	6	0	0	28
UK (05)	43	63	31	0	0	52
BEL (93)	-25	26	24	3	-28	26
BEL (98)	-25	51	37	3	-28	46
BEL (03)	-25	51	37	3	-28	60
DK (93)	-41	27	16	-15	-107	22
DK (98)	-41	42	30	-15	-129	33
DK (10)	29	76	62	23	-8	80
FRG (93)	-25	27	0	6	-29	26
FRG (98)	-25	39	24	6	-42	46
FRG (03)	-10	63	37	21	-26	70
LCP (93)	-25	27	0	-6	-102	20
LCP (98)	-25	39	24	-6	-135	40
LCP (03)	-25	63	37	-6	-179	60

Source: Boehmer-Christiansen and Skea (1990) p.241

APPENDIX III: UK's Net Benefits of Abatement

Maler (1990) predicted that if the UK reduced its emissions by 81 percent, it would receive net benefits equivalent to DM -365M (see table 3). These calculations were based on deducting the cost of abating 81 percent of emissions from the net damage these same emissions caused.

The costs of abatement are based on a paper by Amman and Kornai (1987) - see figure A1 for details - containing the marginal cost of abatement for the UK. Maler is not specific about his method for deriving the marginal benefits; as I could not find information elsewhere, the marginal benefits of abatement in monetary value are derived from Maler's results.

First, I calculate the net cost of abatement. Using the values in figure A1, the marginal costs may be summed in order to find the total costs. A reduction of 81 percent is equal to lowering emissions, either, to a level of 0.88M tonnes of sulphur dioxide or by 3.9M tonnes.[1]

From 0 to 1.3M:	1.3M x DM 1000	=	DM 1300M
From 1.33M to 2.55M:	1.25M x DM 2000	=	DM 2500M
From 2.55M to 2.86M:	0.31M x DM 6000	=	DM 1860M
From 2.86M to 3.46M:	0.11M x DM 8000	=	DM 880M
Total Costs:		=	DM 11340M[2]

1 The calculations are based on reductions from 1987 because, had the British government used cost-benefit analysis to make decisions, it is likely that that year's values would have been used.

2 From Figure A1, the marginal costs of abatement beyond 3.55 (or by 76 percent) rise dramatically. Because of insufficient information I have had to make the unrealistic assumption that total costs of reducing beyond 76 percent are the same as reducing by 76 percent. The maximum total cost of abatement is, therefore, assumed to be DM 11340M.

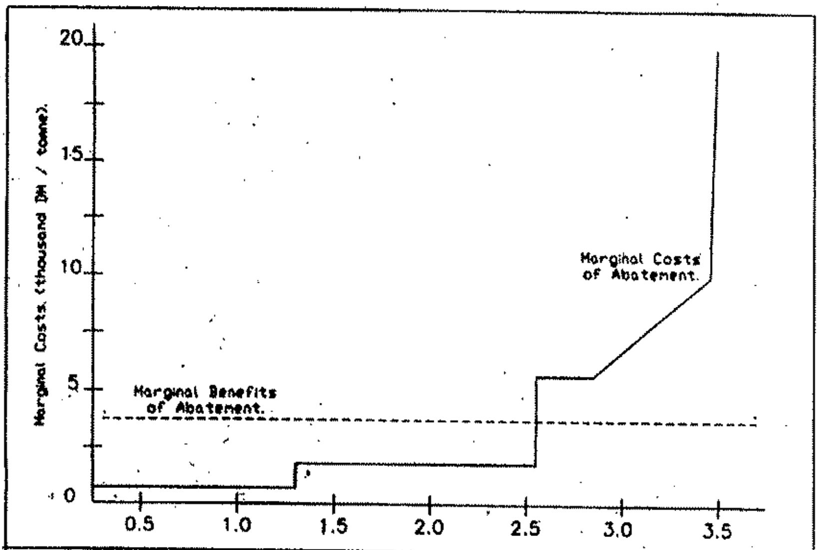

Figure A1 **Abatement Costs for the UK.**

It is possible to find the total benefits from reducing UK sulphur dioxide emissions by 81 percent. It will be equal to the total cost plus the total net benefits from reducing emissions by 81 percent.

	Benefits - Costs	=	Net Benefits
	B - DM 11340M	=	DM - 365M.
Hence,	B	=	DM 10975M.

For simplicity, total benefits are assumed to increase at a constant rate. Thus, benefits amounting to half the above reduction (i.e. 40.5 percent) would be equal to DM 5487.5M. The costs, on the other hand, are not linear;

From 0 to 1.3M:	1.3M x DM 1000
From 1.3M to 1.9M:	0.6M x DM 2000
Total Costs	= DM 2500M

The net benefits for a 40.5 percent reduction are equal to DM 2987.5M, which means the UK will be willing to reduce emissions by such an amount.

As total benefits are assumed to increase at a constant rate, marginal benefits are constant (though theroy suggests they should decline as abatement rises) at

(10975M / 3.46M =) DM 3172 per tonne of sulphur abated.

A figure A2 gives the total costs and benefits for particular sulphur dioxide reductions. This diagram shows at what level marginal costs equal marginal benefits; at 2.55M tonnes abated, which optimises net benefits. Below this level, the marginal costs are DM 2000 and, above it, they are DM 6000. Such a level is equivalent to a 54.5 percent reduction of the 1980 level (4.678M). It is assumed that this amount will be abated over the 13 years leading up to 2003 - though, 17.5 percent of the reduction has already been achieved by 1990.

A further assumption made is that UK government would refuse to reduce emissions beyond the point where total costs of abatement are greater than total benefits. From figure A2, that level is reached when emissions are abated by 3.46M tonnes. I consider that the payoff to the UK from an agreement that requires a reduction of 3.46M tonnes of sulphur dioxide is zero. The range of feasible proposals, therefore, varies between a reduction of 2.55M and 3.46M.

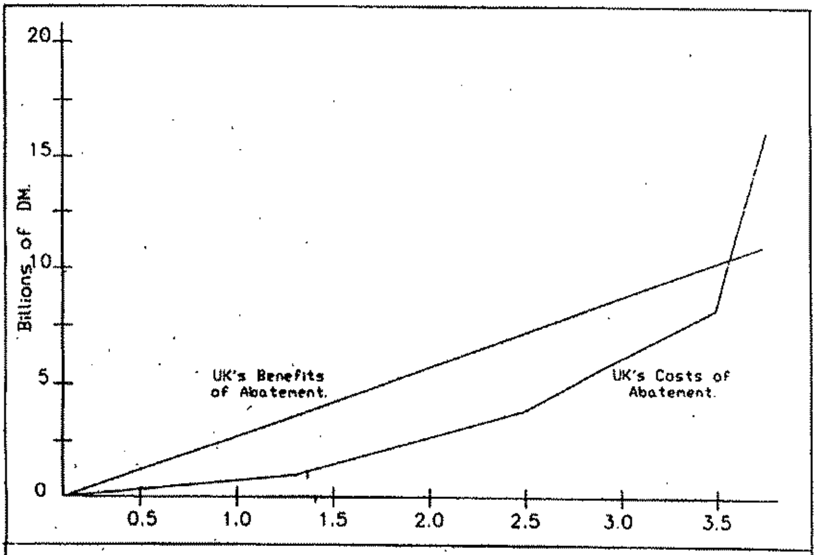

Figure A2 **Net Benefits of Abatement for the UK.**

APPENDIX IV: The Solution to the Rubinstein Model

In a game where offers alternate over infinite time, with perfect and symmetric information, the player who is first to make a proposal will know the opponent's reservation level. Thus, he knows the highest value (M) he can receive, which his opponent will accept with certainty. Thus, in round t-1, he will accept this value discounted one period and not a lower value, and the opponent knows this. Backtracking, in a similar way, to round t-2 means that

$$1 - S_b (1 - S_a . M) = M$$

Thus,

$$M = \frac{1 - S_b}{1 - S_b . S_a .}$$

(For more see Rasmusen (1987) p.235)

APPENDIX V: Calculations related to the Solution

A. Transforming Levels into Rates

The split of the pie or the payoff that is bargained for is based on a utility function. For the model of the LCPD negotiations, the utility function was dependent on the total reduction of sulphur emissions (see Figure 2) and the range of possible proposals (see Appendix III)[1].

I have assumed the UK will maximise net benefits when it reduces emissions by 54.5 percent of the 1980 level. In 1990 emissions reduced

1 In Fouquet (1991), the utility function depends on the annual rate of reduction reflecting the British concern that speed of the reduction was more important than the total amount. I have, however, chosen to use the total reduction as the proposals in the LCPD negotiations took this form.

by 17.4 percent (to a level of 3.862M tonnes)[1]. Thus, the UK when it agrees to a particular reduction will have already abated emissions by 17.4 percent before 1990. So, British large combustion plants would, if reducing emissions by the optimal amount before 2003, need to abate emissions by a further 37.1 percent. The mimimum that the UK government would accept is 74 percent - where total costs and benefits are equal - which means a further reduction from 1990 of 56.6 percent.

Thus, the range of proposals are for further reductions between 37.1 and 56.6 percent. These are turned into annual rates of reduction, as these values reflect the annual marginal costs of abatement and enables me to calculate phased reductions using a UK discount rate. To reduce emissions by a further 37.1 percent for 2003, I divide the value by the number of years available; so,

$$37.1 / 13 = 2.854, \text{ and}$$

$$56.6 / 13 = 4.354.$$

These are average annual rates.

The LCPD agreement states that the UK must reduce emissions by 20, 40, and 60 percent of the 1980 level by 1993, 1998, and 2003. These can be converted into phased annual rates (in percents).

---

1 I assume that the level of reduction for 1990 - 17.4 percent - that actually occurred is equivalent to the one that the UK government anticipated. In other words, this reduction was incorporated in the decision-making process.

$AR_{93} = (0.2 - 0.174) / 3 \times 100$
$= 0.87$
$AR_{98} = (0.4 - 0.2) / 5 \times 100$
$= 4.00$
$AR_{03} = (0.6 - 0.4) / 5 \times 100$
$= 4.00$

B. The Phased Annual Rate

Because the UK is more concerned about the rates that must be achieved in 1993 than 1998 or 2003, there is an annual discount rate to the reduction rates. The rate of 5 percent has been chosen. There is no particular evidence to chose such a value - it may be preferable at a higher rate, as governments are said to have high discount rates.

Thus, each annual rate is discounted by 0.05 per year. Every year from 1990 to the end of the reduction period (e.g. in the final proposal that was 2003) has a new rate; these are summed and divided by the number of years. So, for example, the UK's optimal proposal is

$AR = 2.854.$

To find the phased annual rates, I calculate a step-function

$2.854 \times (0.95)^{mt},$

where mt is the median number of years in the series over reductions. From 1990 to 2003, mt is equal to 6 or 7 (choose, say, 7) and

$2.854 \times (0.95)^{7} = 2.00.$

Thus, the first phase (1993) annual reduction would be

$$AR_{93} = (2.00 + (2.00 / 0.95) + (2.00 / 0.9025)) / 3$$

$$AR_{93} = 2.11.$$

The other phases of the reduction are found in a similar fashion.

The total phase reduction can be found by simply multiplying the annual rates by the number of years in the phase, and add it to the 1990 abatement. For example,

$$TR_{93} = 17.4 + 2.11 \times 3$$

$$= 23.73 \text{ percent reduction from the 1980 level.}$$

C. The Annual Rate as a Share of the Pie

The conversion of values into shares of the pie is obvious once a range for the possible proposals has been chosen. This is the range of average annual rates of 2.854 (equal to 0 - for the RFG) and 4.354 (equal to 1 - for the FRG). Thus, the range is of 1.5.

The solution to the Rubinstein model gave a share of the pie equal to 0.083. this can be converted into an annual rate of reduction of

$$AR = 2.854 + 0.0803 \times 1.5$$

$$= 2.97.$$

D. Turning the Pie into a Proposal

The model gives a share of the pie, which can be changed into an average annual rate for the whole period,

$$
\begin{aligned}
TR &= 17.4 + 2.97 \times 13 \\
&= 56.
\end{aligned}
$$

Using the technique developed in Appenidx V B, I can calculate the Rubinstein solution as a phased annual rate of redcution:

$$
\begin{aligned}
AR_{93} &= 2.2 \\
AR_{98} &= 2.8 \\
AR_{03} &= 3.6.
\end{aligned}
$$

(See Figure A3 for the phased annual rates of reduction).
These can be transformed into total reduction levels:

$$
\begin{aligned}
TR_{93} &= 17.4 + 2.2 \times 3 \\
&= 24 \\
TR_{98} &= 24 + 2.8 \times 5 \\
&= 38 \\
TR_{03} &= 38 + 3.6 \times 5 \\
&= 56.^{1}
\end{aligned}
$$

1 Clearly, a higher discount rate would give a wider spread of values; the first phase would be lower, more closely replicating the actual LCPD agreement.

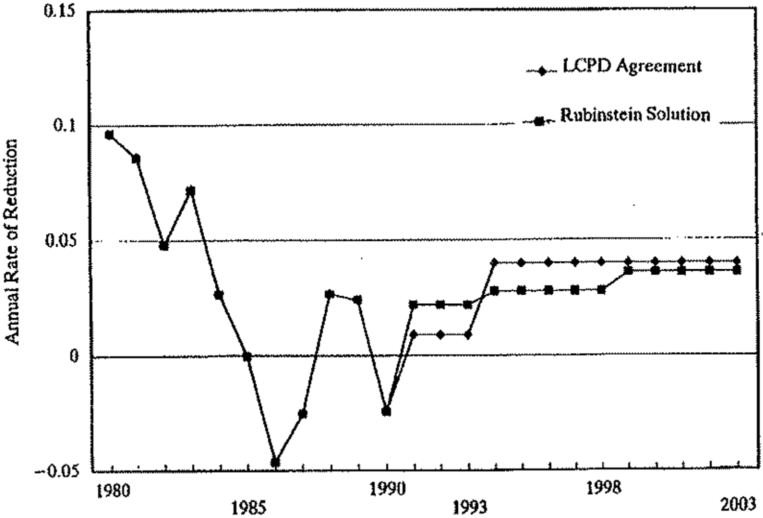

Figure A3 Actual and Predicted Agreement for the LCPD Negotiations

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