CONFLICT RESOLUTION

SYDE 533

Conflict around the formation of US position prior to the Montreal Protocol on substances that deplete the Ozone Layer

PROJECT REPORT

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ABSTRACT

The report presents a detailed stability analysis of the conflict that arose during the formation of U.S. position regarding the Substances depleting Ozone Layer prior to the Montreal Protocol in 1987. The conflict is divided into three time zones- 1970-'74, when the conflict was about Supersonic Transport Systems, Concorde and their effects on the Ozone Layer, 1974-'77, when the ODS in concern was CFC and which resulted in passing of the Clean Air Act and resulted in United States finally taking stand for the protection of the Ozone Layer and 1977-'87, when the problem emerged as an international problem and the different countries had to come to an agreement in the form of the Montreal Protocol of 1987 as the first global step towards the Protection of the Depleting Ozone Layer.

The report also shows how sensitivity analysis and coalition analysis can help obtain different stability situations and states in equilibria.

CONTENTS

I. INTRODUCTION

During the debate over the development of a fleet of supersonic transports in the early 1970s, the depletion of the stratospheric ozone emerged as a major political concern in the United States**.** [1] Because the various parties of the US saw the problem differently, there were different reactions which led to conflicts. Some of them thought the government should act to protect life by restricting or eliminating Chlorofluorocarbons (CFCs), and some thought the government action was unnecessary, harmful, or premature. It became a major political issue with regards to the use of CFCs in aerosol spray cans in the mid-1970s and in 1978 the United States banned the use of CFCs. International conflicts regarding the controlling CFC use started in 1980s and even though, in a way, it continues today, it had then culminated in the 1987 Montreal Protocol.

The Montreal Protocol is a landmark agreement. It is the first international treaty for "mitigating a global atmospheric problem before serious environmental impacts have been conclusively detected". [2] It has also been a model for international agreements on other environmental problems that have had global effects.

This project will analyze the conflict on the human contributions towards the depletion of the Ozone layer prior to the Montreal Protocol in a two stage process- 1) within the United States of America (1970-1977), 2) as an International conflict considering the United States' negotiating position (1977-1987).

II. HISTORICAL BACKGROUND

It was first determined in the 1920s with the help of the Solar UV spectrum that there was a high-altitude ozone layer in the atmosphere. This was proved by a theory about the origin of this ozone layer in 1930 by a British scientist Sydney Chapman. This theory, also known as the Chapman mechanism, also forms the basis for the current understanding of the Stratospheric Ozone. [3]

A research study in 1965 by the English scientist John Hampson on the stratospheric environment and intercontinental ballistic missiles showed that there had been an anthropogenic destruction of the ozone layer. This instigated a discussion and Hampson and Ted Harrison, a Boeing scientist, claimed that the exhaust from the then proposed supersonic fleet of transport planes (SST) could deplete the Ozone layer. [4] Harrison published a 1970 article in Nature estimating that the world SST fleet would lead to a 3.8 percent decrease in global ozone.

In the mid-1960s, James Lovelock, a British scientist, invented an electron capture detector, which could measure minute gas concentrations in the atmosphere. Chlorofluorocarbon (CFC) had been invented in 1928 by a chemist from General Electric, Thomas Midgley. This new compound was developed as a safe replacement for the hazardous refrigerants in use in the refrigerator industry back then. [5] In 1969, Lovelock found concentrations of CFC molecules with the help of his invention in the lower atmosphere and notified the CFC manufacturers.

The origin of the actual CFC-ozone depletion debate was the publication by Sherwood Rowland and Mario Molina in the journal Nature in 1974 of their theory that CFCs could be a source of ozone destroying stratospheric chlorine.

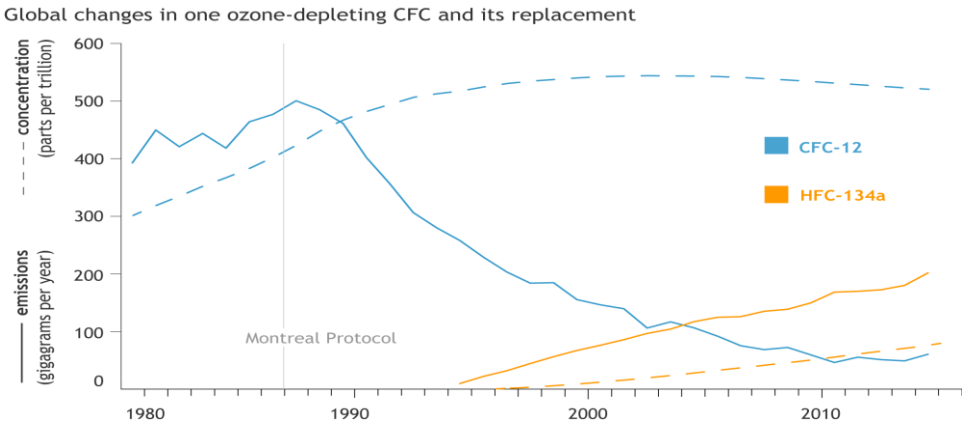

Fig 1

One of the most evident occurrences due to the ozone layer depletion, the Antarctic ozone hole stirred considerable interest among scientists because it had not been earlier predicted by models of atmospheric chemistry. [6] Data from 1987, released after the Montreal Protocol, suggested that CFCs and other anthropogenic pollutants are responsible for the ozone hole. However, meteorological conditions unique to the Antarctic also have magnified the problem. Despite continued debate about its specific cause, the ozone hole has a focused world attention on CFCs and stratospheric ozone depletion.

Recent research continues to show that CFCs have a major role in depleting stratospheric ozone. Other synthetic chemicals have also been identified to be potential stratospheric ozone depleters: most notable are the halons used in fire extinguishers.

The Ozone layer protects the earth from the UV-B radiation in the sun. The UV-B rays can have significant negative effects on living beings on earth. The most significant human health is an increase in skin cancer occurrences. [2] The U.S. Environmental Protection Agency (EPA) has estimated that if CFC use continues to grow at 2.5 percent a year until 2050, it could result in an

additional 150 million skin cancer cases, causing more than 3 million deaths in the U.S. population born before 2075.

Thus, the Montreal Protocol had a lot of significance during that time period and it still holds a model value for all protocol and agreement structures, specially designed for the environmental issues. Before this stable protocol came into action, there were a lot of conflicts and disagreements which can be analyzed and resolved. These conflicts can be categorized as ones which took place within the United States and those that occurred internationally.

III. DECISION MAKERS, OPTIONS AND PREFERENCES

3.1 National Issue for the United States (1970-'77)

Stratospheric ozone depletion emerged as a major issue primarily in the United States in the mid-1970s due to the proposed fleet of U.S. Commercial Supersonic transports. [1] Most European countries were not much concerned about it then. The SST project was controversial long before it actually was proved to be contributing towards the depletion of the Ozone layer. But, when research findings cited the probability of it affecting the Ozone layer and thus increasing the UV-B radiation, it gave the proponents of SST a reason to scare the public. In 1971, the Congress authorized the Department of Transport (DOT) to assess the impact of SST on the Ozone layer depletion. After 3 years of findings, a report was published which was objected by the scientists who had researched, who claimed that DOT had modified the tone of the report and had ignored the impact of SST which their findings had proved. [8] A political compromise was made by killing the SST project but allowing the original 16 models of British/French Concorde which had the same implications as SST, access to U.S airports. The CFC issue was publicized during the DOT project. SST was a potential threat but CFC was an actual one. Both CFC manufacturers and users opposed to any action to regulate CFC. But it was taken seriously by the public and the sale of aerosol spray cans soon fell sharply. [7] Interagency Task Force on Inadvertent Modification of the Stratosphere (IMOS) was formed for a detailed study and as the findings were built on the SST background, the depletion due to CFC theory was proved. It was the era where along with the public opinion there was a "growth of corps of scientists and policymakers who cared about the stratosphere". [2]

Following it, the Toxic substance control act, the Federal Food, Drug and Cosmetics Act and the Clean Air Act were passed which proposed the control and subsequent banning of non-essential

use of CFCs in aerosols. [9] The action taken by the United States was commendable. In less than five years it had moved from the scientific discovery of a potentially serious environmental problem to the implementation of a regulation designed to resolve that problem.

The decision makers in the Ozone Depletion Layer as a national issue can be identified as the U.S. Government, U.S. Government opposition, British/French, Scientists, Industry manufacturing CFC and SST, the regulatory bodies and the media with the public and the environmentalists. The U.S. Government, the British/French and the opposition were in favor of the Supersonic fleet development initially as it meant better transport system, the dominance of U.S. technology and the aircraft industry and a major benefit for the public. The scientists had already started researching and findings were continuously proving that SST could be a probable cause. This changed the government's perspective which engaged scientists for a detailed study. The media and the public were against any substance that was harmful for the environment and in turn for them. The expenditure over these projects show that the government was in fact considering the public opinion seriously. But it also wanted to maintain international relations with Britain and France and thus took a middle road in the SST project where it gave access to its airports for the Concorde which were similar to the SST. But it did help in the formation of a regulatory body to take a serious step even though it meant being against the Industry that manufactured spray cans and refrigerators was to experience a heavy blow of loss. [10] The industry even tried to pay a scientist, quite respected by the peer, to argue against the threat and used local statistics which contradicted the scientist findings. Du Pont, the largest manufacturer of CFCs, spent on advertisements disputing the evidence supporting impacts. The U.S. Government opposition did support the industry till the findings were proved by multiple researches, as it thought the Government wanted to draw a diplomatic conclusion to be a favourite among the

public and other countries. But then the final decision was by the regulatory bodies formed which weighed the magnitudes of all arguments and passed acts to control the non-essential use of substances contributing towards the depletion of the ozone layer.

3.2 International Issue (1977-’87)

It wasn’t enough for only the United States to realize that the Ozone layer depletion was a major environmental issue. It was a global problem and for an effective result would mean taking action at an international level. From 1977-1985, starting from the Vienna Convention, the Stratospheric Ozone Depletion was legitimized as an International problem.

Much before United States implemented aerosol ban as the first response to this problem, international organizations like UNEP, WMO, OECD and EEC had already got involved in the research regarding CFCs and aerosols. In 1977, a meeting was organized by the UNEP where the need for a World Plan of Action was highlighted. The plan asked for a coordinated international effort regarding the issue in the form of research on its extensiveness. Soon after, in 1985, UNEP laid down a framework convention which took the shape of the Vienna Convention adopted by 43 states to protect "human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer." [11]

Even though the process had been initiated, still there were no strict guidelines to stop the use of Ozone layer depleting substances. This was because of a dispute between the United States, Canada, Sweden, Norway, and Finland on one side, known as the Toronto group, and the EEC countries on the other. The Toronto group had already banned the non-essential use of aerosols and hence had agreed on an 80% reduction in CFC manufacture whereas the EEC countries who were only producing 65% of the allowed aerosol production capacity, wanted a production

capacity cap and additionally a 30% reduction in the non-essential use of aerosols. This made negotiations impossible. [2]

Slowly, there were some events that led to a need for immediate and serious action regarding the matter. The CFC percentage had returned to the amount it had been before the aerosol ban. The members of EPA who had initially been against the CFC ban had resigned and soon after the scientists discovered the Antarctic hole. The EPA came up with a program, wishing to be instrumental in the Ozone Layer Protection procedure and decided to hold both domestic and international workshops to help formulate a public consensus regarding the control of CFC production. It was soon realized by the EPA, based on the new research by the scientist community and a strong consensus internationally, that it was time to take action. [7] The European countries, pressured by their own scientific assessments, public consensus as well as a U.S. position regarding the whole matter, agreed on a 50% reduction on CFC manufacture. The most important factor in convincing them was a fear of the United States imposing trade sanctions. In the last stage of the formulation of an international agreement, there was a split in the United States administration. Some of the agencies complained that a complete ban on CFC use was the best. These agencies were actually threatened by the major role EPA had played in deciding the U.S. position in the whole matter. At one point of time, U.S. position did seem weak but it regained its control by deciding on a 50% reduction is CFCs and a complete freeze for halons and thus giving way for CFC substitutes in the market. [12]And everything finally culminated in the Montreal Protocol in 1987.

The major decision makers in the International level of problems are United States Government, EPA, international regulatory bodies like UNEP, the rest of the Toronto group of nations, the EEC countries and the group of scientists. The United States Government wanted to

play a crucial role in the mitigation of the problem but also wanted to appease the different agencies running under its administration. Hence it had to decide on a 50% reduction in CFCs but a complete freeze on halons. [2] The EPA was always aiming at deciding the highest position for the U.S. towards solving the issue and hence worked in favour of control of Ozone layer depleting substances. The regulatory bodies had a major role in bringing all the nations together to work towards the common goal. This was necessary initially when the Ozone layer depletion problem had not even been given enough thought, leave alone responses, at an international level. The Toronto group of nations were in favour of an 80% ban only because they had reached the full production cap and had already implemented the ban of non-essential CFC whereas EEC initially wanted just a 30% reduction at a 65% production cap, which was modified to a 20% reduction [13] at a full cap and was finally increased to a 50% reduction of CFCs in the protocol with a complete ban on halons.

IV. STABILITY AND SENSITIVITY ANALYSIS

4.1 National Issue for United States (1970-'74)

DECISION MAKERS	OPTIONS
Public, Environmentalists and Scientists	Regulate or Ban SST after publications on impact of U.V. radiation
British/French	Continue and ensure economic viability for the Concorde production as not convinced about impacts.
U.S. Government	Ban SST after publications on impact and public concern.
	Take the middle road by banning SST but giving 16 Concorde although only the original ones, access to U.S. airports. Political Compromise
U.S. Opposition	Wanted no ban on SST as still not convinced about the impacts.

Table 1: Decision Makers and Options ('70-'74)

INFEASIBLE STATE	REASON
- - Y Y -	Mutually Exclusive
- Y Y - -	The British/French cannot ensure economic viability of the Concorde if the U.S. Government bans SST and germane.
- N – Y -	If the U.S. Government takes the middle reason, there is no reason for the British/French to kill the Concorde project.

Table 2: Infeasible States ('70-'74)

After removing the infeasible states from the list of options, 16 states are left. These states are then arranged according to the preference of the different Decision Makers.

	Ordered Decimal	Filter	1 0	2 1	3 2	4 3	5 4	6 5	7 10	8 11	9 16	10 17	11 18	12 19	13 20	14 21	15 26	16 27
1 - Public, Environm	Regulate or Ban	-	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2 - British/French	Concorde production	-	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
3 - U.S. Government	Ban	-	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y	N	N
	Middle Road	-	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y
4 - U.S. Opposition	No Ban	-	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Payoff For:	Public, Environmenta	-	6	14	2	10	8	16	4	12	5	13	1	9	7	15	3	11
Payoff For:	British/French	-	10	9	14	13	2	1	6	5	12	11	16	15	4	3	8	7
Payoff For:	U.S. Government	-	3	4	11	12	7	8	15	16	1	2	9	10	5	6	13	14
Payoff For:	U.S. Opposition	-	7	5	8	6	2	1	4	3	15	13	16	14	10	9	12	11

Table 3: Preference List ('70-'74)

With the preference list as above, two complete equilibria states are obtained. The first state represents the Public, Environmentalists and Scientists favouring a regulation or a ban of SST, and the U.S. Government supporting it by imposing a complete ban. Hence, the British/French cannot ensure the economic viability of the Concorde project without the Government support. The U.S. opposition is against the ban.

In the second state, the U.S. Opposition is still against the ban and the Public is favouring it. The U.S. Government decides on taking the middle road and killing the SST project but allowing access to Concorde hence the British/French get U.S. support and continue with Concorde production. This is what that had actually happened in reality.

	Ordered Decimal	Filter	14 21	16 27
1 - Public, Environm	Regulate or Ban	-	Y	Y
2 - British/French	Concorde production	-	N	Y
3 - U.S. Government	Ban	-	Y	N
	Middle Road	-	N	Y
4 - U.S. Opposition	No Ban	-	Y	Y
Payoff For:	Public, Environmenta	-	15	11
Payoff For:	British/French	-	3	7
Payoff For:	U.S. Government	-	6	14
Payoff For:	U.S. Opposition	-	9	11
	Nash	Y	Y	Y
	GMR	-	Y	Y
	SEQ	-	Y	Y
	SIM	-	Y	Y
	SEQ & SIM	-	Y	Y
	SMR	-	Y	Y

Table 4: Equilibria Results ('70-'74)

4.1.1 SENSITIVITY ANALYSIS

If we carry out a sensitivity analysis of the conflict, we notice that modifying certain aspects of the game can change the states in equilibria.

- If the U.S. Government gives preference to the public opinion, two new states of partial equilibria are obtained with the new preference lists: State 10 where British/French and U.S. Government do nothing and the Public and U.S. Opposition stick to their opinions of Ban and No Ban respectively and State 12 where in addition to the Public and U.S. Opposition opinions in State 10, the British/French continue with the Concorde Production.

	Ordered		10	12	14	16
	Decimal	Filter	17	19	21	27
1 - Public, Environm	Regulate or Ban	-	Y	Y	Y	Y
2 - British/French	Concorde production	-	N	Y	N	Y
3 - U.S. Government	Ban	-	N	N	Y	N
	Middle Road	-	N	N	N	Y
4 - U.S. Opposition	No Ban	-	Y	Y	Y	Y
Payoff For:	Public, Environmenta	-	13	9	15	11
Payoff For:	British/French	-	11	15	3	7
Payoff For:	U.S. Government	-	9	13	11	15
Payoff For:	U.S. Opposition	-	13	14	9	11
	Nash	-			Y	Y
	GMR	Y	Y	Y	Y	Y
	SEQ	-			Y	Y
	SIM	-			Y	Y
	SEQ & SIM	-			Y	Y
	SMR	-	Y	Y	Y	Y

Table 5: Equilibria Results with change of U.S. Government preference ('70-'74)

- If the British/French are not considered as a Decision Maker are the same preferences are kept, only 1 state of equilibria is obtained where the Public and U.S. Opposition stick to their opinions of Ban and No Ban respectively and the U.S. Government takes the Middle Road which was again what happened in the reality.

	Ordered Decimal	Filter	1 0	2 1	3 2	4 3	5 4	6 5	7 8	8 9	9 10	10 11	11 12	12 13
1 - Public, Envirome	Regulate or Ban	-	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2 - U.S. Government	Ban	-	N	N	Y	Y	N	N	N	N	Y	Y	N	N
	Middle Road	-	N	N	N	N	Y	Y	N	N	N	N	Y	Y
3 - U.S. Opposition	No Ban	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
Payoff For:	Public, Enviromental	-	2	8	6	12	4	10	1	7	5	11	3	9
Payoff For:	U.S. Government	-	3	4	7	8	11	12	1	2	5	6	9	10
Payoff For:	U.S. Opposition	-	6	5	2	1	4	3	12	11	8	7	10	9
	Nash	-												Y
	GMR	-												Y
	SEQ	-												Y
	SIM	-												Y
	SEQ & SIM	-												Y
	SMR	-												Y

Table 6: Equilibria Results with removal of British/French as Decision Maker ('70-'74)

4.2 National Issue for United States (1974-'77)

DECISION MAKERS	OPTIONS
Public, Environmentalists and Scientists	Regulate or Ban CFC after publications on impact of U.V. radiation
Production Industry	Ban production of CFC if regulatory bodies decide on banning CFC.
	Reduce the production of CFC if regulatory bodies decide on reducing the non-essential use of CFC.
Regulatory Bodies	Decide on banning CFC if the amount produced is threatening to life on earth
	Decide to reduce the non-essential use of CFC because the continuing CFC production within limit is safe.

Table 7: Decision Makers and Options ('74-'77)

INFEASIBLE STATE	REASON
- Y Y - -	Mutually Exclusive
- - - Y Y	Mutually Exclusive
- N – Y -	If Regulatory Bodies decide to ban CFC, Industry cannot continue production.

Table 8: Infeasible States ('74-'77)

After removing the infeasible states from the list of options, 14 states are left. These states are then arranged according to the preference of the different Decision Makers.

	Ordered		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Decimal	Filter	0	1	2	3	4	5	10	11	16	17	18	19	20	21
1 - Public, Environm	Ban or Reduce	-	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2 - Production Indus	Ban	-	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
	Reduce	-	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y
3 - Regulatory Bodie	Ban	-	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N
	Reduce	-	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
Payoff For:	Public, Environmenta	-	1	2	9	10	5	6	13	14	3	4	11	12	7	8
Payoff For:	Production Industry	-	14	13	6	5	10	9	2	1	12	11	4	3	8	7
Payoff For:	Regulatory Bodies	-	1	1	1	1	1	1	3	3	1	1	1	1	2	2

Table 9: Preference List ('74-'77)

With the preference list as above, three complete equilibria states and two partial equilibria states are obtained. The first state represents the Public, Environmentalists and Scientists favouring a regulation or a ban of CFC and no action by other decision makers. The second state of equilibrium shows a ban on CFC being agreed upon by the Industry as well. The third state of equilibrium shows a reduction decision by the regulatory bodies but no action being taken by the industry. The partial equilibria are almost the same states as the ones with complete equilibria but with a modification in the decision of the Public.

In reality, a mix of the states 8 and 10 were seen. The regulatory bodies did agree on a ban and the Industry had adhered to the decision, but the Industry could not suggest substitutes for CFCs as refrigerants. So ultimately the Regulatory bodies realized they could only decide to ban aerosols which were non-essential. [14]

	Ordered		2	7	8	9	10
	Decimal	Filter	1	10	11	16	17
1 - Public, Environm	Ban or Reduce	-	Y	N	Y	N	Y
2 - Production Indus	Ban	-	N	Y	Y	N	N
	Reduce	-	N	N	N	N	N
3 - Regulatory Bodie	Ban	-	N	Y	Y	N	N
	Reduce	-	N	N	N	Y	Y
Payoff For:	Public, Environmenta	-	2	13	14	3	4
Payoff For:	Production Industry	-	13	2	1	12	11
Payoff For:	Regulatory Bodies	-	1	3	3	1	1
	Nash	-	Y		Y		Y
	GMR	Y	Y	Y	Y	Y	Y
	SEQ	-	Y		Y		Y
	SIM	-	Y		Y		Y
	SEQ & SIM	-	Y		Y		Y
	SMR	-	Y	Y	Y	Y	Y

Table 10: Equilibria Results ('74-'77)

4.3 International Issue (1977-'87)

DECISION MAKERS	OPTIONS
Toronto Group	Reduce the production of CFC to 80% of the production cap as already non-essential use had been banned.
	Reduce the production of CFC to 50% of production cap at least, keeping in mind the EEC group had less production cap and split in Reagan Administration.
	Impose trade sanctions if EEC group does not agree to at least 50% reduction.
EEC Group	Reduce the production of CFC to 80% of production cap because of publications about impact and pressure from Toronto group.
	Reduce the production of CFC to 50% of production cap due to fear of trade sanctions.

Table 11: Decision Makers and Options ('77-'87)

INFEASIBLE STATE	REASON
Y Y - - -	Mutually Exclusive
- - - Y Y	Mutually Exclusive
- - Y Y -	No Trade sanctions if 80% reduction is agreed upon.
- - Y – Y	No Trade sanctions if 50% reduction is agreed upon.

Table 12: Infeasible States ('77-'87)

After removing the infeasible states from the list of options, 12 states are left. These states are then arranged according to the preference of the different Decision Makers.

	Ordered		1	2	3	4	5	6	7	8	9	10	11	12
	Decimal	Filter	0	1	2	4	5	6	8	9	10	16	17	18
1 - Toronto Group	Reduction of 80%	-	N	Y	N	N	Y	N	N	Y	N	N	Y	N
	Reduction of 50%	-	N	N	Y	N	N	Y	N	N	Y	N	N	Y
	Trade sanctions	-	N	N	N	Y	Y	Y	N	N	N	N	N	N
2 - EEC	Reduction of 80%	-	N	N	N	N	N	N	Y	Y	Y	N	N	N
	Reduction of 50%	-	N	N	N	N	N	N	N	N	N	Y	Y	Y
Payoff For:	Toronto Group	-	1	9	5	2	10	6	4	12	8	3	11	7
Payoff For:	EEC	-	12	11	10	6	5	4	3	2	1	9	8	7

Table 13: Preference List ('77-'87)

With the preference list as above, two equilibria states are obtained- one complete and other partial. The first state represents the Toronto group sticking to its 80% reduction policy but the EEC group having no intentions of a reduction which leads to Toronto group taking action and imposing trade sanctions. This would have taken place if the EEC group had no fear of the losses due to the trade sanctions.

In the second state, the Toronto group sticks to its 80% reduction policy with no trade sanctions because the EEC group accepts a 50% reduction policy. This happened in reality and was termed as the conditions of the Montreal Protocol. [11]

	Ordered		5	11
	Decimal	Filter	5	17
1 - Toronto Group	Reduction of 80%	-	Y	Y
	Reduction of 50%	-	N	N
	Trade sanctions	-	Y	N
2 - EEC	Reduction of 80%	-	N	N
	Reduction of 50%	-	N	Y
Payoff For:	Toronto Group	-	11	10
Payoff For:	EEC	-	5	8
	Nash	-	Y	
	GMR	-	Y	Y
	SEQ	Y	Y	Y
	SIM	-	Y	
	SEQ & SIM	-	Y	Y
	SMR	-	Y	Y

Table 14: Equilibria Results ('77-'87)

V. COALITION ANALYSIS

As an extra topic analysis, a coalition analysis was performed on the conflict which arose as a National Issue for the United States between 1970-'74. A coalition is defined as "an alliance for combined action, especially a temporary alliance of political parties forming a government or of states." [16] In game theory, a coalition can be formed if two decision makers can find a mutual agreement to one or more of the options in the course of action they can undertake.

Out of the conflicts in the three different time periods, 1970-'74 was chosen because one can see that the U.S. Government has three options out of which one was to take the middle road and make a political compromise and allow U.S. airport access to Concorde, hence favouring the British/French [15] and the other was to favour a no ban by agreeing to the reports by DOT, similar to the U.S. opposition. Thus, the following two kinds of coalitions can be analyzed and the equilibria results can be compared with the original to see if the coalition would be beneficial to either or both of the members of the coalition or not:

5.1 U.S. Government coalition with U.S. Opposition

Coalitions: 1, 2, [3, 4]

	Ordered		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Decimal	Filter	0	1	2	3	4	5	10	11	16	17	18	19	20	21	26	27
1 - Public, Environm	Regulate or Ban	-	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2 - British/French	Concorde production	-	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
3 - U.S. Government	Ban	-	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y	N	N
	Middle Road	-	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y
4 - U.S. Opposition	No Ban	-	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Payoff For:	Public, Environmenta	-	6	14	2	10	8	16	4	12	5	13	1	9	7	15	3	11
Payoff For:	British/French	-	10	9	14	13	2	1	6	5	12	11	16	15	4	3	8	7
Payoff For:	U.S. Government	-	3	4	11	12	7	8	15	16	1	2	9	10	5	6	13	14
Payoff For:	U.S. Opposition	-	7	5	8	6	2	1	4	3	15	13	16	14	10	9	12	11
	Nash	-						Y		Y				Y		Y		Y
	GMR	-						Y		Y		Y		Y		Y		Y
	SEQ	-						Y		Y				Y		Y		Y
	SIM	-						Y		Y				Y		Y		Y
	SEQ & SIM	-						Y		Y				Y		Y		Y
	SMR	-						Y		Y		Y		Y		Y		Y

Table 15: Coalition analysis of U.S. Government with U.S. Opposition

The coalition analysis obtains 3 additional complete equilibria and 1 partial equilibria. The states in equilibria are similar to the ones obtained earlier but with modifications which implement a logical OR operation between the decisions taken by U.S. Government and U.S. Opposition.

For e.g. State 8 is similar to State 14, but with the U.S. Opposition wanting a ban on SST. But since the government and the opposition are in a coalition and the government wants to take a middle road, Concorde production will be supported by U.S. altogether.

Similarly, Concorde production is not possible in States 6 and 10 because the U.S. Government wants a ban on SST. State 12 would ensure the Concorde project is a success cause of 'No Ban' Decisions from both the government and the opposition.

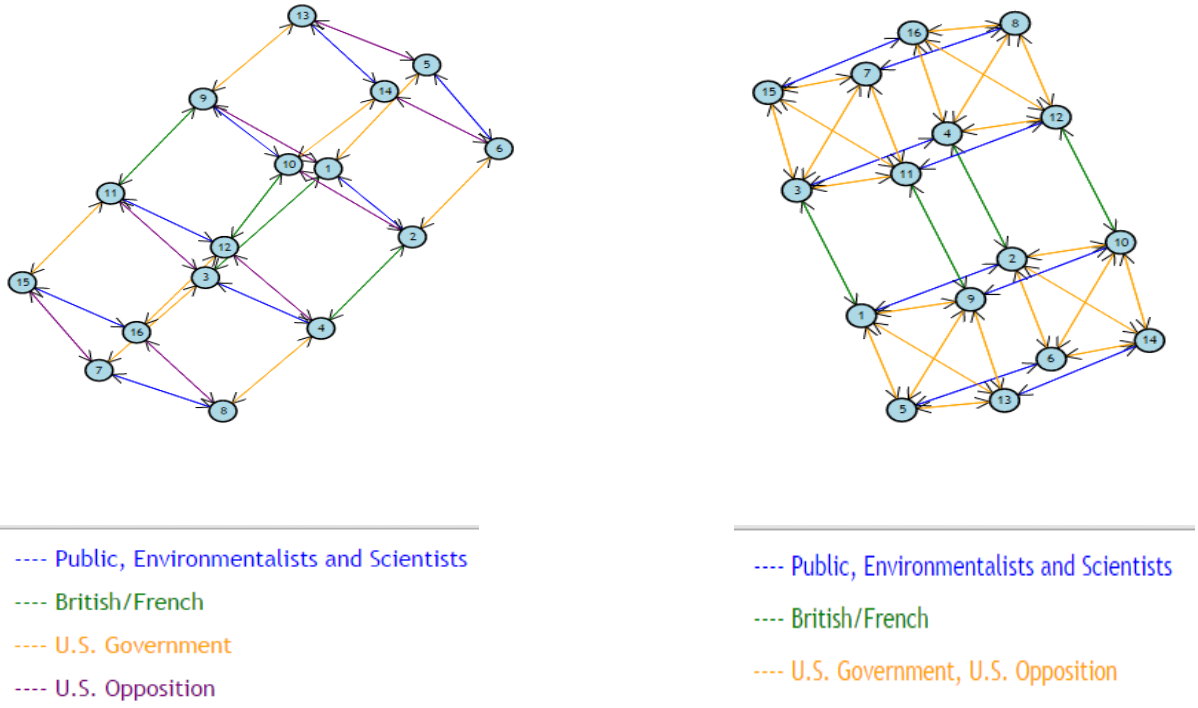

Fig 2: Graph Model before and after coalition.

5.2 U.S. Government coalition with British/French

The coalition analysis obtains 1 equilibrium state same as the original analysis and an additional complete equilibrium state 12. The State 12 represents an equilibrium condition where the Concorde production would continue and an economic viability would be ensured even if the Government decides not to take the middle road in the conflict. This is because the British/French and the U.S. Government have formed a coalition.

Coalitions: 1, [4], [3, 2]

	Ordered		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Decimal	Filter	0	1	2	3	4	5	10	11	16	17	18	19	20	21	26	27
1 - Public, Environm	Regulate or Ban	-	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
2 - British/French	Concorde production	-	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
3 - U.S. Government	Ban	-	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y	N	N
	Middle Road	-	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y
4 - U.S. Opposition	No Ban	-	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Payoff For:	Public, Environmenta	-	6	14	2	10	8	16	4	12	5	13	1	9	7	15	3	11
Payoff For:	British/French	-	10	9	14	13	2	1	6	5	12	11	16	15	4	3	8	7
Payoff For:	U.S. Government	-	3	4	11	12	7	8	15	16	1	2	9	10	5	6	13	14
Payoff For:	U.S. Opposition	-	7	5	8	6	2	1	4	3	15	13	16	14	10	9	12	11
	Nash	-												Y				Y
	GMR	-												Y				Y
	SEQ	-												Y				Y
	SIM	-												Y				Y
	SEQ & SIM	-												Y				Y
	SMR	-												Y				Y

Table 16: Coalition analysis of U.S. Government with British/French

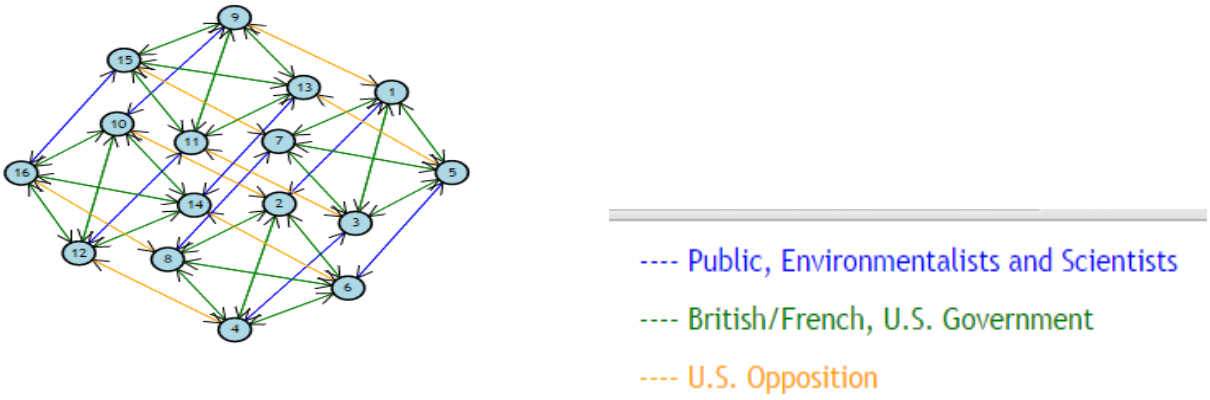

Fig 3: Graph Model after Coalition

VI. CONCLUSIONS

The conflict that arose due to the Depletion of the Ozone Layer, regarding the control of the production of the substances that cause the depletion was analyzed and equilibria results were obtained.

In the two time periods of 1970-'74 and 1974-'77 where the conflict was due to the National Issue in the United States and 1977-'87 where it was an International Issue, the equilibria results reflected the actual happenings as reported by numerous articles and stated by protocols and acts that were passed.

- 1970-'74: SST project was killed due to the publications about the harmful effects of the depleting Ozone layer and the strong opposition by the Public, Environmentalists and Scientists, but the U.S. Government, as a political compromise, decided to go further with the original Concorde project of 16 aircrafts and allow access to U.S. airports.
- 1974-'77: CFC was initially banned but later it was realized that there was no substitute for CFC as refrigerants. Hence, non-essential use of CFC in aerosols was banned and the Clean Air Act of 1977 was passed. The Industries, however were not ready for the sudden economic setback.
- 1977-'87: Ozone Layer Depletion emerged as an International problem and the two group of nations- the Toronto group who had already banned the non-essential use of CFC and the EEC group who had recently realized the harmful effects of the ODS decided on at least 50% reduction in the CFC production which culminated as the Montreal Protocol of 1987.

The sensitivity analysis for the first time period, where the Public Opinion was prioritized for the U.S. Government, gave two additional partial equilibria where U.S. Government and Opposition both favour a no ban and the Public favours a regulation or a ban. Only the British/French preference changes.

In the coalition analysis, we see that additional equilibria states are obtained when the U.S. Government forms a coalition with the Opposition or the British/French. They gave the Decision Makers more options in equilibria and hence there was less of a conflict.

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