Multilateral Bargaining Over Trade Policies

by

Glenn W. Harrison*

August 9, 1994

* Dewey H. Johnson Professor of Economics, Department of Economics, College of Business Administration, University of South Carolina. Research support from the Office of the U.S. Trade Representative is gratefully acknowledged.

1. INTRODUCTION

Is it possible to design a bargaining institution that will substantially improve the outcome of international trade negotiations conducted on a multilateral basis? Rausser and Simon [1991] propose a multilateral bargaining (MB) institution which has many attractive theoretical properties, and which appears to be general enough to encompass realistic classes of trade negotiation problems. Harrison, McCabe, Rausser and Simon [1992] provide some elementary "stress tests" of the MB institution in the form of laboratory experiments using contrived preferences. In this paper I extend the "lab stress testing" to assess the outcomes that the MB institution would theoretically achieve using less contrived negotiation problems.

In section 2 I present a brief overview of the main properties of the MB institution, including a series of "large" numerical examples. These examples are still contrived in the sense of employing artifical preference structures, but are useful to illustrate the general numerical properties of the model. They provide the backdrop to our simulations using more realistic preference structures appropriate for negotiations over trade policies. In section 3 I review alternative approaches to estimating "realistic" policy preferences. In section 4 I employ one of these methods to generate some preference structures over agricultural trade policy reforms, and solve the resulting MB game.

2. THE MULTILATERAL BARGAINING MODEL

There are several key features of the MB model, each of which is important to the interpretation of the numerical results reported later.

The first feature is to have some credible *default outcome* written into legislative stone, in the spirit of Gramm-Rudman or Super 301, with the parties to any negotiation being given the choice of living with that default or coming to some negotiated alternative. That is, the legislative tablet that incorporated the default would have an "escape clause" allowing the Executive[1] to substitute the substance of any negotiated agreement with the relevant

[1] In the context of trade negotiations we have in mind the Office of the U.S. Trade Representative (USTR).

parties.

The second feature is to allow all parties to have some *access* to make proposals. This is intended to capture the notion that any party that is interested in some policy decision is able to get it's preferences heard, but that such access may vary widely for different lobby groups. There is also a normative desire here: each bargainer should have a sense that their voice will be heard, even if it is not heard as often as some others! The normative motivation is that parties will often accept wildly asymmetric outcomes if they at least perceive the "bargaining process" to have been fair in some sense.[2]

The third feature is that *coalition formation* should be explicitly recognized as the major backroom activity of large-scale policy negotiations. Accordingly, one should allow agents to engage in this explicitly in the new institution, since it would occur outside of the institution if it were not internalized. It would be naive to try to impose an institution that ignored such activities, since any properties claimed for the institution might be hopelessly fragile to the behavior assumed away.

The fourth feature is that *voting power* can differ from agent to agent. Thus the number of votes that one agent may bring to a coalition could differ greatly from another. This admits the possibility that agents might effect asymmetric outcomes through the institution even if they are otherwise identical to other agents.[3]

The final feature of the institution is that there be a *minimal role for government* during the negotiations. The reasons for this requirement might seem rather technical at first, but they turn out to be crucial to the ability of the MB model to deliver general results. The effect of this feature is to ensure that a unique noncooperative solution generally exists to the game defined by the MB institution. We explain the logic of this requirement below.

2.1 The Model

The MB institution can be characterized by a model of noncooperative multilateral bargaining with a central player.[4] The model has $n+1$ players, called the player set. The zero'th player is distinguished from the others and

[2] A cynical counterpart to this argument is that the parties that want to encourage the use of the institution to resolve disputes may be able to use this argument to convince aggrieved agents that the *process*, at least, was "fair".

[3] "Identical" with respect to their preferences and access.

[4] Rausser and Simon [1991] present the formal model, along with proofs of all results stated below. They also discuss a number of simple generalizations of the model not covered here (e.g., allowing for time-discounting during negotiations and risk aversion).

is called the central player. Players *1* through *n* are peripheral players.

The players participate in a sequential, multilateral bargaining game that is similar in spirit to the bilateral game of Ståhl [1972] and Rubinstein [1982]. Their objective in bargaining is to form a coalition, which is just a subset of the player set, and to choose an m-dimensional vector from a set of feasible vectors, called the choice set and assumed to be compact. The choice set may be different for different coalitions.

The central player is distinguished from the others in that she must be included in every coalition. Each player has a utility function defined on the choice set. We assume that utility functions are continuous and strictly quasi-concave.

Problems of this kind are typically formulated as cooperative games. Cooperative game theorists specify some solution concept that satisfies certain appealing properties and then study the set of choices that satisfy the given criterion. Perhaps the most familiar cooperative solution concept is the Core.[5] In the context of the MB institution, a vector x is in the Core if it is feasible for some coalition and if, for every coalition C, there is no feasible vector that is weakly preferred to x by each member of C and strictly preferred by one member.

Noncooperative bargaining theory differs from cooperative game theory in that it attempts to model the actual process of negotiation, rather than just the outcome of the negotiation. A noncooperative model of multilateral bargaining includes an extensive form which stipulates a particular set of negotiating rules that players must follow.

A natural research program, referred to as the "Nash Program" after Nash [1953], is to study the cooperative and noncooperative versions of a game in conjunction with each other. First one studies a particular cooperative solution concept, then one asks whether the equilibria (usually the subgame perfect equilibria) of some noncooperative model implement the cooperative solutions. Following this approach, we study below the relationship between the Core of various bargaining games and the subgame perfect equilibria of our noncooperative version of these games.

The game has a finite number of periods T, each of which is divided into three sub-periods. In the *first* sub-period a player is chosen by Nature to be the proposer. Nature makes it's choice according to a probability

[5] Equally familiar, perhaps, is the axiomatic Nash [1950] Solution, which generalizes naturally to more than two bargainers. We discuss the Nash Solution later.

distribution over the player set that is prespecified as part of the description of the game. In the *second* sub-period the proposer announces a coalition, of which he must be a member, and a vector that is feasible for that coalition. In the *third* sub-period the remaining members of the proposed coalition each choose whether to accept or reject the proposed vector. If all accept, the game ends. If not, the next period begins and a new proposer is selected. If agreement is not reached by the Tth period then players receive a predetermined disagreement payoff.

A *strategy* for player i specifies the vector that he will announce in each period if selected to be the proposer, as well as a set of vectors that i will accept in each period if he is a member of a coalition announced by some other proposer. A strategy profile is a list of strategies, one for each player. Each strategy profile defines an outcome for the game, which is just a function assigning to each element of the choice set the probability that the game will end with an agreement to select this vector. Note that only a finite number of these probabilities will be positive. Moreover, these positive probabilities need not sum to unity, since the players may never reach an agreement.[6]

2.2 Equilibrium Outcomes

The standard solution concept for games of this kind is *subgame perfection.* Loosely, a strategy profile is subgame perfect if, starting from any stage of the game, each player's strategy is optimal given the strategies chosen by the other players. This concept is insufficiently discriminating for present purposes, since the MB game has many subgame perfect equilibria, some of which have very undesirable properties.[7] Fortunately there are several equilibrium refinements that eliminate these "bad" equilibria. The best-known of these is the *properness* criterion due to Myerson [1978].

For simplicity, assume that our agents are actually playing in a discrete version of our game in which they

---

[6] We are just describing the strategy space here. Equilibrium outcomes, to be defined momentarily, will not admit disagreements.

[7] For example, consider the strategy profile in which each player refuses to accept any proposal in any round. The outcome of this game can only be the disagreement outcome. To see that these strategies form a subgame perfect equilibrium, observe that since at least one member of every coalition is rejecting every proposal, it makes no difference whether the other members accept or reject any proposal. It can also be shown that this is a trembling-hand perfect equilibrium. It is apparent that equilibria like this are silly, especially when players' disagreement payoffs are extremely low.

have a finite set of strategies.[8] In such games a *trembling-hand perfect equilibrium* is the limit of a sequence of (mixed) strategy profiles in which (i) positive probability weight is assigned to every strategy, and (ii) strategies that are payoff-dominated along the sequence are assigned probability weight vanishing to zero. In other words, trembling-hand perfect equilibria are Nash Equilibria that are robust to perturbations in which vanishingly small probability is assigned to any action that is not a best response to similarly perturbed strategies for the other players. These perturbations are familiarly known as *trembles.*

The properness criterion restricts the set of admissible trembles and thereby further restricts the set of equilibria. Specifically, if any action is inferior to a second against a sequence of perturbed strategies for the other players, then the first must be assigned vanishingly small weight *relative* to the second, even though the mass assigned to the second may itself vanish in the limit.

Every T-period game has a proper equilibrium. Moreover, this equilibrium is generically unique. A striking feature of the model is that there are equilibria in which players fail to agree until the final rounds of bargaining. An equilibrium outcome is the outcome defined by a proper equilibrium. Note that since agents may fail to agree at the beginning of the game, the equilibrium outcome need not coincide with the distribution over first period proposals.

The theoretical analysis of Rausser and Simon [1991] concerns the equilibrium outcomes of games with an arbitrarily large number of periods. Accordingly, the bargaining model is defined as a sequence of T-period bargaining games, with T growing to infinity. A solution to the model is a limit of the equilibrium outcomes of the T-period games.

2.3 Results

The first major analytical result for the model is that *a solution exists.* That is, the outcomes for the T-period games always converge as T grows large. It is here that the central player has a crucial role: when there is no player that is a member of every coalition, T-period outcomes will not in general converge.

[8] Our game actually allows each agent an infinite number of strategies. The application of properness to such games is not trivial, and is explained in detail by Simon and Stinchcombe [1991]. All of the results stated here generalize to infinite games.

The second major result is that, generically, *this solution is deterministic.* More precisely, there is generically a unique vector x with the property that for every ϵ there exists a T sufficiently large that the agreed upon vector in any game with more than T periods is within ϵ of x with probability one. When such a vector x exists we will refer to it as the solution vector.

The last major result is that the *solution is always in the Core* of the corresponding cooperative game.

2.4 Some Intuition

We now offer an intuitive explanation of how these results are obtained, and why the "minimal government" assumption is so important. First notice that the Government is not needed at all when the Core is non-empty. When the Core is otherwise empty, however, the presence of a Government agent is crucial. Loosely, if there is no "minimal government" agent then it is possible for something akin to a "majority rule cycle" to develop over successive rounds of negotiations.

This cycling takes the form of one agent becoming pivotal to a coalition and being bribed to join it, resulting in a different agent becoming pivotal to some coalition that will now bribe him to join them, resulting in yet another coalition regarding the original agent as now sufficiently important to be bribed away from his second coalition. Whenever one or more agents cycle in this manner from coalition to coalition, then we have an indeterminacy.

It turns out that such indeterminacies are rife in this sort of model without unpalatable restrictions on coalition formation or preferences. These cycles are similar in certain respects to the Condorcet cycle in political theory. Thus, we would expect them to occur whenever the cooperative game that is associated with our institution does not have a Core outcome. It is well-known that the existence of the Core in spatial environments, such as when agents have Euclidean preferences over polices, is a knife-edge outcome.

The key insight of Rausser and Simon [1991] is to note that it is often a natural feature of negotiations there be an agent, which we will call the Government, that has (i) veto power over any proposal in any round, and (ii) some positive access to be able to make proposals. These two conditions ensure that a solution exists. To further ensure that a "good" solution exists, we might additionally require that the Government agent have everybody's welfare at heart, no matter how weighted.

First notice how this resolves the indeterminacy. We could give such a Government agent 100% access in all bargaining rounds, with the result being an arbitrated outcome in which the Government selects some outcome that maximizes it's payoff function. One such candidate function might be the product of the utility gains for all private agents relative to the disagreement outcomes, which will generate the unique cooperative Nash [1950] Solution.

Now let the Government have less than 100% access. Note that each private agent must include the Government in it's proposals in each round, and that it must make a proposal that the Government is willing to vote for. Moreover, the Government's expected payoff as the game progresses will be monotonically decreasing.

The fact that there is now an agent that has a decreasing expected payoff as the game progresses means that the earlier cycling of one or more private agents cannot occur indefinitely for sufficiently long games. Consider the sequence of games in which the horizon T is allowed to get larger and larger. It may be for some small T that some private agent can cycle in the above manner for the early rounds of the game. As T gets larger the Government player gets more "expensive" to include in any coalition (her participation constraint binds more tightly due to higher and higher expected payoffs), and hence *all other private players become relatively less expensive* to include as T increases. Thus the pivotal private agent that was cycling before and causing the indeterminacy becomes non-pivotal, and *remains non-pivotal,* at some point as T gets larger. In the extreme case there is no coalition that is feasible other than the one that gives the Government her bliss point. Thus we have a guarantee of convergence to a unique outcome, providing we impose some simple regularity conditions on the Government's payoff function (e.g., strict quasi-concavity).

The intuition behind the fact that the MB game implements the Core is straightforward. Recall that a vector x is said to be in the Core if it is feasible for some coalition and if, for every coalition C, there is no feasible vector that is weakly preferred to x by each member of C and strictly preferred by one member. Assume that some vector other than the Core has been proposed as the solution for a MB game of given length T. Allowing T to increase, the members of the Core-implementing coalitions will be certain to have some chance of getting to propose.[9] Given

[9] Even if the sum of their access probabilities is small, for T arbitrarily large they only have to wait their turn patiently.

that they will get to propose for T sufficiently large, it is apparent that they will always propose the Core. If they did not then the members of the proposed coalition that strictly prefer the Core will veto the proposal and just wait until they get to make the proposal.

The intuition behind these results suggests some interesting trade-offs in the specific implementation of the MB institution. We imagine that the Government, acting as a Stackelberg principal in the institution design setting, can vary certain of the parameters of the game so as to ensure that a solution is attained reasonably quickly. The notion of a "minimal" Government role in our institution is flexible enough to allow the Government to vary it's involvement in negotiations as needed. Thus if a Core solution exists without the Government, it might let the private agents bargain by themselves. If a Core solution does not exist without the Government, then it would give itself some positive access probability. If convergence were not attained for some reasonable negotiating horizon T the Government might increase it's own access or the access of certain agents.

2.5 Numerical Implementation

We now consider several explicit examples that have been solved numerically. The first example is the simplest possible setting, in which five agents have spatial preferences over two policies and a Core exists without the Government as an active negotiator. The two policies are referred to unimaginatively as a horizontal coordinate and a vertical coordinate. The second example illustrates a similar game in which the Core does not exist if the Government is not present. We demonstrate the effect of varying the role of the Government player.

All of the examples discussed in this section have the same coalition structure. Table 1 lists these coalitions, which are referred to numerically in the detailed listings. There are 16 admissible coalitions (numbered from 1 to 16) and 5 players (numbered from 1 to 5). Each line beginning "Members of coalition number..." is followed by five columns, specifying which players are included in this coalition. For example, coalition #2 consists of players #1, #2, and #3.

A Game With A Core Solution

Table 2 presents the solution for the first example. The first section of Table 2 lists the parameters of the

Table 1: Alternative Coalitions

Members of coalition number 1:	IN	IN	IN	IN	IN
Members of coalition number 2:	IN	IN	IN	OUT	OUT
Members of coalition number 3:	IN	OUT	IN	OUT	IN
Members of coalition number 4:	OUT	IN	OUT	IN	IN
Members of coalition number 5:	IN	IN	OUT	IN	OUT
Members of coalition number 6:	OUT	IN	IN	IN	OUT
Members of coalition number 7:	IN	OUT	IN	IN	OUT
Members of coalition number 8:	IN	IN	OUT	OUT	IN
Members of coalition number 9:	IN	OUT	OUT	IN	IN
Members of coalition number 10:	OUT	OUT	IN	IN	IN
Members of coalition number 11:	OUT	IN	IN	OUT	IN
Members of coalition number 12:	IN	OUT	IN	IN	IN
Members of coalition number 13:	OUT	IN	IN	IN	IN
Members of coalition number 14:	IN	IN	IN	OUT	IN
Members of coalition number 15:	IN	IN	IN	IN	OUT
Members of coalition number 16:	IN	IN	OUT	IN	IN

bargaining problem. The first five lines give the ideal points, or bliss points, of each player in terms of the horizontal and vertical coordinate that generates the greatest payoff for that player. Thus player #2 has a bliss point of (30, 52), which is to say that she receives the highest possible payoff when the policy values are equal to this. As the policy values deviate from these values her payoffs decline.

Specifically, the payoff to agent i is a linear function of the Euclidean distance from the ideal point. The intercept of this linear function, denoted α_i, determines the payoff when agent i's ideal point is the chosen policy vector (i.e., when the Euclidean distance from her ideal point is zero). The coefficient of this linear function, denoted β_i, determines the rate at which payoffs decline from the maximum payoff as the Euclidean distance increases. The second set of five numbers in Table 2 describing the utility functions show the values of these two coefficients for each agent.

Each player receives a payoff of zero if there is no agreement. This can be viewed as a convenient and common normalization.

Each of players #2 through #5 have an equal probability in this game of being asked to make a proposal, but player #1 has 12 times the chance of getting to make a proposal as any of the others. Thus player #1 is asked to make the proposal 75% of the time, and each of the other players is asked 6.25% of the time. In this game we do not need to include the Government as an active player, hence it has an access probability of zero and is not included in any of the 16 coalitions.

The remainder of Table 2 summarizes the outcome of negotiations in each round of bargaining. For simplicity we assume here that there are only five rounds of negotiation, such that $T=5$. Table 2 lists the detailed results for each of rounds #1 through #5.

Consider the six rows of numbers below the statement "Round #1", at the bottom of the table. The first five rows contain nine columns. For $1 \leq i \leq 5$, the first column of row i is the coalition selected by player i in the

Table 2: A Game With a Core Solution

Ideal point of player number 1:	39.000	68.000
Ideal point of player number 2:	30.000	52.000
Ideal point of player number 3:	25.000	72.000
Ideal point of player number 4:	62.000	109.000
Ideal point of player number 5:	165.000	32.000
Utility coefficients of player number 1 (alpha, beta):	90.000	1.000
Utility coefficients of player number 2 (alpha, beta):	70.000	1.000
Utility coefficients of player number 3 (alpha, beta):	70.000	1.000
Utility coefficients of player number 4 (alpha, beta):	90.000	1.000
Utility coefficients of player number 5 (alpha, beta):	110.000	1.000

Round #5							
#15	39.000	68.000	90.000	51.642	55.440	42.989	-21.042
#15	30.000	52.000	71.642	70.000	49.384	24.632	-26.473
#15	25.000	72.000	75.440	49.384	70.000	37.674	-35.602
#15	62.000	109.000	42.989	4.632	17.674	90.000	-18.600
#9	126.269	45.996	0.000	-26.456	-34.554	0.000	68.817
Expected payoffs:			79.379	44.829	47.986	41.761	-16.523
Round #4							
#15	39.000	68.000	90.000	51.642	55.440	42.989	-21.042
#2	33.793	58.743	79.379	62.263	54.092	32.369	-23.905
#2	28.788	70.918	79.379	51.044	66.060	39.470	-31.663
#10	46.553	76.479	78.645	40.450	47.986	53.997	-16.523
#4	53.287	61.555	74.327	44.829	39.846	41.761	-5.557
Expected payoffs:			86.983	51.143	54.579	42.717	-20.634
Round #3							
#15	39.000	68.000	90.000	51.642	55.440	42.989	-21.042
#11	38.472	64.495	86.456	54.904	54.579	39.659	-20.634
#6	35.005	70.180	85.449	51.143	59.831	42.717	-25.486
#10	40.403	71.255	86.456	48.114	54.579	46.513	-20.634
#4	42.915	65.740	85.480	51.143	51.023	42.717	-16.662
Expected payoffs:			88.990	51.563	55.331	42.967	-20.995
Round #2							
#15	39.000	68.000	90.000	51.642	55.440	42.989	-21.042
#11	38.699	66.754	88.718	52.872	55.331	41.755	-20.995
#6	37.564	68.813	88.350	51.563	57.038	42.967	-22.647
#10	39.403	69.217	88.718	50.383	55.331	44.247	-20.995
#4	40.416	67.213	88.380	51.563	53.858	42.967	-19.465
Expected payoffs:			89.635	51.631	55.427	42.988	-21.038
Round #1							
#15	39.000	68.000	90.000	51.642	55.440	42.989	-21.042
#11	38.875	67.545	89.529	52.099	55.427	42.532	-21.038
#6	38.475	68.297	89.397	51.631	56.025	42.988	-21.628
#10	39.134	68.452	89.529	51.182	55.427	43.449	-21.038
#4	39.500	67.722	89.427	51.631	54.882	42.988	-20.484
Expected payoffs:			89.868	51.641	55.440	42.989	-21.04

current round. The second and third columns list the policy vector proposed by i: the second column is the value of the horizontal coordinate, and the third column is the value of the vertical coordinate.

Columns four through eight specify the payoff that each player will earn if the corresponding policy vector is accepted. Thus reading down column four for Round #1 shows that player #1 will receive 90.000, 89.529, 89.397, 89.529 or 89.427 if players 1 through 5, respectively, are selected in this round to be the proposer (and behave optimally).

The sixth row lists the expected payoff for each player conditional on reaching this round of negotiations. It is calculated by simply multiplying the payoff to the agent in that column by the probability that each of the row agents gets to be the proposer. Thus, for player #1, the first payoff listed above is multiplied by 0.75 and the next four payoffs by 0.0625 to obtain the expected payoff in round #1 of 89.868 listed in row 7.

The MB model is solved by standard dynamic programming techniques[10] starting from round #5. Our maintained hypothesis is that if no agreement is reached in the last round of negotiations (round #5 here) then each player earns a zero payoff. Consequently, the optimal response for all players except #5 in this round is to propose their globally optimal policy vector. This simply implies that each of these players will propose their ideal point in round #5, which is what we see in Table 2. Since any player except #5 will accept any proposal rather than incur

[10] An appendix details the computational software developed to solve this class of problems.

the zero disagreement payoff, the proposer can choose any one of the coalitions excluding player #5 of which she is member. When the proposer is indifferent between coalitions, our computer algorithm chooses the one indexed by the larger number.

Now consider the penultimate round of negotiations, which is round #4 in this instance. A member j of a coalition will accept a policy vector proposed by i in this round if and only if the payoff received by j from the proposal is at least as large as j's *expected* payoff conditional on reaching the next round. For example, player #1 will not accept any proposal in round #4 that does not earn her at least 79.379, since that is her expected payoff from playing in round #5 and she would veto any proposal that gave her less than that.

It follows that to determine her optimal proposal player i must solve a separate nonlinear programming problem *for each coalition* to which she belongs and hence could propose. This problem would also have constraints to ensure that all of the members of each feasible coalition have an incentive not to veto it. In our last example, anybody considering including player #1 in their proposed coalition in round #4 must ensure that the policy proposal generates a payoff of at least 79.379 for player #1 (or, to extend the example, 44.829 for player #2, 47.986 for player #3, and so on). If player #1 is offered less than 79.379 in round #4 she will rationally veto the proposal if she can, preferring the "lottery" of proceeding into round #5.

In the current example the policy space has only two dimensions. Since each coalition has three, four, or five members, there are two, three, or four "participation constraints" depending on the size of the coalition. Each of these constraints ensures that the corresponding coalition member[11] would vote for the proposal. In round #2, for example, player #1's participation is a binding constraint for players #1 and #2. It is not binding for players #3 and #4, since they do not include player #1 in their proposed coalition.

Having solved each of the nonlinear programming problems, conditional on each of the feasible coalitions, player i then picks the coalition that yields her the highest payoff. If the payoff exceeds i's expected payoff conditional on reaching the next round, then i will propose this coalition and the corresponding policy vector. Note that there may be rounds in which member i makes a proposal that is *not* accepted.[12] This does not occur in the

[11] Other than the proposer, since the objective function being maximized in this programming problem is her payoff.

[12] This can happen for one of two reasons. First, i's best feasible alternative may yield her a lower payoff than her expected payoff conditional on passing to the next round. Second, there may be no proposal available to i that satisfies the necessary participation constraints.

numerical example considered here, however.

Consider player #1's choice of coalition in round #5. She chooses coalition #15, consisting of all players except #5. She could have received the same payoff had she chosen coalition #14, which contains the same members as coalition #15 except that player #4 is discarded; it is still a majority coalition. Our algorithm chose coalition #15 simply because the index 15 is larger than the index 14. It is perfectly possible in general that a player can be indifferent in terms of expected payoffs between choosing one coalition or another, even if his policy proposals would differ conditional on either coalition being selected (this is not true for round #5). Indeed as we converge on a solution to our game (for increasing *T*) we know that this indeterminacy is more and more likely.[13]

The solution to the MB game in Table 2 is found by allowing the number of rounds to increase until all players make the same policy proposal. Considerable convergence has occurred over these five rounds. The solution in this game is the Core outcome (39, 68), which also corresponds to the ideal point of player #1.

Player #1 has a very simple strategy in this game: propose her ideal point whenever asked! Any coalition that does not include player #5 will accept this proposal in any round.

Each of the other players have relatively simple strategies as a function of the round that they are in. As already noted, all except player #5 offer their own ideal point in round #5 if negotiations reach that point. In round #4, however, they compromise their offer in the direction of the Core and away from their own ideal point.

One measure of the success of a bargaining session is the percentage of the possible pie on the negotiating table that was actually taken away from the table by the agents. In this particular game we have five subgames, consisting of the full 5-round game, the 4-round game (beginning in round #2), the 3-round game (beginning in round #3), the 2-round game (beginning in round #4), and the 1-round game (beginning in round #5). The maximum payoff over all agents for each of these subgames is seen[14] to be 1095, 1093, 1090, 1074 and 987, respectively, for a total of 5338. Note how the aggregate pie does not rapidly decline until the penultimate round of bargaining: a "failure to communicate" in round #1 is not all that costly[15] provided the agents get their act together in round

---

[13] This follows from our analytical result that the solution is generically deterministic. For large enough *T* all players make essentially the same policy proposal in each round.

[14] By looking at the expected payoff lines for the round in which the subgame begins, and adding these values over all five agents.

[15] Individually or socially.

#2 and come to an agreement.

The Role of the Government

It is a simple matter to perturb the spatial preferences of our first example so as to generate a bargaining game in which no Core solution exists. Consider the preference configuration represented in Tables 3, 4 and 5. Unless some parameter is listed in Tables 4-5 it is identical to the parameters used in the preceding Table. In the games studied here we also give each active player equal access in each round unless otherwise stated.

Table 3 presents the game in which the Government is an active player. For transparency we assume the simplest possible utility function for Government: the sum of the utilities of private agents. This implies that an increase in the utility of one agent is a perfect substitute for an increase in the utility of any other agent. The Government is reported here as the sixth player. One reads the Government's proposal in any round from the sixth row, and the payoffs to the Government from the last column.

In this example we set $T=50$ and observe convergence to the solution (67, 66). Note that this solution is not in the convex hull of ideal points of players 1, 2 and 3, even though these three agents constitute a majority and are closer to each other than to players 4 and 5. If any of these agents had proposed such a solution it would have been possible for one or both of the excluded agents to upset it with a counter-proposal.

Table 3 makes the role of the Government in this game quite transparent. In each round the Government proposes the solution vector, ensuring itself a payoff of 310.122 if selected to make the proposal. Working backwards from round #50, each private agent must include the Government in it's proposal and give the Government at least it's expected payoff from going into the next bargaining round. Since the Government is more and more likely to get to make it's proposal as T expands (i.e., as we move down the table from round #50), it's expected payoff increases steadily. Eventually each and every player must give the Government it's most preferred policy outcome, since the Government knows that it can get essentially that expected payoff by just vetoing anything less and getting into subsequent negotiating rounds.

Table 3 raises an important question: why doesn't the Government simply impose it's most preferred outcome and save all of the negotiating hassle? One answer is that such an institution would not be perceived by private agents as a *fair process*, even if it did bring about a *fair outcome* by some standards. The Government's most preferred point could reflect some Social Welfare Function (as in our example) or satisfy some axiom-set (such as the set defining the Nash [1950] Solution). We do not presume consensus on the Government objective function, merely that it be plausible for the Government to honestly *claim* that it is being fair to all in a manner consistent with it's explicit objective function.

This general distinction is an important one in multilateral trade negotiations. The Uruguay Round conducted under the auspices of the GATT has become extraordinarily pluralized, especially in relation to the hierarchical negotiations of the Kennedy and Tokyo Rounds. In those negotiations the larger countries simply presented the smaller countries with a series of "done deals", which they could either accede to or ignore. These processes were perceived by many mid-sized and small countries to be unfair, providing one rationale for their widespread abrogation of the principles of GATT association in subsequent trade policy.

If one is to reform the GATT negotiations process so as to effect better outcomes from the perspective of all parties, the perception of a fair

Table 3: A Game With the Government Included

Ideal point of player number 1: 71.000 82.000
Ideal point of player number 2: 93.000 70.000
Ideal point of player number 3: 86.000 20.000
Ideal point of player number 4: 21.000 20.000
Ideal point of player number 5: 13.000 97.000
Utility coefficients of player number 1 (alpha, beta): 90.000 1.000
Utility coefficients of player number 2 (alpha, beta): 110.000 1.000
Utility coefficients of player number 3 (alpha, beta): 110.000 1.000
Utility coefficients of player number 4 (alpha, beta): 90.000 1.000
Utility coefficients of player number 5 (alpha, beta): 130.000 1.000

Round #50								
#16	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#16	93.000	70.000	64.940	110.000	59.512	2.342	45.567	282.361
#15	86.000	20.000	26.211	59.512	110.000	25.000	23.896	244.620
#16	21.000	20.000	10.351	22.342	45.000	90.000	52.586	220.278
#16	13.000	97.000	30.092	25.567	3.896	12.586	130.000	202.140
#16	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			49.185	64.410	54.183	27.498	64.910	260.186
Round #49								
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567	282.361
#6	82.078	26.119	33.031	64.780	102.732	28.616	31.026	260.186
#10	32.715	34.968	29.355	40.275	54.653	70.993	64.910	260.186
#9	32.071	81.514	51.068	47.993	28.194	27.498	105.433	260.186
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			56.985	72.015	58.630	27.418	64.058	279.105
Round #48								
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567	282.361
#6	77.798	35.189	42.698	72.015	92.738	31.206	40.449	279.105
#10	42.235	40.293	39.336	51.182	61.759	60.627	66.201	279.105
#9	40.419	76.749	58.972	56.988	37.212	30.020	95.913	279.105
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			61.577	76.538	59.651	26.542	64.257	288.565
Round #47								
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#2	89.684	69.160	67.330	106.579	60.702	5.536	48.419	288.565
#6	76.196	41.063	48.735	76.538	86.767	30.922	45.604	288.565
#10	46.929	44.588	45.513	57.385	63.835	54.267	67.565	288.565
#9	45.331	74.220	63.178	62.144	42.222	30.571	90.450	288.565
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			64.712	78.614	60.036	26.059	64.908	294.329
Round #46								
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#2	86.252	68.456	69.602	103.078	61.543	8.723	51.383	294.329
#6	74.437	44.693	52.535	78.614	82.734	31.134	49.312	294.329
#10	50.231	47.641	49.851	61.739	64.795	49.770	68.174	294.329
#9	48.836	72.705	65.966	65.753	45.510	30.395	86.705	294.329
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			66.912	79.704	60.211	25.847	65.498	298.172
Round #25								
#8	68.303	69.197	76.916	85.290	57.717	21.751	68.101	309.775
#2	70.190	66.829	74.807	86.971	60.575	22.084	65.339	309.775
#6	67.982	62.738	70.503	83.950	63.619	26.487	65.216	309.775
#10	65.259	63.201	70.344	81.438	62.078	28.152	67.764	309.775
#9	65.088	67.301	74.156	81.958	58.283	25.339	70.040	309.775
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.374	83.951	60.458	24.753	67.297	309.833
Round #1								
#8	67.524	66.248	73.869	84.250	60.198	24.400	67.401	310.118
#2	67.713	66.025	73.690	84.402	60.475	24.423	67.128	310.118
#6	67.477	65.586	73.212	84.098	60.795	24.899	67.114	310.118
#10	67.214	65.633	73.201	83.846	60.651	25.053	67.366	310.118
#9	67.191	66.065	73.616	83.893	60.243	24.765	67.601	310.118
#2	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.518	84.098	60.473	24.708	67.322	310.118

process could well substitute for the perception of a fair negotiation *outcome*. Thus highly asymmetric outcomes might be deemed fair by all parties if they result from a fair process.

What Role for Government?

Table 4 considers the previous example with one variation: in each round the Government has a greater chance of being able to make the proposal. Specifically, we let the Government have ten times the chance of being selected to make a proposal than any of the private agents. The purpose of this variation is to demonstrate how one might modify the institution so as to ensure a more rapid convergence to the solution.

Comparison of Table 3 and 4 reveals that virtually all of the convergence that previously occurred over a horizon of 50 rounds now occurs over a much shorter horizon. Instead of having to contemplate a negotiation process of 50 rounds[16], the players in this game only need to contemplate a negotiation process over 9 rounds[17]. In each case they will come to the same solution.

What If There Were No Government?

Table 5 considers the last two examples without a Government player. We report results from the ten-round subgame starting in round #41. The policy proposals for earlier rounds are virtually identical to those shown for round #41. We observe some movement towards the solution, largely on the part of players #4 and #5. However, no player is able to come up with a proposal that is acceptable in the sense that any two other players would do at least as well as they expect to in the next round.

This is a *negotiating stalemate* in which at least one player in any feasible coalition would prefer to veto the solution (67, 66) than to accept it (were it proposed). Notice the *social loss* involved here. If the Government player were active the social pie would be 310.118 (=73.518+84.098+60.473+24.708+67.322), whereas left to their own devices the players only realize 278.556 (=56.858+72.987+58.321+27.208+61.182) of this. Note that adding the Government is *not a Pareto improvement*, since player #4 would do worse with the Government active.

[16] Starting in round #1 of the game described in Table 3.

[17] Starting in round #42 of the game described in Table 4.

Table 4: A Game With an Increased Role for Government

Round #50								
#16	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#16	93.000	70.000	64.940	110.000	59.512	2.342	45.567	282.361
#15	86.000	20.000	26.211	59.512	110.000	25.000	23.896	244.620
#16	21.000	20.000	10.351	22.342	45.000	90.000	52.586	220.278
#16	13.000	97.000	30.092	25.567	3.896	12.586	130.000	202.140
#16	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			63.785	76.224	57.958	25.824	66.356	290.147
Round #49								
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092	301.594
#2	88.783	68.958	67.947	105.656	60.963	6.386	49.195	290.147
#6	74.913	41.476	49.287	76.224	85.831	31.967	46.837	290.147
#10	47.793	45.383	46.648	58.525	64.130	53.093	67.751	290.147
#9	46.244	73.802	63.922	63.090	43.103	30.570	89.462	290.147
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			70.199	81.963	60.333	25.296	66.436	304.227
Round #48								
#8	70.385	79.308	87.238	85.544	48.671	12.823	69.950	304.227
#2	78.707	67.611	73.677	95.509	61.833	15.187	58.020	304.227
#6	70.801	52.874	60.873	81.963	73.783	30.327	57.281	304.227
#10	57.503	54.698	59.545	71.346	65.100	39.636	68.600	304.227
#9	56.712	70.114	71.414	73.712	51.956	28.464	78.681	304.227
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			72.528	83.272	60.406	24.901	67.049	308.157
Round #47								
#8	69.265	73.688	81.509	85.980	53.764	17.806	69.097	308.157
#2	73.936	67.387	75.095	90.757	61.101	18.953	62.250	308.157
#6	68.955	58.329	66.240	83.272	68.052	28.610	61.982	308.157
#10	61.979	59.439	65.702	77.230	63.822	33.126	68.276	308.157
#9	61.585	68.728	73.728	78.559	55.497	26.584	73.788	308.157
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.163	83.787	60.466	24.811	67.240	309.467
Round #46								
#8	68.587	70.422	78.173	85.583	56.656	20.668	68.386	309.467
#2	71.212	67.052	75.051	88.014	60.679	21.187	64.536	309.467
#6	68.217	61.540	69.351	83.812	64.814	27.111	64.378	309.467
#10	64.396	62.181	69.109	80.347	62.609	29.482	67.920	309.467
#9	64.171	67.743	74.192	81.083	57.503	25.633	71.055	309.467
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.403	83.990	60.467	24.744	67.298	309.903
Round #45								
#8	68.138	68.523	76.223	85.094	58.293	22.350	67.943	309.903
#2	69.628	66.679	74.617	86.393	60.533	22.594	65.766	309.903
#6	67.859	63.393	71.129	84.005	62.968	26.135	65.665	309.903
#10	65.721	63.760	71.011	82.016	61.770	27.431	67.675	309.903
#9	65.580	67.039	74.087	82.420	58.720	25.192	69.483	309.903
#3	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.483	84.062	60.469	24.719	67.316	310.049
Round #44								
#8	67.852	67.422	75.086	84.720	59.224	23.337	67.682	310.049
#2	68.703	66.390	74.222	85.436	60.491	23.460	66.440	310.049
#6	67.667	64.458	72.144	84.068	61.910	25.546	66.380	310.049
#10	66.458	64.669	72.084	82.927	61.243	26.268	67.526	310.049
#9	66.369	66.584	73.903	83.151	59.449	24.974	68.572	310.049
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.508	84.087	60.471	24.711	67.320	310.097
Round #43								
#8	67.677	66.784	74.425	84.473	59.756	23.913	67.530	310.097
#2	68.165	66.198	73.946	84.876	60.479	23.978	66.818	310.097
#6	67.562	65.072	72.726	84.089	61.302	25.197	66.783	310.097
#10	66.872	65.194	72.694	83.434	60.925	25.605	67.439	310.097
#9	66.818	66.306	73.758	83.559	59.879	24.858	68.044	310.097
#14	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.515	84.096	60.473	24.709	67.321	310.113
Round #42								
#8	67.572	66.415	74.042	84.321	60.061	24.248	67.441	310.113
#2	67.854	66.080	73.772	84.550	60.475	24.284	67.032	310.113
#6	67.503	65.426	73.061	84.096	60.952	24.992	67.012	310.113
#10	67.108	65.496	73.044	83.719	60.737	25.224	67.389	310.113
#9	67.076	66.141	73.662	83.790	60.129	24.793	67.739	310.113
#2	67.426	65.910	73.518	84.101	60.475	24.708	67.320	310.122
Expected payoffs:			73.517	84.099	60.474	24.708	67.321	310.119

Table 5: A Game Showing the Effect of Not Having the Government

Round #50							
#16	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#16	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#15	86.000	20.000	26.211	59.512	110.000	25.000	23.896
#16	21.000	20.000	10.351	22.342	45.000	90.000	52.586
#16	13.000	97.000	30.092	25.567	3.896	12.586	130.000
Expected payoffs:			44.319	60.472	52.924	28.056	64.428
Round #49							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.926	21.507	28.343	60.472	106.576	28.056	27.098
#10	30.628	33.842	27.158	37.905	52.924	73.139	64.428
#9	25.319	81.794	44.319	41.299	23.394	28.056	110.430
Expected payoffs:			50.952	66.923	57.724	28.388	63.523
Round #48							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.044	28.340	35.215	66.923	100.770	28.388	32.628
#10	35.790	34.551	30.914	42.697	57.724	69.252	63.523
#9	31.976	80.626	50.952	48.058	28.796	28.388	104.936
Expected payoffs:			54.404	70.524	58.603	27.744	63.349
Round #47							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.075	32.065	38.852	70.524	97.312	27.744	35.196
#10	36.758	34.727	31.628	43.612	58.603	68.432	63.349
#9	35.433	80.559	54.404	51.473	31.105	27.744	102.187
Expected payoffs:			55.965	72.110	58.549	27.323	63.278
Round #46							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.164	33.692	40.419	72.110	95.780	27.323	36.237
#10	36.669	34.617	31.487	43.478	58.549	68.572	63.278
#9	36.994	80.603	55.965	52.999	32.062	27.323	100.939
Expected payoffs:			56.562	72.705	58.423	27.182	63.222
Round #45							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.166	34.314	41.024	72.705	95.182	27.182	36.654
#10	36.502	34.495	31.290	43.271	58.423	68.778	63.222
#9	37.592	80.587	56.562	53.590	32.449	27.182	100.434
Expected payoffs:			56.763	72.901	58.355	27.167	63.194
Round #44							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.130	34.529	41.242	72.901	94.964	27.167	36.825
#10	36.413	34.431	31.186	43.162	58.355	68.886	63.194
#9	37.795	80.547	56.763	53.796	32.607	27.167	100.243
Expected payoffs:			56.826	72.960	58.330	27.182	63.184
Round #43							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.097	34.601	41.319	72.960	94.886	27.182	36.898
#10	36.379	34.408	31.148	43.122	58.330	68.926	63.184
#9	37.860	80.513	56.826	53.866	32.674	27.182	100.170
Expected payoffs:			56.847	72.978	58.323	27.197	63.182
Round #42							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.077	34.626	41.348	72.978	94.857	27.197	36.930
#10	36.370	34.402	31.138	43.111	58.323	68.936	63.182
#9	37.881	80.492	56.847	53.891	32.704	27.197	100.141
Expected payoffs:			56.855	72.984	58.321	27.204	63.182
Round #41							
#8	71.000	82.000	90.000	84.940	46.211	10.351	70.092
#2	93.000	70.000	64.940	110.000	59.512	2.342	45.567
#6	82.066	34.636	41.360	72.984	94.845	27.204	36.944
#10	36.369	34.402	31.137	43.110	58.321	68.938	63.182
#9	37.889	80.482	56.855	53.901	32.717	27.204	100.128
Expected payoffs:			56.858	72.987	58.321	27.208	63.182

3. ESTIMATING REALISTIC PREFERENCE STRUCTURES

We now turn to consider the question of estimating preference structures over trade policies that are in some sense more "realistic" than those discussed above. There are two broad approaches to this estimation problem. The first is to simply ask people what their preferences are, and the second is to infer those preferences using one or more assumptions about how those preferences are reflected in observed behavior. These two approaches boil down to either conducting some survey of agents or else inferring policy preferences using some model of behavior.

Each approach has strengths and weaknesses. The survey approach has the strength of being direct, and involving the least number of auxiliary assumptions. It has the danger of being difficult to implement in any "demand-revealing" way, as discussed below. Moreover, there is mounting evidence that the popular belief that hypothetical surveys, such as those used in natural resource damage assessment and litigation, are unable to accurately reflect the real economic commitment that agents would actually be willing to make (see Cummings and Harrison [1992]).

The use of model-consistent preferences has the strength that it often enables one to infer preference structures indirectly from readily observed data. As we will see below, it also has the strength that the results of applying the MB institution to these preferences can be compared easily with alternative non-cooperative and cooperative outcomes. Specifically, we can compare the welfare results of using the MB institution in international agricultural trade negotiations with the outcome of a retaliatory trade war as well as an "arbitrated" negotiated solution. The other advantage of this approach is that it is generally much less costly to implement[18] than a survey, whether or not the survey is hypothetical in the sense of offering the respondents no financial rewards for "good" responses. The major disadvantage of this approach is that it is conditional on the perceived validity of the underlying model, including the methods used to parameterize the model from observed data.

[18] Presuming that a rich enough model already exists, of course.

4. AN APPLICATION TO AGRICULTURAL TRADE REFORM

4.1 Generating Model-Consistent Preferences

In this section we use the multi-regional computational general equilibrium (CGE) model developed by Harrison, Rutherford and Wooton [1989] [1990] [1991] to generate policy preferences. These preferences apply to four agents: agricultural interests in the EC, non-agricultural interests in the EC, agricultural interests in the US, and non-agricultural interests in the US. The trade reforms being contemplated are those analyzed by Harrison and Rutström [1991c], hereafter HR. We briefly review the policy simulations and results of HR, and then explain how we use their results to calibrate trade negotiations between the EC and the US as a noncooperative MB game.

HR studied a bilateral[19] trade war between the US and the EC with respect to agricultural protection using a computable GE trade model to generate payoffs to each government. Each of the US and EC was assumed to adopt policies that operate in a non-discriminatory fashion.[20]

There are three important steps in generating the payoff matrices which form the basis of the HR trade wars and our analysis. The first step is to define the objective function of the governments of the EC and US, taking into account the relative political influence weights of agricultural and non-agricultural interests. These weights will be used to calibrate access probabilities in our MB game. The second step is to define the policy instruments that may be used as strategies. The third step is to allow for the uncertainty underlying any particular numerical simulation model, using techniques of sensitivity analysis and expected utility theory. Each of these steps is reviewed briefly below.

Payoffs

HR assume that each of the governments in the US and EC have an objective function that they use to decide when a policy change is an improvement or not. These objective functions have just two arguments: the

---

[19] All other nations were assumed to be strategically passive in their policy experiments. It would be straightforward to relax this assumption in later work.

[20] That is, the EC might increase protection against imports from all sources (rather than just against imports from the United States, for example). The effects of a geographically discriminatory trade war might be quite different, and could also be evaluated in later work.

welfare of sectional agricultural interests, and the welfare of the rest of society (i.e., non-agricultural interests). The key issue resolved by HR is how the government weights these two factors. We use these political weights to calibrate the *access weights* that each agent receives in the MB negotiation game evaluated later.

Before addressing this issue, however, we should note how HR measure the welfare of each of these groups. The welfare of society as a whole is given by changes in welfare of the consumers of the country. This is measured in terms of the Equivalent Variation (EV) in benchmark dollar terms (the base year is 1980 in this model, and the benchmark monetary measure is the U.S. dollar). This is a standard measure of changes in welfare for models where consumers are homogeneous within each country.

The welfare of agricultural interests is measured by looking at the change in the real income of a household that derives it's income solely from agriculture.[21] Given that we know how any set of trade policies affects the welfare of agricultural interests and the welfare of the economy as a whole, it is a straightforward matter to net out the former from the latter to obtain the change in the welfare of non-agricultural interests. Our governments are then assumed to apply relative political weights to these two welfare changes in order to evaluate the overall affect of the policy change in a linear objective function.

To derive the political weights on agricultural and non-agricultural interests, HR assume that the benchmark equilibrium policies in our model are the outcome of a political lobbying process.[22] The interpretation of these weights is straightforward. They tell us the range of weights within which lies the weight that one lobby group must

---

[21] Specifically, let agricultural land and capital be specific to agriculture with no useful employment in any other sector. Whenever there is some policy change there will be some change in the return to this factor, invariably reflecting the fate of the sector to which it is specific. Thus a decline in agricultural production will typically result in a decline in the relative price of factors specific to agriculture. The real income of the household owning this factor is then calculated by deflating with the change in the cost of living. It is perfectly possible for the return to the factor to decline but for the real income of the household owning the factor to increase (this would occur if the cost of living dropped by a greater percentage than the return to the factor). In the CGE model that HR employ there are two sectors that are "agricultural" in the broad sense used here. One is called AGR and refers to primary agricultural production. The other sector is called FOO and refers to food products. It is appropriate to consider these two jointly since much of the trade in agricultural goods occurs after they have been processed to some extent and hence are treated statistically as food products. In effect HR are assuming that these two sectors coordinate their political lobbying activities perfectly. Given that the levels of protection afforded their sectors are changed equally, this assumption is plausible enough.

[22] Specifically, allow the US government to consider two alternative policy options: maintaining the status quo in terms of agricultural support, or complete (unilateral) abolition of agricultural support. HR consider more than one alternative to the status quo, but for illustrative purposes just assume that there is one liberalization alternative. Assume that the lobbying groups have opposite interests in the policy being considered. This is always the case for the policies being considered. Agricultural interests prefer more agricultural support and non-agricultural interests less. A minimal weight on agricultural payoffs in the objective function is calculated such that none of the alternatives to status quo that are preferred by the non-agricultural interest groups would be chosen. For this illustrative example it would imply that the weighted payoffs to the government from complete (unilateral) abolition of agricultural support is less than that in the status quo. Similarly, a maximal weight for agricultural payoffs will have to be calculated when allowing for alternatives with higher levels of support than status quo. These alternatives would be preferred by agricultural groups. The weighted payoff to the government from this higher support alternative must be less than their weighted payoff in the status quo.

receive in terms of the government's objective function so as to rationalize the fact that the CGE model has a support level equal to the value assumed. No empirical rabbit is being pulled out of the air, since HR are not claiming that they have estimated these weights. Rather, they are just taking a particular model that represents the support policies that were assumed or observed to be in effect in the benchmark year, and asking how one could explain that using a simple model of government behavior. As constructed, the weights are best described as being model-consistent rather than being empirical estimates.

Further, HR make no attempt at explaining the political lobbying process that leads to the establishment of these weights. They simply take them as given in the benchmark. The benchmark is therefore assumed to be in both economic and political equilibrium.

Policy Instruments

The policy instruments considered here are directly related to the agricultural support policies in the two countries. Detailed descriptions may be found in Harrison, Rutherford and Wooton [1990] [1991] and HR.

The Common Agricultural Policy (CAP) in the EC is modelled as a threshold price constraint on the import price of goods in agriculture and food that is enforced through a variable import levy. In addition there is an intervention price constraint on domestic goods, above the threshold price, that is supported by intervention purchases and export subsidies. The share of intervention purchases that is exported is fixed at 82% for agriculture and 87% for food. The export subsidy is determined such that these exports can be sold on the international market. The fraction of the intervention purchases that is not exported in simply treated as a waste to the economy (i.e., it is stockpiled and does not enter any agent's consumption). The final instrument of the CAP is an exogenously determined production subsidy.

In any one simulation all three of these instruments (the threshold price, the intervention price, and the production subsidy) are manipulated simultaneously and to the same extent. That is, if we scale the CAP down by 25% then all three are lowered by this percentage.[23]

---

[23] One aspect of the HR simulations should be noted: the treatment of the CAP as a set of endogenous policies. The issue arises when we compare the payoffs to countries under a zero-CAP scenario to the payoffs for the same countries under an epsilon-CAP scenario. In the first case it is natural in terms of the economics of the policy to "turn off" the endogenous features of the CAP, whereas in the latter case the CAP

The agricultural policies of the US are simply exogenously determined import tariffs, export subsidies, and production subsidies. Again they are manipulated simultaneously and with equal percentage changes in any one simulation.

The simulations investigated by HR involve independently changing the EC and the US protection levels from -100% to +100% in steps of 25%. All bilateral combinations are evaluated.

Model Uncertainty

Like any numerical simulation model, the CGE model used by HR is calibrated to particular values of certain parameters that may or may not be reliable estimates of the "true value". Recognizing this fact, it is becoming common in policy applications of such models to undertake a systematic sensitivity analysis of results, at least with respect to the elasticity specifications adopted (see Harrison, Jones, Kimbell and Wigle [1992] and Harrison and Vinod [1992]). HR conduct an extensive sensitivity analysis using the statistical procedures developed by Harrison and Vinod [1992].

The upshot of running such a sensitivity analysis is that HR generate a *distribution* of solution values for any particular counter-factual policy simulation. In other words, if the EC dismantles the CAP they are able to say something such as "the mean change in the objective function value in the EC is -8.3%, with a standard deviation of 0.6%". They can also make statements as to the reliability of a qualitative result. For example, one can say such things as "the probability of a welfare gain to the EC from dismantling the CAP is 0%". Such statements reflect the intrinsic uncertainty about the particular empirical model underlying the simulations.

---

does remain endogenous albeit at a tiny level. The issue here is the possibility for some discontinuity in payoffs to countries as we make an arbitrarily small change in the CAP scenario. If the U.S. engages in some agricultural support program that causes world prices as perceived by the EC to increase above unity (the benchmark value), then it would make a difference if the zero-CAP scenario were implemented as a set of exogenous or endogenous polices. If the policies were endogenous then there would be some variable import levy set up to insulate EC domestic agents; if the policies were exogenous there would be no such response. The discontinuity arises when we study an epsilon-CAP scenario in which the EC sets threshold prices at one millionth of a penny above the benchmark prices. For all substantive purposes this may seem like the zero-CAP option, but it is not since it calls for endogenous variations in the import levy. From the perspective of game theory this type of discontinuity is bothersome if one insists on interpreting the strategy space as continuous. HR were not so restricted in their numerical work, preferring to deal with finite numbers of discrete pure strategies. As such there is no formal problem in allowing the CAP to be exogenous in the zero-CAP scenario and yet endogenous in the epsilon-CAP scenario. More important than the potential problems of formal interpretation, the economics of the CAP require that one recognize the discontinuity inherent in moving from an endogenous policy to an exogenous policy, even if the benchmark values (which are *ceteris paribus* the policy values of other countries) are identical. As such HR defend their approach as being more natural than the alternative of studying a zero-CAP scenario in which the import levy and export subsidy remained endogenous. In the event this problem does not arise in the numerical simulations, since HR do not examine epsilon-CAP scenarios that are all that close to the zero-CAP scenario. But it is important to be aware of this possibility in any further work.

A natural question arises for the conduct of the HR trade war. It is natural to assume that this is a game in which all agents know the relevant payoffs to every agent. In effect we are assuming that all agents might agree on the basic empirical model being used to generate the payoffs of alternative strategy combinations, even if neither side thinks that the model is "true" in any deeper sense. For present purposes we suppose that the agents adopt the CGE model we use here.

If this is so, then how are we to deal with the uncertainty over the model's results? Expected utility theory provides a natural answer to this question. We know how to evaluate the utility (or payoffs) to each agent given that they agree on the model and the particular set of elasticities used in any counterfactual policy simulation. This was discussed above. Now we must extend that calculation to allow for the fact that different elasticities will result in the same model giving different payoffs for the same counterfactual policy simulation. Expected utility theory assumes that the expected utility of some uncertain outcome is just the probability-weighted average utility of the utilities associated with each outcome.[24]

The HR sensitivity analysis undertakes a calculation of this kind over more than two sets of elasticities. In fact our sample sizes for *each cell of the payoff matrices* used here are equal to 500. The simple logic of the above expected payoff calculation is just the same, however.

Table 6 summarizes the HR analysis of the robustness of these results. In Table 6a the robustness of both unilateral and bilateral elimination of agricultural support policies is illustrated. Our results are very robust to variations in elasticity values. Standard deviations are consistently low and the qualitative results[25] are certain to 100% with only two exceptions -- the change in the weighted payoffs to the US government's objective function has approximately a 5% chance of being of the opposite sign. Table 6b illustrates partial and full bilateral liberalizations with equally robust results. Qualitative results always hold with 100% certainty with respect to variations in elasticity values.

It should be noted that HR employ prior probabilities for the different sets of elasticities that reflect our

[24] To be specific, assume that we just try two sets of elasticities, called High and Low for convenience, and one counterfactual policy simulation, such as the dismantling of the CAP and US farm support policies. Assume hypothetically that the payoff to the EC is 1.44 if elasticities are Low and 2.22 if they are High. If there is a 65% chance of the elasticities being Low and only a 35% chance of them being High, then the expected utility of this uncertain prospect to the EC is just 0.65(1.44)+0.35(2.22) = 0.936+0.777 = 1.713.

[25] The qualitative result refers to the sign of the change.

Table 6: Results of Policy Simulations and Sensitivity Analysis

A: Sensitivity Analysis and Results

EC Strategy	US Strategy	Description	Weighted EC	Weighted US	Agriculture EC	Agriculture US	Non-Agriculture EC	Non-Agriculture US
-100%	-100%	Mean	-2.388	0.156	-7.231	-1.717	10.068	3.085
		Std. Dev.	0.197	0.100	0.421	0.356	0.388	0.307
		Prob. of Gain	0.0	0.950	0.0	0.0	1.0	1.0
-100%	SQ	Mean	-2.546	1.025	-8.339	5.862	12.351	-6.540
		Std. Dev.	0.285	0.167	0.633	0.568	0.618	0.463
		Prob. of Gain	0.0	1.0	0.0	1.0	1.0	0.0
SQ	+100%	Mean	-0.339	-0.221	0.007	-4.713	-1.230	6.805
		Std. Dev.	0.014	0.081	0.002	0.280	0.053	0.232
		Prob. of Gain	0.0	0.961	1.0	0.0	0.0	1.0

B: Additional Sensitivity Analysis

EC Strategy	US Strategy	Mean	Standard Deviation	Probability of Gain
		Agriculture in EC		
-100%	SQ	-8.339	(0.633)	0.0
-100	SQ	-8.339	(0.633)	0.0
-75	SQ	-3.439	(0.008)	0.0
-50	SQ	-2.299	(0.005)	0.0
-25	SQ	-1.153	(0.002)	0.0
+25	SQ	+1.159	(0.003)	1.0
+50	SQ	+2.325	(0.005)	1.0
+75	SQ	+3.497	(0.009)	1.0
+100	SQ	+4.676	(0.011)	1.0
		Non-Agriculture in EC		
-100%	SQ	12.351	(0.618)	1.0
-75%	SQ	8.677	(0.731)	1.0
-50	SQ	5.859	(0.477)	1.0
-25	SQ	2.962	(0.240)	1.0
+25	SQ	-3.011	(0.248)	0.0
+50	SQ	-6.081	(0.248)	0.0
+75	SQ	-9.240	(0.739)	0.0
+100	SQ	-12.381	(1.049)	0.0
		Agriculture in US		
-100%	SQ	-4.713	(0.280)	0.0
-75	SQ	-3.592	(0.218)	0.0
-50	SQ	-2.455	(0.148)	0.0
-25	SQ	-1.250	(0.080)	0.0
+25	SQ	1.315	(0.091)	1.0
+50	SQ	2.678	(0.183)	1.0
+75	SQ	4.114	(0.297)	1.0
+100	SQ	5.570	(9.423)	1.0
		Non-Agriculture in US		
-100%	SQ	6.805	(0.232)	1.0
-75	SQ	5.274	(0.178)	1.0
-50	SQ	3.654	(0.120)	1.0
-25	SQ	1.888	(0.066)	1.0
+25	SQ	-2.074	(0.075)	0.0
+50	SQ	-4.296	(0.145)	0.0
+75	SQ	-6.709	(0.238)	0.0
+100	SQ	-9.279	(0.350)	0.0

knowledge about these estimates, rather than always assuming diffuse priors. As such the sensitivity analysis does involve greater weight being given to elasticity values that are *a priori* more likely to be observed. We thereby constrain the range of counterfactual policy results to be consistent with elasticity values that are *uncertain but not unrealistic.*

For example, the sensitivity analysis is much more likely to pick a value for an elasticity drawn from a Normal distribution within one standard deviation of the mean than it is to pick a value between one and two standard deviations from the mean. The objective is not to "let anything happen", but just to provide an honest assessment of the intrinsic uncertainty surrounding numerical calculations such as those employed here.[26]

The Model-Consistent Political Weights

Complete and unilateral liberalization of the CAP in 1985 results in reductions in the real income of agricultural interests in the EC of 8.34 billion 1980 U.S. dollars[27], and overall welfare gains to non-agricultural interests in the EC of 12.35 billion. The minimal political weight on agricultural interests consistent with the CAP being in place in our benchmark equilibrium is therefore 0.597 (=12.35/20.69). Thus one does not have to give agricultural interests much more than half-weight in order to rationalize the existence of the CAP in this model, at least in relation to complete liberalization as the alternative.

A similar calculation for complete and unilateral liberalization of agricultural support by the US results in reductions in real income of agricultural interests of 4.71 billion[28] and increases in the real income of the non-agricultural US interests of 6.81 billion. Thus the minimal political weight on agricultural interests in the US is 0.591 (=6.81/11.52). This weight is coincidentally quite close to the weight found for the EC.

It should be emphasized that each of these weights are based on the average changes in real income over

[26] This may seem to be a minor point, but there are many instances in policy applications of models such as these in which authors have not constrained their elasticity specifications to realistic values, and managed to find that a given policy can have virtually any qualitative effect. Such analyses have led many people to avoid the use of sensitivity analysis on the false grounds that it *necessarily* involves drawing indeterminate policy conclusions.

[27] This figure is composed of losses to three distinct groups. Land and Capital that are specific to AGR in the EC each lose 3.7012% of their real income with CAP liberalization, and Capital specific to FOO in the EC loses 8.3813% of it's real income. The endowments of each of these factors, in billions of dollars, are 64.0213, 28.7632, and 58.4979, respectively. The total loss of 8.34 is therefore computed as 0.037012(64.0213+28.7632)+ 0.083813(58.4979).

[28] This is also composed of losses to three factor groups. Capital and Land specific to AGR in the US each lose 7.51% of their real income due to the removal of support, and Capital specific to FOO in the US loses 2.76% of its real income. These factors have initial endowments of 12.1979, 27.1501, and 63.6760 billion, respectively. Weighted by the percentage changes in real income, these endowments add up to the overall loss of 4.71 billion reported in the text.

500 simulations, reflecting an extensive sensitivity analysis with respect to key elasticities and parameters in the underlying empirical model.

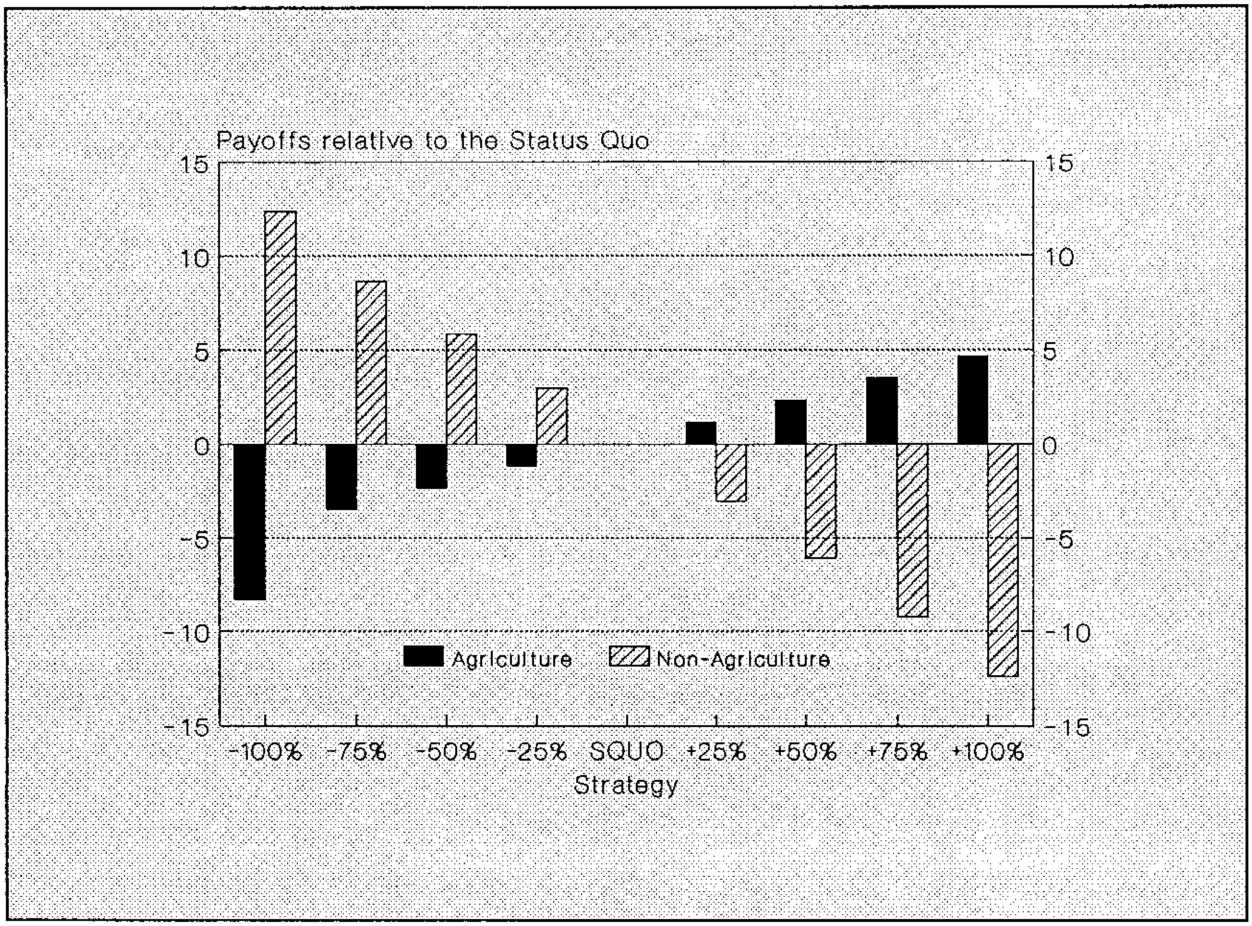

Figure 1: Payoffs to Interest Groups in the European Communities

HR examine how the political weights change as they consider alternatives to the status quo other than complete liberalization. Figures 1 through 4 display the results of comparable calculations for a wide range of unilateral policy alternatives by the EC and US. Table 7 lists the corresponding values in these figures.

It is apparent from these results that agricultural interests in each of the EC and US would lobby against liberalization of agricultural support and in favor of increases in that support. Conversely, non-agricultural interests would have diametrically opposed lobbying activities. These qualitative results are quite intuitive. They do, however, imply that one must take a little care in interpreting the political weights.

Consider the political weights within the EC first. In order to rationalize the status quo as compared to 100% liberalization of the CAP HR found that agricultural interests needed a weight of at least 0.597 in the

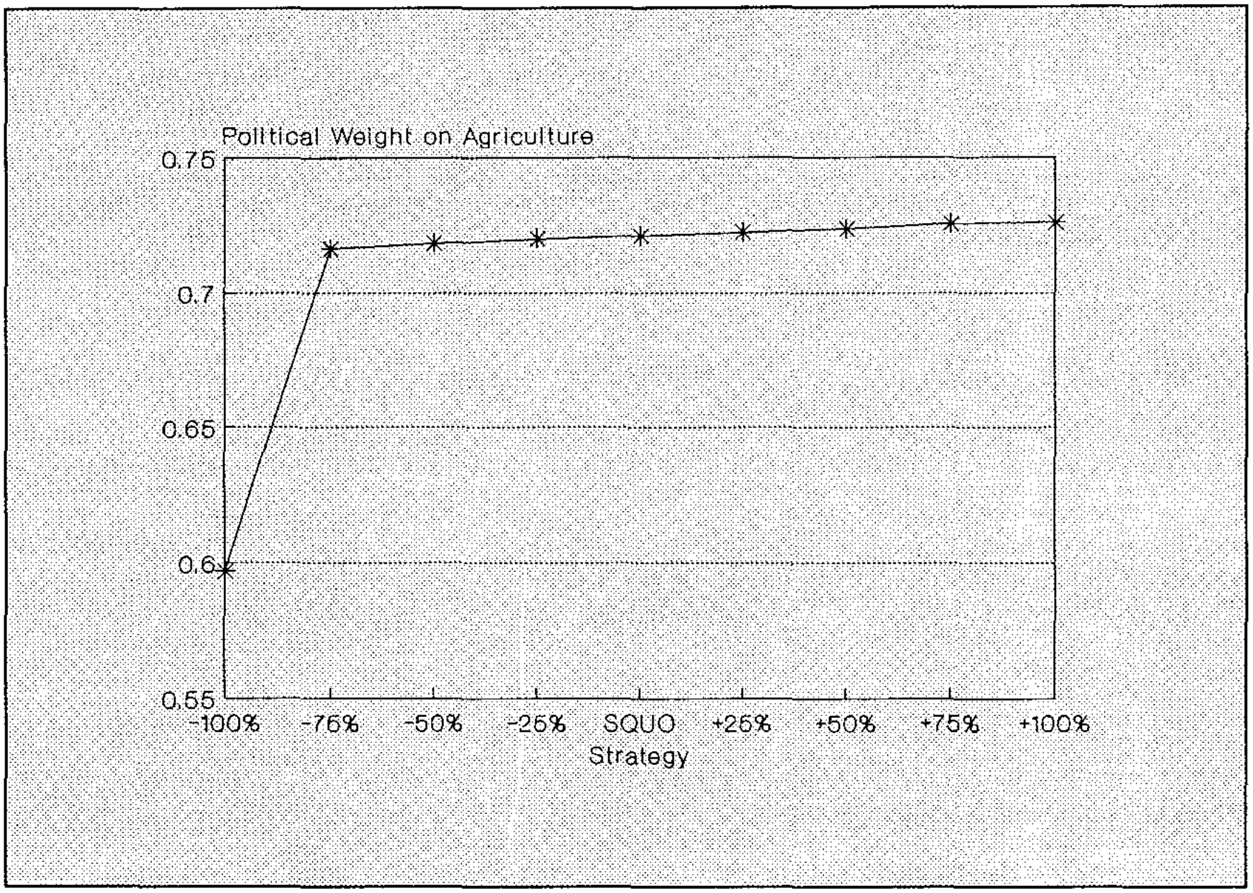

Figure 2: Political Weights in the European Communities

objective function of the EC "government". For all other reductions in the CAP this weight must be higher, around 0.71 or 0.72 depending on the precise alternative to the status quo.

Now consider the alternative of increasing the CAP by 100%. In this case agricultural interests gain by 4.6760 billion as compared to the status quo and non-agricultural interests lose by 12.3811 billion. The political weight of 0.274139 is calculated as the minimal weight required on non-agricultural interests so as to rationalize why the status quo was the benchmark in this model. This means that one minus this weight, or 0.725861, is the maximal feasible weight on agricultural interests that is consistent with the status quo being preferred by the EC "government".

HR therefore find that there is a reasonably tight bound on the political weights for agricultural interests that is consistent with the status quo. Specifically, this weight can lie between 0.719766 and 0.722099 for the EC,

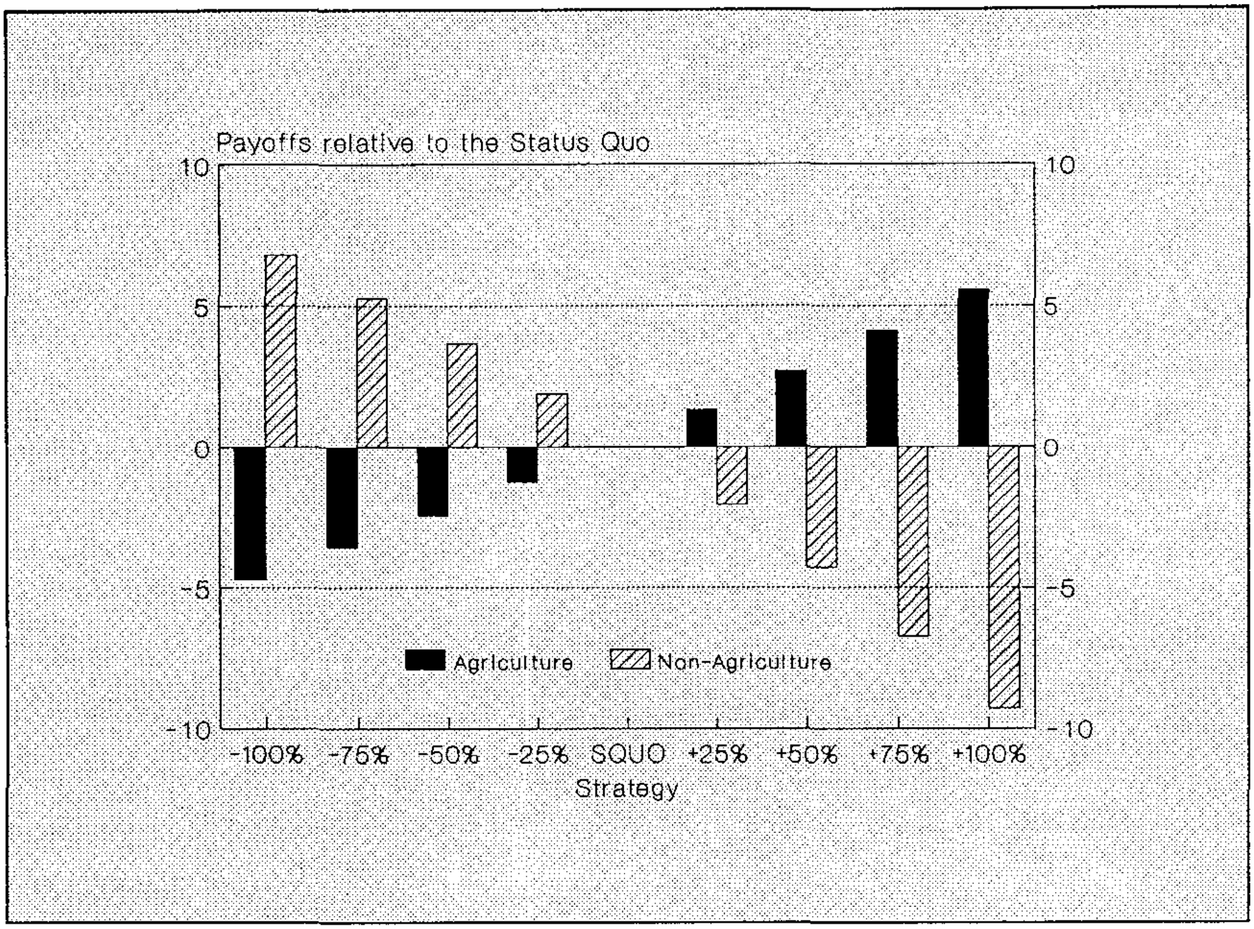

Figure 3: Payoffs to Interest Groups in the United States

and between 0.601696 and 0.611874 for the US.[29] Any lower weight than given by these bounds would result in the gains to non-agricultural interests outweighing the losses to agricultural interests in the government's "eyes", and the alternative to the status quo being chosen by the government. Similarly, any higher weight would result in the gains to agricultural interests outweighing the losses to non-agricultural interests.[30]

Why are these weights so stable for all of the alternatives other than complete liberalization? The reason is that the *ratio* of the change in real income of agricultural interests and non-agricultural interests is relatively constant. The *absolute level* of these changes in real income vary significantly with the different alternative policies,

[29] One could evaluate policy alternatives that are arbitrarily close to the status quo and obtain even tighter bounds, but these intervals are more than adequate for present purposes. Moreover, it is not obvious that such marginal changes in policies are feasible from a negotiating perspective, notwithstanding the nihilistic rhetoric commonplace in the GATT bargaining process.

[30] To see this point transparently, consider the effects of having weights of zero and one on agricultural interests. In the first case the government would completely ignore agricultural interests and fully liberalize unilaterally, whereas in the second case the government would completely ignore non-agricultural interests and expand agricultural support (to the maximal level of +100% considered here).

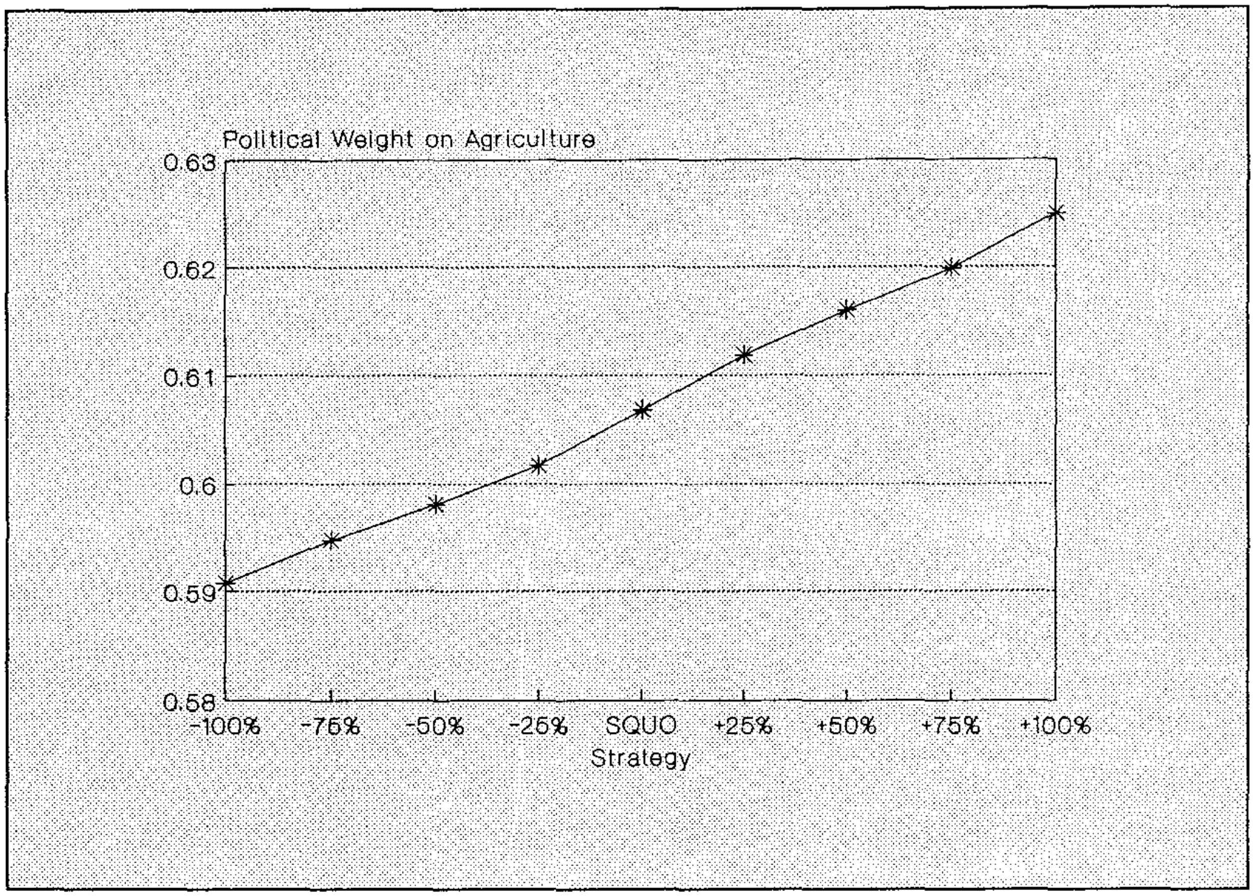

Figure 4: Political Weights in the United States

but the ratio of the two does not for all but complete liberalization.

It is particularly noteworthy that there is a difference when we consider complete liberalization rather than just a scaling up or down of the CAP. This indicates that it will be much easier to get the EC to engage in partial liberalizations than it will be to get them to engage in complete liberalizations in the sense that the political influence weight for agriculture only has to be lowered by a small fraction to remove enough opposition to full liberalization[31]. This may seem like a trivial conclusion until one notices that in terms of the political weights we have calculated it will be just as easy to get the EC to engage in a 75% liberalization as in a 25% liberalization. This analysis as to the political ease of alternative reforms has nothing to do with the absolute size of the real income changes that they imply for any group of agents, but rather with their effect on their *relative* lobbying

[31] Recall the earlier discussion of why there is a difference between partial and full liberalizations of the CAP. The latter involves a fundamental "regime change" in relation to the variables that are endogenous and exogenous (e.g., the import levy is no longer variable, but fixed).

Table 7: The Political Weights

All payoffs are measured in billions of US dollars.

Country	Strategy	Payoffs from not being in the Status Quo: Ag.	Non-Ag.	Political Weight for Ag.	Check-Sum Net Contribution
EC	-100%	-8.3392	12.3511	0.596951	0.000000
	-75%	-3.4392	8.6774	0.716156	-0.000000
	-50%	-2.2995	5.8592	0.718155	0.000000
	-25%	-1.1532	2.9618	0.719766	-0.000000
	+25%	1.1588	-3.0111	0.722099	0.000000
	+50%	2.3247	-6.0808	0.723436	0.000000
	+75%	3.4972	-9.2397	0.725429	-0.000000
	+100%	4.6760	-12.3811	0.725861	0.000000
US	-100%	-4.7134	6.8053	0.590805	-0.000000
	-75%	-3.5925	5.2744	0.594842	0.000000
	-50%	-2.4548	3.6537	0.598134	0.000000
	-25%	-1.2495	1.8876	0.601696	0.000000
	+25%	1.3154	-2.0737	0.611874	0.000000
	+50%	2.6779	-4.2959	0.616004	-0.000000
	+75%	4.1145	-6.7094	0.619869	-0.000000
	+100%	5.5696	-9.2794	0.624916	-0.000000

influence.

Given this range of political weights HR determine the objective function weights on agricultural interests used in their simulations for the EC and US such that each want to adopt the status quo. For the EC this weight is roughly 0.72 and for the US it is roughly 0.61, comfortably within the bounds noted earlier.

The Trade War

HR simulate an agricultural trade war by evaluating the economic effects of each country adopting values for their agricultural support policies that are -100%, -75%, -50%, -25%, 0%, +25%, +50%, +75%, or +100% of the status quo values. This trade war therefore involves 81 (=9×9) policy combinations, or 81 distinct policy simulations.

Each of these 81 policy simulations is solved repeatedly as part of our sensitivity analysis, with every major elasticity being randomly perturbed in each simulation. In each cell HR conduct a sensitivity analysis with a sample size of 500, implying a total of 40,500 (=81×500) solutions of the CGE model. From this sensitivity analysis for each cell one can determine the average changes in the real income of agricultural and non-agricultural interests.

Table 8: Unweighted Payoffs to Agricultural Interests (in billions of U.S. dollars)

EC Policy	US Policy	EC Payoff	US Payoff
-100%	-100%	-7.231	-1.717
	-75%	-7.427	0.020
	-50%	-7.695	1.816
	-25%	-7.979	3.791
	SQUO	-8.339	5.862
	+25%	-8.644	8.045
	+50%	-9.066	10.287
	+75%	-9.532	12.815
	+100%	-9.902	15.478
-75%	-100%	-3.431	-4.050
	-75%	-3.433	-2.957
	-50%	-3.435	-1.789
	-25%	-3.437	-0.581
	SQUO	-3.439	0.676
	+25%	-3.441	1.994
	+50%	-3.443	3.364
	+75%	-3.445	4.809
	+100%	-3.447	6.224
-50%	-100%	-2.291	-4.257
	-75%	-2.293	-3.156
	-50%	-2.295	-2.015
	-25%	-2.298	-0.816
	SQUO	-2.299	0.442
	+25%	-2.301	1.749
	+50%	-2.303	3.118
	+75%	-2.306	4.539
	+100%	-2.308	6.036
-25%	-100%	-1.145	-4.500
	-75%	-1.147	-3.389
	-50%	-1.149	-2.233
	-25%	-1.151	-1.035
	SQUO	-1.153	0.219
	+25%	-1.155	1.519
	+50%	-1.157	2.899
	+75%	-1.159	4.308
	+100%	-1.161	5.819
SQUO	-100%	0.007	-4.713
	-75%	0.006	-3.592
	-50%	0.004	-2.455
	-25%	0.002	-1.250
	SQUO	0.000	0.001
	+25%	-0.002	1.315
	+50%	-0.004	2.678
	+75%	-0.006	4.114
	+100%	-0.008	5.570
+25%	-100%	1.167	-4.887
	-75%	1.165	-3.816
	-50%	1.163	-2.653
	-25%	1.161	-1.461
	SQUO	1.159	-0.208
	+25%	1.157	1.101
	+50%	1.155	2.457
	+75%	1.153	3.862
	+100%	1.151	5.339
+50%	-100%	2.333	-5.096
	-75%	2.331	-3.995
	-50%	2.329	-2.851
	-25%	2.327	-1.652
	SQUO	2.325	-0.408
	+25%	2.323	0.894
	+50%	2.321	2.251
	+75%	2.319	3.696
	+100%	2.317	5.139
+75%	-100%	3.505	-5.276
	-75%	3.503	-4.184
	-50%	3.501	-3.051
	-25%	3.499	-1.854
	SQUO	3.497	-0.601
	+25%	3.496	0.702
	+50%	3.493	2.074
	+75%	3.492	3.465
	+100%	3.490	4.953
+100	-100%	4.683	-5.472
	-75%	4.683	-4.354
	-50%	4.680	-3.227
	-25%	4.678	-2.043
	SQUO	4.676	-0.789
	+25%	4.674	0.508
	+50%	4.674	1.876
	+75%	4.671	3.270
	+100%	4.669	4.783

Tables 8 and 9 report these unweighted changes in real income (in billions of dollars, per annum). The first line of Table 8 is read as follows. When the EC adopts a policy of -100% liberalization (complete abolition of the CAP) and the US does likewise, agricultural real income in the EC goes down by 7.231 billion relative to the status quo and by 1.717 billion in the US relative to the status quo. The second line shows that when the EC maintains it's policy of full liberalization but the US only liberalizes by 75%, agricultural real income in the EC goes down by 7.427 billion and goes up in the US by 0.020 billion.

Similar interpretations apply to the payoff reported in Table 9. The first and second lines there correspond

Table 9: Unweighted Payoffs to Non-Agricultural Interests (in billions of U.S. dollars)

EC Policy	US Policy	EC Payoff	US Payoff
-100%	-100%	10.068	3.085
	-75%	10.517	1.050
	-50%	11.073	1.179
	-25%	11.662	-3.724
	SQUO	12.351	-6.540
	+25%	13.044	-9.658
	+50%	13.888	-13.075
	+75%	14.797	-16.966
	+100%	15.661	-21.258
-75%	-100%	7.394	6.311
	-75%	7.737	4.776
	-50%	7.974	3.103
	-25%	8.377	1.314
	SQUO	8.677	-0.615
	+25%	9.045	-2.705
	+50%	9.383	-4.953
	+75%	9.657	-7.397
	+100%	10.107	-9.958
-50%	-100%	4.542	6.461
	-75%	4.891	4.932
	-50%	5.188	3.291
	-25%	5.508	1.516
	SQUO	5.859	-0.408
	+25%	6.137	-2.479
	+50%	6.514	-4.719
	+75%	6.824	-7.137
	+100%	7.102	-9.756
-25%	-100%	1.674	6.647
	-75%	2.027	5.115
	-50%	2.329	3.472
	-25%	2.658	1.704
	SQUO	2.962	-0.213
	+25%	3.278	-2.266
	+50%	3.572	-4.509
	+75%	3.877	-6.907
	+100%	4.181	-9.529
SQUO	-100%	-1.230	6.805
	-75%	-0.921	5.274
	-50%	-0.610	3.654
	-25%	-0.303	1.888
	SQUO	0.000	-0.001
	+25%	0.300	-2.074
	+50%	0.597	-4.296
	+75%	0.888	-6.709
	+100%	1.184	-9.279
+25%	-100%	-4.222	6.934
	-75%	-3.933	5.453
	-50%	-3.598	3.818
	-25%	-3.306	2.069
	SQUO	-3.011	0.177
	+25%	-2.722	-1.874
	+50%	-2.457	-4.084
	+75%	-2.187	-6.460
	+100%	-1.870	-9.037
+50%	-100%	-7.260	7.093
	-75%	-6.963	5.593
	-50%	-6.711	3.981
	-25%	-6.426	2.236
	SQUO	-6.081	0.352
	+25%	-5.797	-1.682
	+50%	-5.570	-3.884
	+75%	-5.252	-6.291
	+100%	-5.023	-8.834
+75%	-100%	-10.394	7.229
	-75%	-10.115	5.745
	-50%	-9.814	4.147
	-25%	-9.552	2.410
	SQUO	-9.240	0.529
	+25%	-9.017	-1.502
	+50%	-8.739	-3.711
	+75%	-8.478	-6.062
	+100%	-8.235	-8.642
+100%	-100%	-13.509	7.378
	-75%	-13.309	5.878
	-50%	-12.956	4.294
	-25%	-12.716	2.574
	SQUO	-12.381	0.700
	+25%	-12.207	-1.324
	+50%	-11.949	-3.523
	+75%	-11.613	-5.874
	+100%	-11.459	-8.466

to the same policy packages as discussed above. In this case one can see from the first line that complete liberalization by the EC and US results in a 10.068 billion gain in real income for non-agricultural interests in the EC and a gain of 3.085 billion in the US.

These payoffs are unweighted in the sense that we have not yet applied the political weights to each interest group to determine the payoff in the "government" objective function in each country. Using the weights of 0.72 and 0.61 for the EC and US discussed earlier, HR obtain the weighted payoffs shown in Table 10. Consider the first line again. The weighted payoff to the EC "government" is -2.388 billion, which is the sum of the weighted loss of 5.206 (= 0.72×7.231) to agricultural interests and the weighted gain of 2.818 (= 0.28×10.068) to non-agricultural interests.

Table 10: Weighted Payoffs to Government (in billions of U.S. dollars)

EC Policy	US Policy	EC Payoff	US Payoff
-100%	-100%	-2.388	0.156
	-75%	-2.403	0.422
	-50%	-2.440	0.648
	-25%	-2.479	0.860
	SQUO	-2.546	1.025
	+25%	-2.571	1.141
	+50%	-2.639	1.176
	+75%	-2.720	1.201
	+100%	-2.744	1.151
-75%	-100%	-0.400	-0.009
	-75%	-0.305	0.059
	-50%	-0.241	0.119
	-25%	-0.129	0.158
	SQUO	-0.047	0.172
	+25%	0.055	0.161
	+50%	0.149	0.120
	+75%	0.223	0.049
	+100%	0.348	-0.087
-50%	-100%	-0.378	-0.077
	-75%	-0.281	-0.002
	-50%	-0.200	0.054
	-25%	-0.112	0.093
	SQUO	-0.015	0.111
	+25%	0.061	0.100
	+50%	0.166	0.062
	+75%	0.250	-0.014
	+100%	0.327	-0.123
-25%	-100%	-0.356	-0.153
	-75%	-0.258	-0.072
	-50%	-0.175	-0.008
	-25%	-0.085	0.033
	SQUO	-0.001	0.050
	+25%	0.086	0.043
	+50%	0.167	0.010
	+75%	0.251	-0.066
	+100%	0.335	-0.167
SQUO	-100%	-0.339	-0.221
	-75%	-0.254	-0.134
	-50%	-0.168	-0.072
	-25%	-0.084	-0.026
	SQUO	0.000	0.000
	+25%	0.082	-0.006
	+50%	0.164	-0.042
	+75%	0.244	-0.107
	+100%	0.325	-0.221
+25%	-100%	-0.342	-0.277
	-75%	-0.263	-0.201
	-50%	-0.170	-0.129
	-25%	-0.090	-0.084
	SQUO	-0.009	-0.058
	+25%	0.071	-0.059
	+50%	0.144	-0.094
	+75%	0.218	-0.164
	+100%	0.305	-0.268
+50%	100%	-0.353	-0.342
	-75%	-0.271	-0.256
	-50%	-0.202	-0.186
	-25%	-0.124	-0.136
	SQUO	-0.029	-0.112
	+25%	0.049	-0.111
	+50%	0.111	-0.142
	+75%	0.199	-0.199
	+100%	0.262	-0.311
+75%	-100%	-0.387	-0.399
	-75%	-0.310	-0.312
	-50%	-0.227	-0.243
	-25%	-0.155	-0.191
	SQUO	-0.069	-0.160
	+25%	-0.008	-0.158
	+50%	0.068	-0.182
	+75%	0.140	-0.251
	+100%	0.207	-0.349
+100%	-100%	-0.411	-0.461
	-75%	-0.355	-0.364
	-50%	-0.258	-0.294
	-25%	-0.192	-0.242
	SQUO	-0.100	-0.208
	+25%	-0.053	-0.206
	+50%	0.019	-0.229
	+75%	0.111	-0.296
	+100%	0.153	-0.384

The Retaliatory Nash Equilibrium of the Trade War

Given the payoffs to each government shown in Table 10, it is a straightforward matter to verify that the status quo is a Nash Equilibrium (NE) of this trade war. This follows by the way that the political weights have been constructed for each agent: neither has any unilateral incentive to choose a policy that differs from the status quo.[32]

To see this, examine the line in the payoff matrix that corresponds to both players choosing the status quo. Each player receives a payoff of zero, since there is obviously no change in the real income of any interest group.[33] Now evaluate the alternative policies that the US could adopt, assuming that the EC maintains its status

[32] Indeed, verifying that the status quo is a NE is a useful consistency check on the way that the political weights have been computed.

[33] Strictly speaking the minimal political weight on agricultural interests is zero at this point, but this is a mere technicality.

quo polices. Any such unilateral deviation by the US results in it receiving a loss relative to the status quo. Hence the US has no incentive to unilaterally deviate from the status quo, given that the EC is at the status quo. Similarly, by comparing the lines of the payoff table corresponding to the US adopting the status quo[34] we see that the EC does not gain by unilaterally deviating from the status quo. This verifies that the status quo is a NE.

It does not follow that this is the only NE. The political weights have only been constructed to ensure that the status quo is a best-response given that the other player is choosing the status quo also. They do not ensure that the status quo is a best-response if the other agent is deviating from the status quo. For example, if the EC completely liberalizes the CAP then the best-response for the US would be to increase agricultural support by 75%.

Nonetheless, it turns out that the status quo is indeed the only NE of this game.

The Cooperative Nash Solution

Given the policy alternatives considered thus far we can determine the unique negotiation outcome using the Nash Solution (NS) with the NE as the disagreement outcome in the event of a breakdown in negotiations. An appendix describes the NS formally. For the calibrated political weights the NS is for the EC to liberalize the CAP by 75% and for the US to increase agricultural support by 50%. This generates losses to EC agricultural interests of 3.443 billion, gains to US agricultural interests of 3.364 billion, gains to EC non-agricultural interests of 9.383 billions, and losses to US non-agricultural interests of 4.953 billion.

It is impossible to conceive of a NS where no one loses relative to the status quo as the effects on agricultural and non-agricultural groups, both in the EC and the US, are diametrically opposite. If an agricultural group gains the corresponding non-agricultural group loses. All that we can conclude therefore is that with the existing political influence weights in the government planning function a cooperative NS exists such that the EC would completely eliminate the CAP and the US would augment its agricultural protection program with net gains in both countries objective functions (15% for the EC and 12% for the US).

---

[34] These lines are in the middle of each block of payoffs, and are not contiguous.

4.2 The Multilateral Bargaining Game

We use the simulation results of HR to calibrate a MB game, so as to see how the outcome changes if this game is employed instead of a retaliatory trade war or a cooperative NS imposed.

There are four private players in the MB game, and one Government player which we will interpret as the (reconstituted) GATT. The private players, of course, are the agricultural and non-agricultural interests of the EC and the US. Each has an ideal point over the space of policy alternatives considered in Tables 8 and 9. For agricultural interests in the EC it is the outcome (100, -75)[35], and for agricultural interests in the US it is the outcome (-100, 100). For non-agricultural interests in the EC the ideal point is (-100, 100), and for non-agricultural interests in the US it is (100, -100). The utility function intercepts and coefficients are set at 1000 and 1, without loss of generality.[36]

If we represent EC reform on the vertical axis and US reform on the horizontal axis, we have the ideal points of US non-agricultural interests and EC agricultural interests clustered together in the top left corner, the ideal point of US agricultural interests diametrically opposed at the bottom right-hand corner, and EC non-agricultural interests at the bottom left-hand corner. Thus three of the four private agents have an interest in having the US reduce agricultural protection, but there is no simple majority in terms of EC agricultural reform. The trade war outcome, of course, was found to be the (0, 0) outcome, whereas the cooperative NS outcome was (-75, 50). Figure 5 illustrates these ideal points and outcomes.

The access weights assumed for each private agent in the MB game are derived from the political weights generated by HR. We assume that each country as a whole has equal access to the negotiating table, but each of the interests within each country have access to each of the national negotiators in proportion to the political weights calibrated by HR and described above. Thus we have access weights of 0.36 (=0.72/2) and 0.14 (=0.28/2) for agricultural and non-agricultural interests in the EC, respectively, and access weights of 0.305 (=0.61/2) and 0.195

[35] Inspection of Table 8 shows that the outcomes (100, -100) and (100, -75) result in the same payoff to agricultural interests in the EC. We assume that an agent is prepared to make any costless concession, such as when the Philippines offered to remove import tariffs on snow-blowers in recent negotiations on ASEAN trade liberalization.

[36] The specific values for these parameters are of little interest since we are free to transform them as long as we preserve the preference ordering of the agents (strictly, we are allowed any positive affine transform, which is more restrictive than allowing monotonic transformations). For numerical reasons it is nice to keep utility levels positive for all feasible proposals.

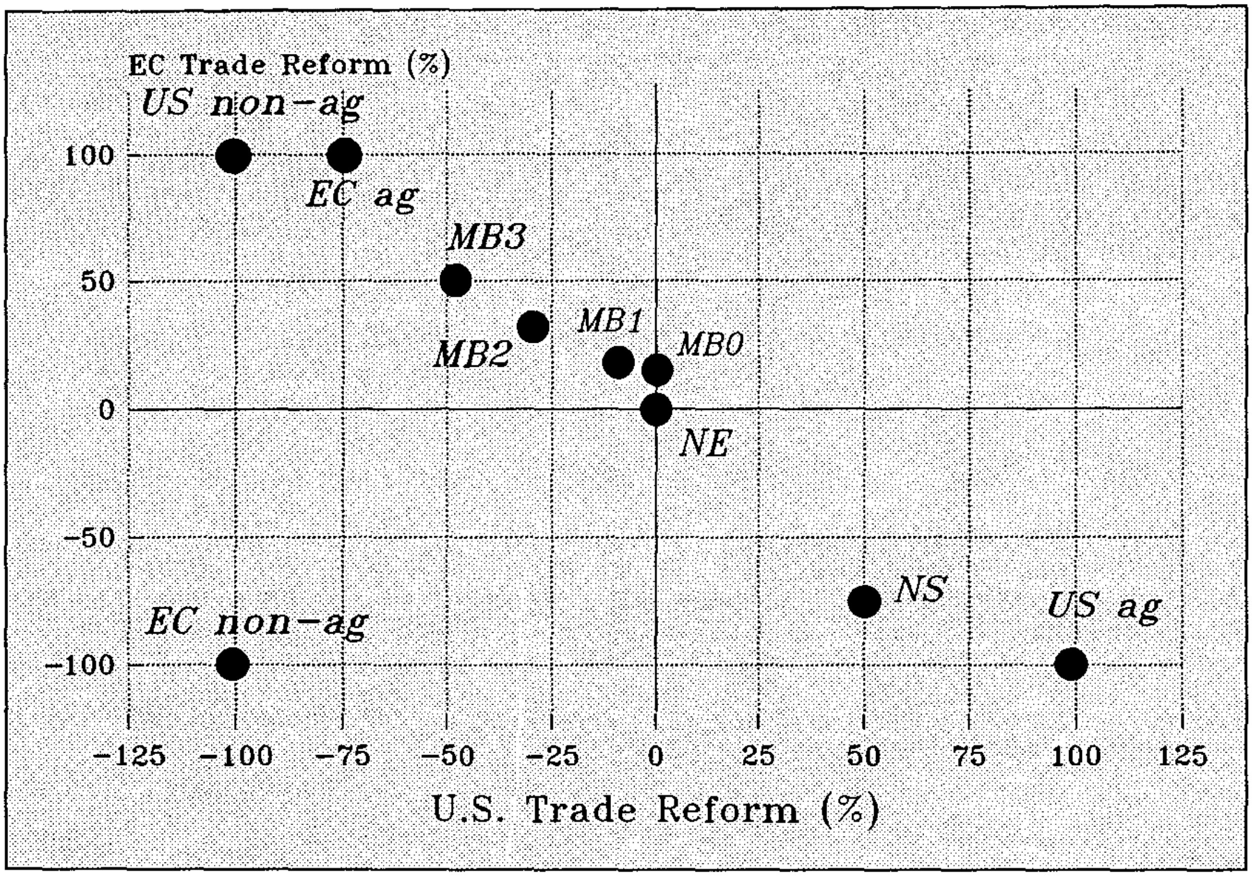

Figure 5: Preferences Over Agricultural Trade Reform

(=0.39/2) for agricultural and non-agricultural interests in the US. Each of the US and EC is accorded one vote, which is operationalized by giving each of the interest groups within each these regions a vote of one-half.

Tables 11-14 show the outcomes of various multilateral bargaining games computed using these preferences. We first compute the MB outcome assuming that the GATT takes no role in negotiations. We then allow it to have more and more influence, and see how this changes the solution. Specifically, we allow the GATT to have more "influence" by jointly increasing it's access probability *and* it's voting power. In game MB0 it has neither. In game MB1 it has an access probability of 0.1 and a vote of 0.1, which corresponds to the GATT having the tenth of the influence that either the US or the EC has. In game MB2 we increase these from 0.1 to 0.5, giving the GATT more of a say but still less than each of the US and the EC. Finally, in game MB3 we increase the access probability and vote of the GATT to 1, putting it on a par with the US and the EC. It would be possible in future work to study the effect of varying the access probabilities of the GATT without varying it's voting power, or *vice versa*.

Table 11: Multilateral Bargaining With No GATT

Round #1							
#5	100.000	-75.000	1000.000	734.246	734.246	975.000	3443.493
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#4	100.000	-100.000	975.000	717.157	717.157	1000.000	3409.315
Expected Payoff			876.865	849.174	849.174	865.135	3440.349
Round #2							
#5	13.508	0.681	885.072	849.174	849.174	867.269	3450.690
#5	7.331	6.085	876.865	857.382	857.382	859.140	3450.768
#5	7.331	6.085	876.865	857.382	857.382	859.140	3450.768
#4	6.650	-6.650	884.302	849.174	849.174	867.983	3450.634
Expected Payoff			881.270	852.827	852.827	863.791	3450.714
Round #3							
#5	10.759	3.086	881.420	852.827	852.827	863.653	3450.726
#2	3.845	-3.526	880.191	853.366	853.366	863.791	3450.714
#2	3.845	-3.526	880.191	853.366	853.366	863.791	3450.714
#2	4.256	-3.879	880.730	852.827	852.827	864.330	3450.714
Expected Payoff			880.738	853.067	853.067	863.846	3450.719
Round #4							
#5	10.579	3.244	881.180	853.067	853.067	863.415	3450.728
#5	10.246	3.534	880.738	853.508	853.508	862.978	3450.732
#5	10.246	3.534	880.738	853.508	853.508	862.978	3450.732
#2	4.095	-3.700	880.495	853.067	853.067	864.090	3450.718
Expected Payoff			880.850	853.263	853.263	863.352	3450.728
Round #5							
#5	10.431	3.373	880.983	853.263	853.263	863.220	3450.730
#2	3.584	-3.167	879.767	853.805	853.805	863.352	3450.728
#2	3.584	-3.167	879.767	853.805	853.805	863.352	3450.728
#2	3.996	-3.521	880.308	853.263	853.263	863.893	3450.728
Expected Payoff			880.310	853.504	853.504	863.410	3450.729
Round #100							
#5	-3.202	15.302	862.869	871.378	871.378	845.258	3450.882
#5	-3.454	15.522	862.534	871.712	871.712	844.926	3450.885
#5	-3.454	15.522	862.534	871.712	871.712	844.926	3450.885
#2	-8.893	9.208	862.346	871.378	871.378	845.779	3450.881
Expected Payoff			862.618	871.527	871.527	845.212	3450.883
Round #101							
#5	-3.314	15.399	862.720	871.527	871.527	845.110	3450.883
#2	-9.305	9.598	861.781	871.945	871.945	845.212	3450.883
#2	-9.305	9.598	861.781	871.945	871.945	845.212	3450.883
#2	-8.990	9.322	862.200	871.527	871.527	845.630	3450.883
Expected Payoff			862.201	871.713	871.713	845.257	3450.883
Round #199							
#5	-14.413	25.111	847.972	886.275	886.275	830.462	3450.983
#2	-19.721	19.926	847.212	886.613	886.613	830.544	3450.983
#2	-19.721	19.926	847.212	886.613	886.613	830.544	3450.983
#2	-19.468	19.701	847.551	886.275	886.275	830.882	3450.983
Expected Payoff			847.552	886.425	886.425	830.580	3450.983
Round #200							
#5	-14.526	25.211	847.821	886.425	886.425	830.312	3450.984
#5	-14.729	25.388	847.552	886.695	886.695	830.045	3450.985
#5	-14.729	25.388	847.552	886.695	886.695	830.045	3450.985
#2	-19.580	19.802	847.400	886.425	886.425	830.732	3450.983
Expected Payoff			847.619	886.545	886.545	830.275	3450.984

Table 11 presents the results of game MB0, in which the GATT has no influence. This game requires a large number of iterations to settle down, and *appears* to converge to a "limit cycle" as illustrated for rounds 199 and 200. This solution consists of a cycle between the outcome (-15, 25) and the outcome (-20, 20). The fact that

Table 12: Multilateral Bargaining With a Minimal GATT

Round #1							
#5	100.000	-75.000	1000.000	734.246	734.246	975.000	3443.493
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#4	100.000	-100.000	975.000	717.157	717.157	1000.000	3409.315
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
Expected Payoff			863.899	862.886	862.886	851.682	3441.354
Round #2							
#5	3.189	9.710	871.361	862.886	862.886	853.683	3450.815
#5	-2.426	14.623	863.899	870.347	870.347	846.281	3450.874
#5	-2.426	14.623	863.899	870.347	870.347	846.281	3450.874
#4	-3.046	3.046	870.735	862.886	862.886	854.271	3450.778
#5	-5.136	11.428	863.899	870.215	870.215	846.802	3451.131
Expected Payoff			867.553	866.570	866.570	850.167	3450.861
Round #3							
#5	0.331	12.039	867.676	866.570	866.570	850.045	3450.861
#2	-5.692	6.203	866.716	866.989	866.989	850.167	3450.861
#2	-5.692	6.203	866.716	866.989	866.989	850.167	3450.861
#2	-5.375	5.928	867.135	866.570	866.570	850.586	3450.861
#2	-2.680	9.118	867.264	866.843	866.843	850.167	3451.117
Expected Payoff			867.154	866.764	866.764	850.201	3450.885
Round #4							
#5	0.064	12.029	867.481	866.765	866.765	849.874	3450.884
#5	-0.168	12.260	867.154	867.092	867.092	849.547	3450.884
#5	-0.168	12.260	867.154	867.092	867.092	849.547	3450.884
#2	-5.384	6.194	866.965	866.765	866.765	850.391	3450.884
#5	-2.748	9.207	867.154	866.954	866.954	850.055	3451.117
Expected Payoff			867.228	866.914	866.914	849.850	3450.905
Round #5							
#5	-0.167	11.993	867.330	866.914	866.914	849.747	3450.906
#2	-5.660	6.682	866.449	867.304	867.304	849.850	3450.906
#2	-5.660	6.682	866.449	867.304	867.304	849.850	3450.906
#2	-5.365	6.426	866.839	866.914	866.914	850.239	3450.906
#2	-2.913	9.334	866.946	867.161	867.161	849.850	3451.118
Expected Payoff			866.852	867.094	867.094	849.885	3450.925
Round #20							
#5	-2.722	11.790	865.522	868.683	868.683	848.182	3451.071
#5	-2.829	11.904	865.367	868.839	868.839	848.025	3451.071
#5	-2.829	11.904	865.367	868.839	868.839	848.025	3451.071
#2	-5.341	8.985	865.277	868.683	868.683	848.427	3451.071
#5	-4.060	10.426	865.367	868.745	868.745	848.269	3451.125
Expected Payoff			865.402	868.752	868.752	848.170	3451.076
Round #21							
#5	-2.830	11.773	865.451	868.752	868.752	848.121	3451.076
#2	-5.477	9.211	865.030	868.938	868.938	848.170	3451.076
#2	-5.477	9.211	865.030	868.938	868.938	848.170	3451.076
#2	-5.331	9.094	865.217	868.752	868.752	848.355	3451.076
#2	-4.145	10.481	865.266	868.845	868.845	848.170	3451.125
Expected Payoff			865.222	868.836	868.836	848.187	3451.081
Round #69							
#5	-4.991	11.600	863.902	870.226	870.226	846.776	3451.130
#2	-5.337	11.265	863.847	870.250	870.250	846.782	3451.130
#2	-5.337	11.265	863.847	870.250	870.250	846.782	3451.130
#2	-5.310	11.258	863.873	870.226	870.226	846.805	3451.130
#2	-5.163	11.429	863.878	870.236	870.236	846.782	3451.131
Expected Payoff			863.872	870.237	870.237	846.784	3451.130
Round #70							
#5	-5.016	11.589	863.890	870.237	870.237	846.767	3451.130
#5	-5.021	11.610	863.872	870.255	870.255	846.748	3451.130
#5	-5.021	11.610	863.872	870.255	870.255	846.748	3451.130
#2	-5.301	11.283	863.864	870.237	870.237	846.793	3451.130
#5	-5.156	11.446	863.872	870.242	870.242	846.775	3451.131
Expected Payoff			863.877	870.245	870.245	846.765	3451.130

there appears to be no (necessary) determinate solution in the absence of an essential player reflects a general feature

Table 13: Multilateral Bargaining With a Weak GATT

Round #1							
#5	100.000	-75.000	1000.000	734.246	734.246	975.000	3443.493
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#4	100.000	-100.000	975.000	717.157	717.157	1000.000	3409.315
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
Expected Payoff			829.325	899.450	899.450	815.809	3444.034
Round #2							
#5	-24.328	33.787	834.797	899.450	899.450	817.362	3451.058
#5	-28.446	37.390	829.325	904.921	904.921	811.919	3451.087
#5	-28.446	37.390	829.325	904.921	904.921	811.919	3451.087
#4	-28.900	28.900	834.439	899.450	899.450	817.708	3451.046
#5	-30.472	35.031	829.325	904.842	904.842	812.233	3451.242
Expected Payoff			831.303	902.870	902.870	814.083	3451.126
Round #3							
#5	-27.260	35.633	831.374	902.870	902.870	814.012	3451.126
#2	-31.010	31.915	830.901	903.071	903.071	814.083	3451.126
#2	-31.010	31.915	830.901	903.071	903.071	814.083	3451.126
#2	-30.859	31.781	831.102	902.870	902.870	814.284	3451.126
#5	-28.912	33.813	831.303	902.870	902.870	814.193	3451.237
Expected Payoff			831.175	902.930	902.930	814.129	3451.163
Round #4							
#5	-27.623	35.314	831.308	902.930	902.930	813.995	3451.163
#5	-27.718	35.409	831.175	903.063	903.063	813.862	3451.163
#5	-27.718	35.409	831.175	903.063	903.063	813.862	3451.163
#2	-30.566	32.165	831.086	902.930	902.930	814.217	3451.163
#5	-29.118	33.768	831.175	902.990	902.990	814.082	3451.237
Expected Payoff			831.195	902.990	902.990	814.014	3451.188
Round #5							
#5	-27.929	35.063	831.241	902.990	902.990	813.968	3451.188
#2	-30.440	32.576	830.923	903.126	903.126	814.014	3451.188
#2	-30.440	32.576	830.923	903.126	903.126	814.014	3451.188
#2	-30.336	32.487	831.059	902.990	902.990	814.150	3451.188
#2	-29.175	33.809	831.105	903.059	903.059	814.014	3451.238
Expected Payoff			831.078	903.053	903.053	814.020	3451.205
Round #6							
#5	-28.191	34.868	831.169	903.053	903.053	813.929	3451.204
#5	-28.255	34.934	831.078	903.145	903.145	813.838	3451.204
#5	-28.255	34.934	831.078	903.145	903.145	813.838	3451.204
#2	-30.159	32.762	831.021	903.053	903.053	814.078	3451.204
#5	-29.190	33.834	831.078	903.087	903.087	813.985	3451.238
Expected Payoff			831.092	903.092	903.092	813.940	3451.216
Round #7							
#5	-28.397	34.699	831.122	903.092	903.092	813.910	3451.215
#2	-30.076	33.036	830.910	903.183	903.183	813.940	3451.215
#2	-30.076	33.036	830.910	903.183	903.183	813.940	3451.215
#2	-30.005	32.978	831.001	903.092	903.092	814.031	3451.215
#2	-29.229	33.859	831.031	903.133	903.133	813.940	3451.238
Expected Payoff			831.013	903.133	903.133	813.945	3451.223
Round #8							
#5	-28.575	34.564	831.074	903.133	903.133	813.884	3451.223
#5	-28.616	34.610	831.013	903.194	903.194	813.823	3451.223
#5	-28.616	34.610	831.013	903.194	903.194	813.823	3451.223
#2	-29.882	33.166	830.976	903.133	903.133	813.982	3451.223
#5	-29.237	33.878	831.013	903.152	903.152	813.921	3451.238
Expected Payoff			831.023	903.157	903.157	813.891	3451.228
Round #9							
#5	-28.711	34.453	831.043	903.157	903.157	813.871	3451.228
#2	-29.829	33.345	830.901	903.218	903.218	813.891	3451.228
#2	-29.829	33.345	830.901	903.218	903.218	813.891	3451.228
#2	-29.780	33.309	830.963	903.157	903.157	813.951	3451.228
#2	-29.265	33.893	830.982	903.182	903.182	813.891	3451.238
Expected Payoff			830.970	903.184	903.184	813.894	3451.231
Round #10							
#5	-28.827	34.366	831.011	903.183	903.183	813.853	3451.231
#5	-28.853	34.398	830.970	903.224	903.224	813.812	3451.231
#5	-28.853	34.398	830.970	903.224	903.224	813.812	3451.231
#2	-29.702	33.430	830.945	903.183	903.183	813.919	3451.231
#5	-29.268	33.907	830.970	903.195	903.195	813.878	3451.238
Expected Payoff			830.977	903.199	903.199	813.858	3451.233

of this multilateral bargaining institution stressed earlier in section 2.4. As it happens, this game does eventually

Table 14: Multilateral Bargaining With a Strong GATT

Round #1							
#5	100.000	-75.000	1000.000	734.246	734.246	975.000	3443.493
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
#4	100.000	-100.000	975.000	717.157	717.157	1000.000	3409.315
#5	-100.000	100.000	734.246	1000.000	1000.000	717.157	3451.404
Expected Payoff			805.556	924.587	924.587	791.146	3445.876
Round #2							
#5	-43.246	50.340	809.659	924.587	924.587	792.343	3451.176
#5	-46.334	53.043	805.556	928.691	928.691	788.255	3451.193
#5	-46.334	53.043	805.556	928.691	928.691	788.255	3451.193
#4	-46.675	46.675	809.426	924.587	924.587	792.570	3451.171
#5	-47.869	51.267	805.556	928.638	928.638	788.465	3451.297
Expected Payoff			806.672	927.526	927.526	789.517	3451.240
Round #3							
#5	-45.904	51.770	806.716	927.526	927.526	789.472	3451.240
#2	-48.323	49.344	806.451	927.636	927.636	789.517	3451.240
#2	-48.323	49.344	806.451	927.636	927.636	789.517	3451.240
#2	-48.240	49.271	806.562	927.526	927.526	789.627	3451.240
#2	-47.103	50.546	806.607	927.586	927.586	789.517	3451.295
Expected Payoff			806.587	927.580	927.580	789.519	3451.268
Round #4							
#5	-46.282	51.431	806.653	927.580	927.580	789.454	3451.267
#5	-46.328	51.477	806.588	927.646	927.646	789.388	3451.267
#5	-46.328	51.477	806.588	927.646	927.646	789.388	3451.267
#2	-47.928	49.670	806.544	927.580	927.580	789.563	3451.267
#5	-47.114	50.562	806.588	927.605	927.605	789.497	3451.295
Expected Payoff			806.595	927.607	927.607	789.471	3451.281
Round #5							
#5	-46.540	51.187	806.617	927.607	927.607	789.450	3451.281
#2	-47.745	49.979	806.484	927.663	927.663	789.471	3451.281
#2	-47.745	49.979	806.484	927.663	927.663	789.471	3451.281
#2	-47.702	49.944	806.540	927.607	927.607	789.527	3451.281
#2	-47.136	50.576	806.562	927.631	927.631	789.471	3451.295
Expected Payoff			806.552	927.631	927.631	789.473	3451.288

converge to the determinate solution (0, 12.5) as displayed in Figure 5, but only after 1000 or more iterations! The greatest change in proposed policies occurs after just one round of bargaining, but thereafter the "progress" in negotiations is extremely slow.

Table 12 illustrates the gain in negotiation speed that can be achieved by having a minimal role for the GATT in multilateral bargaining. This is game MB1, resulting in a solution (-5, 12) after 70 rounds. As illustrated, however, a good approximation of this solution is attained after just 30 or so rounds. Note how the solution is substantively altered by having the GATT assume some role. Thus the GATT is not neutral in these negotiations proceedings: it speeds up the negotiations, but does have some effect on the outcome.

Table 13 shows how much we can speed negotiations up by giving the GATT a greater role. In this case, game MB2, we end up at a solution (-29, 34) after only ten rounds. Moreover, we are in the ball-park of this solution after only two or three rounds of negotiation!

Finally, Table 14 shows the effect of giving the GATT the same influence in negotiations as each of the US and EC. In this case, game MB3, the solution is (-47, 50) and is achieved after only five rounds. Indeed, we are virtually at that point by round 2.

These negotiated outcomes are illustrated in Figure 5, along with the outcomes described earlier (the retaliatory trade war outcome is marked NE and the axiomatic Nash Solution is marked NS). It is apparent that the multilateral bargaining outcomes are quite different from the axiomatic NS, irrespective of the role of Government. This could change, of course, if we had endowed the GATT with a utility function which mimicked the utility function which is being maximized when computing the NS. That is, we can expect the multilateral bargaining outcomes to be sensitive to the particular way in which the GATT trades off the welfare of the individual players. Thus further study of the effects of alternative specifications of this utility function would be worthwhile.

One intriguing feature of the multilateral bargaining outcomes is that incorporating the GATT appears to affect negotiated outcomes "monotonically". By this we refer to the slow movement away from MB0 as we consider MB1, MB2 and MB3. This result just indicates again the value of looking at specific cases of preferences.

APPENDIX A: Computing Solutions

The MB game is a dynamic non-linear programming problem that is solved using GAMS, documented in Brooke, Kendrick and Meeraus [1988]. The following GAMS code is relatively self-documenting and illustrates how we do this:

```
$TITLE MULTILATERAL BARGAINING GAME

$OFFUPPER
$OFFSYMXREF

SETS
  I  Agents           / gatt
                        agec
                        nonagec
                        agus
                        nonagus  /
  J  Policy Dimensions  / ecreform
                        usreform  /
  C  Coalitions        / C1*C5 /
  T  Periods           / T0*T0 / ;

ALIAS  (I,K), (I,II), (C,CC), (T,TT)  ;

* Define the ideal points (or bliss points) of each agent, around which
* their indifference curves over policies will be defined.

PARAMETER  A(I,J)  Ideal Points of Agents
  /    gatt    .ecreform            0
       gatt    .usreform            0
       agec    .ecreform            100
       agec    .usreform            -75
       nonagec.ecreform             -100
       nonagec.usreform             100
       agus    .ecreform            -100
       agus    .usreform            100
       nonagus.ecreform             100
       nonagus.usreform             -100   / ;

* Define the intercept of the utility functions of agents.

PARAMETER  INTERCEPT(I)  Intercept of Utility Functions
  /    gatt                 0
       agec                 1000
       nonagec              1000
       agus                 1000
       nonagus              1000   / ;

* Define the coefficient of the utility functions of agents.

PARAMETER  COEFF(I)  Coefficient of Utility Functions
  /    gatt                 0
       agec                 1
       nonagec              1
       agus                 1
       nonagus              1   / ;

* Define the access weights of each agent.

PARAMETER  ACCESS(I)  Access weights
  /    gatt                 .1
       agec                 .36
       nonagec              .14
       agus                 .305
       nonagus              .195   / ;

* Define the default policy values.
```

```
PARAMETER  DEFAULT(J)  Default policies
  /   ecreform                    0
      usreform                    0   / ;

* Define the default utility levels.

PARAMETER  UDINPUT(I)  Default utility levels as input
  /   gatt                        0
      agec                        0
      nonagec                     0
      agus                        0
      nonagus                     0   / ;

* Define the possible coalitions.

PARAMETER  COALITIONS(C,I)  Feasible Coalitions
/ (C1*C5) . gatt      1
(C1, C3, C4, C5) . agec     1
(C1, C2, C3, C5) . nonagec  1
(C1, C2, C4, C5) . agus     1
(C1, C2, C3, C4) . nonagus  1  / ;

* This file contains the essential problem logic for the MB problem. It will
* be included with a generating file which contains the specific parametric
* instance to be solved.

* The scalar SIGMA defines the substitutability of agents in the governments
* utility function.

* The scalar SELECTG will indicate if we are picking out the government (=1)
* or not (=0).

* The scalar SACCESS is used to hold the sum of the access weights.

SCALARS
    SIGMA    SUBSTITUTABILITY OF AGENTS IN GOVERNMENT UTILITY    /2.0/
    SELECTG  INDICATOR THAT WE ARE SELECTING THE GOVERNMENT AGENT /1.0/
    SACCESS  SUM OF THE ACCESS WEIGHTS                       /0.0/ ;

* Re-normalize the access probabilities to sum to one.

SACCESS = SUM(I, ACCESS(I))   ;
ACCESS(I) = ACCESS(I) / SACCESS;

* These arrays will facilitate the looping as well as the solution report.

PARAMETERS
   UNEXT(I)          RESERVATION UTILITY FOR AGENT IN NEXT PERIOD
   SELECTI(II)       WEIGHTS TO SELECT AGENTS
   SELECTC(CC)       WEIGHTS TO SELECT COALITIONS
   UREP(CC,TT,II,K)  OPTIMAL UTILITY LEVELS FOR EACH COALITION
   XREP(CC,TT,J,K)   OPTIMAL POLICY PROPOSALS FOR EACH COALITION
   UDREP(TT,K)       RESERVATION UTILITY OF AGENTS
   CHOOSE(TT,II)     UTILITY IN COALITION CHOSEN BY COLUMN AGENT
   BESTC(TT,I,II)    UTILITY OF ROW AGENT IN PROPOSAL BY COLUMN AGENT;

* Initialize UNEXT() at values for UDINPUT. To be re-initialized as time
* goes by...

UNEXT(I) = UDINPUT(I) ;

* Define the variables used to construct the problem.

VARIABLES
       GU        GOVERNMENT UTILITY
       GUDEF     DEFAULT GOVERNMENT UTILITY
       U(I)      UTILITY OF AGENT I
       UDEF(I)   DEFAULT UTILITY OF AGENT I
       X(J)      POLICY PROPOSALS
       OBJ       OBJECTIVE FUNCTION (UTILITY OF PROPOSER);

* Define each of the equations of the problem.

EQUATIONS
       GOVT        DEFINE UTILITY FUNCTION OF THE GOVERNMENT
       GOVTDEF     DEFINE DEFAULT UTILITY OF THE GOVERNMENT
       UTILITY(I)  DEFINE UTILITY FUNCTION OF AGENT I
```

```
        UDEFAULT(I)   DEFINE DEFAULT UTILITY OF AGENT I
        PROPOSE       DEFINE UTILITY OF PROPOSER AS OBJECTIVE
        UVOTERS(C,I)  ENSURE UTILITY OF VOTERS EXCEEDS DEFAULT
        VETO          ENSURE GOVERNMENT VETO POWER;

* Define the government's utility functions as a CES function of the
* utility of all agents. Define the government's default utility in a
* similar fashion. In this version we will simplify things by just assuming
* perfect substitutability between individual agent utilities. Similarly
* for the GOVTDEF definition below.

GOVT..

  GU    =E= SUM(K $ (ORD(K) NE 1), U(K));

GOVTDEF..

  GUDEF =E= SUM(K $ (ORD(K) NE 1), UDEF(K));

* This is the Euclidean distance metric being used to define the utility of
* each agent as we move away from his ideal point A(,). We also get the
* government utility "defined" here, since we use U() for deciding on the
* best proposals as well as the reservation utilities.

UTILITY(I) $ (ORD(I) NE 1)..

    U(I) =E= INTERCEPT(I) - COEFF(I) * SQRT( SUM(J,
                  ( (X(J) - A(I,J)) * (X(J) - A(I,J))  ) ) );

* Specify the default utility values directly via UDINPUT parameter values.
* These values will be re-set by the program SOLVE as time goes by.

UDEFAULT(I) $ (ORD(I) NE 1)..

  UDEF(I) =E= UNEXT(I) ;

* The next set of constraints ensure that each voter in active coalition C
* gets more utility than his default, but weight each by (a) whether or not
* the voter is in the coalition (COALITIONS()=1), and (b) whether
* or not this coalition is being considered just now (SELECT()=1).
* Note that the government is not included here.

UVOTERS(C,I) $ (ORD(I) NE 1)..

    U(I)    * SELECTC(C) * COALITIONS(C,I) =G=
    UDEF(I) * SELECTC(C) * COALITIONS(C,I);

* Let the government have veto power.

VETO..

    GU =G= GUDEF  ;

* This is the objective function, which will depend on the agent
* making the proposal (picked out by SELECT() as we loop over II, which is
* aliased with I, below).

PROPOSE..

    OBJ =E= (1.0 - SELECTG) * SUM(I $ (ORD(I) NE 1), SELECTI(I) * U(I) )
              + SELECTG  * GU;

* Define the model.

MODEL BARG / ALL /     ;

* Initialize the pointer arrays for agents and committees at zero.

SELECTI(I) = 0.0       ;
SELECTC(C) = 0.0       ;

* Solve the model, looping over all time periods TT, agents II and coalitions
* CC. This is a conservative solution approach which will ensure that we
* have found the best coalition.

LOOP (TT,

      LOOP (II $ (ACCESS(II) GT 0.0),
```

```
          SELECTI(II) $ (ORD(II) NE 1) = 1.0;
          SELECTG     $ (ORD(II) EQ 1) = 1.0;
          SELECTG     $ (ORD(II) NE 1) = 0.0;

          LOOP (CC $ (COALITIONS(CC,II) EQ 1),
               SELECTC(CC) = 1.0;
               X.L(J)  $ (ORD(II) GT 1) = A(II,J)       ;

               SOLVE BARG USING NLP MAXIMIZING OBJ;

* If the model solves then save the solution...

               U.L(I)  $ (ORD(I) EQ 1) = GU.L;

               UREP(CC,TT,I,II)  $ ((BARG.MODELSTAT EQ 2) OR
                              (BARG.MODELSTAT EQ 7))
                              = U.L(I);
               XREP(CC,TT,J,II)  $ ((BARG.MODELSTAT EQ 2) OR
                              (BARG.MODELSTAT EQ 7))
                              = X.L(J);

* ... but if it does not solve then set the values to the expected
* utility of going into the next period (i.e., passing). This will happen
* as we approach a solution of the overall multiperiod game, so it is
* important not to "abort" at this stage. The following "abort" code is
* remarked out but is useful for debugging purposes. Note that not being
* able to find a solution means that the agent and coalition being considered
* in this loop cannot find a proposal that would be voted in.
*
*              ABORT $ ((BARG.MODELSTAT NE 2) AND
*                   (BARG.MODELSTAT NE 7))
*                   "**** THE MODEL DID NOT SOLVE";

               UREP(CC,TT,I,II)  $ ((BARG.MODELSTAT NE 2) AND
                              (BARG.MODELSTAT NE 7))
                              = UNEXT(I);
               XREP(CC,TT,J,II)  $ ((BARG.MODELSTAT NE 2) AND
                              (BARG.MODELSTAT NE 7))
                              = 0.0;

               SELECTC(CC) = 0.0              );

* Now find the best coalition for this proposer. This works fine except
* for agents which have a best proposal that earns them negative payoff.
* SOLVE over-rides this by figuring the best coalition directly from
* the UREP values displayed below.

          CHOOSE(TT,II)  = SMAX((K,CC), SELECTI(II) * UREP(CC,TT,II,K)
                              + SELECTG    * UREP(CC,TT,II,K));

* This next line is not correct ... it picks out the best values for each
* agent, rather than picking out the best coalition from the perspective
* of the proposing agent. Again, SOLVE over-rides this.

          BESTC(TT,I,II) = SMAX((K,CC), UREP(CC,TT,I,II) $
                              (CHOOSE(TT,II) GT 0.0) );
          SELECTI(II) = 0.0       );

     UNEXT(I) = SUM(K, (ACCESS(K) * BESTC(TT,I,K)) );
     UDREP(TT,I) = UNEXT(I); );

* The program SOLVE will read the values for UREP and XREP, and decide
* which are the best proposals for each agent in this period. It will then
* re-initialize UDINPUT if need be and run through another period.

DISPLAY COALITIONS, ACCESS, BESTC, CHOOSE, UDREP, UREP, XREP;
```

The program SOLVE, referred to in this GAMS code, essentially controls the sequence of such GAMS problems that must be solved. First it solves the series of problems for each agent and each coalition for the terminal bargaining round. Then, using the expected payoffs for each agent from the last round, it can set up the problems for the next-to-last round (since we know the "reservation payoff" that each agent must receive in order to accept a proposal rather than force play into the terminal round). It does this until we have solved the game for the fixed number of periods (five in the example discussed in the text) or until we have met some convergence tolerance defined in terms of expected payoffs and messages. Details on the program SOLVE may be obtained from Glenn Harrison.

The foregoing procedures are effective in generating a solution, as well as documenting our computational procedures. However, they have one computational disadvantage for certain purposes, and that is that they require DOS-level interaction between the program SOLVE and GAMS. It would clearly be much faster to solve the problem entirely in one job. In fact we could do this with certain new features available in recent 80386 releases of GAMS, but these are not features that are available to the general public.

The SOLVE program reads in a description of the MB problem contained in a "configuration file". The format of these files is described in Harrison, McCabe, Rausser and Simon [1992]. For demonstration purposes we list below the configuration files employed for the simulations reported in Section 4.2 of the text:

```
==> AGWAR0.CNF ... configuration file for AGWAR negotiation

[nagents]       ' Number of agents, including Government
 5              '

[agents]        ' Names of agents (up to 60 characters).
gatt
agec
nonagec
agus
nonagus

[npolicies]     ' Number of policy dimensions
 2

[policies]      ' Names of policy dimension (up to 60 characters)
ecreform
usreform

[nplayers]      ' Number of experimental subjects (live + simulated)
5

[players]       ' Player ID's, with an asterisk for simulated players
1
2
3
4
5

[ngroups]       ' Number of experimental groups (or clones)
1

[simulated]     ' Agent or player ID and an asterisk if simulated
gatt    *
agec    *
nonagec *
agus    *
nonagus *
```

```
[voting power]        ' Agent or player ID and number of votes
gatt    0
agec     0.5
nonagec  0.5
agus     0.5
nonagus  0.5

[access]              ' Agent or player ID and access probability
gatt    0
agec     0.36
nonagec  0.14
agus     0.305
nonagus  0.195

[matched proposals]   ' Have proposals from the same agents over replications
no

[u-default]           ' Agent or player ID and default utility level
gatt    0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-default] values

[u-squo]              ' Agent or player ID and status quo utility levels
gatt    0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-squo] values

[u-ideal points]      ' Ideal points of Euclidean Utility function
gatt      0    0
agec     100  -75
nonagec  -100  100
agus     -100  100
nonagus   100 -100

[u-intercept]         ' Intercepts of Euclidean Utility function
gatt    0
agec     1000
nonagec  1000
agus     1000
nonagus  1000

[u-coefficient]       ' Coefficients of Euclidean Utility function
gatt    0
agec     1
nonagec  1
agus     1
nonagus  1

[nperiods]            ' Number of periods per game (T)
9

[nrepetitions]        ' Maximal number of times we play the whole game
1

[time]                ' Maximal number of seconds per period
120

[shuffle]             ' Shuffle players from game to game ("yes" or "no")
yes

[path]                ' Path for all messages (this is system-specific)


[solver]              ' Call to GAMS solver
gams

[government]          ' Indicate whether or not there is a Government
no
```

```
==> AGWAR1.CNF ... configuration file for AGWAR game with minimal GATT

[nagents]          ' Number of agents, including Government
 5

[agents]           ' Names of agents (up to 60 characters).
gatt
agec
nonagec
agus
nonagus

[npolicies]        ' Number of policy dimensions
 2

[policies]         ' Names of policy dimension (up to 60 characters)
ecreform
usreform

[nplayers]         ' Number of experimental subjects (live + simulated)
5

[players]          ' Player ID's, with an asterisk for simulated players
1
2
3
4
5

[ngroups]          ' Number of experimental groups (or clones)
1

[simulated]        ' Agent or player ID and an asterisk if simulated
gatt     *
agec     *
nonagec  *
agus     *
nonagus  *

[voting power]     ' Agent or player ID and number of votes
gatt     0.1
agec     0.5
nonagec  0.5
agus     0.5
nonagus  0.5

[access]           ' Agent or player ID and access probability
gatt     0.1
agec     0.36
nonagec  0.14
agus     0.305
nonagus  0.195

[matched proposals]  ' Have proposals from the same agents over replications
no

[u-default]        ' Agent or player ID and default utility level
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-default] values

[u-squo]           ' Agent or player ID and status quo utility levels
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-squo] values

[u-ideal points]   ' Ideal points of Euclidean Utility function
gatt      0    0
agec      100  -75
nonagec   -100  100
```

```
agus    -100  100
nonagus   100  -100

[u-intercept]        ' Intercepts of Euclidean Utility function
gatt     0
agec     1000
nonagec  1000
agus     1000
nonagus  1000

[u-coefficient]      ' Coefficients of Euclidean Utility function
gatt     0
agec     1
nonagec  1
agus     1
nonagus  1

[nperiods]           ' Number of periods per game (T)
9

[nrepetitions]       ' Maximal number of times we play the whole game
1

[time]               ' Maximal number of seconds per period
120

[shuffle]            ' Shuffle players from game to game ("yes" or "no")
yes

[path]               ' Path for all messages (this is system-specific)


[solver]             ' Call to GAMS solver
gams

[government]         ' Indicate whether or not there is a Government
yes
```

==> AGWAR2.CNF ... configuration file for AGWAR game with moderate GATT

```
[nagents]            ' Number of agents, including Government
 5

[agents]             ' Names of agents (up to 60 characters).
gatt
agec
nonagec
agus
nonagus

[npolicies]          ' Number of policy dimensions
 2

[policies]           ' Names of policy dimension (up to 60 characters)
ecreform
usreform

[nplayers]           ' Number of experimental subjects (live + simulated)
5

[players]            ' Player ID's, with an asterisk for simulated players
1
2
3
4
5

[ngroups]            ' Number of experimental groups (or clones)
1

[simulated]          ' Agent or player ID and an asterisk if simulated
gatt     *
agec     *
nonagec  *
agus     *
nonagus  *
```

```
[voting power]        ' Agent or player ID and number of votes
gatt     0.5
agec     0.5
nonagec  0.5
agus     0.5
nonagus  0.5

[access]              ' Agent or player ID and access probability
gatt     0.5
agec     0.36
nonagec  0.14
agus     0.305
nonagus  0.195

[matched proposals]   ' Have proposals from the same agents over replications
no

[u-default]           ' Agent or player ID and default utility level
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-default] values

[u-squo]              ' Agent or player ID and status quo utility levels
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-squo] values

[u-ideal points]      ' Ideal points of Euclidean Utility function
gatt      0    0
agec      100  -75
nonagec  -100  100
agus     -100  100
nonagus   100  -100

[u-intercept]         ' Intercepts of Euclidean Utility function
gatt     0
agec     1000
nonagec  1000
agus     1000
nonagus  1000

[u-coefficient]       ' Coefficients of Euclidean Utility function
gatt     0
agec     1
nonagec  1
agus     1
nonagus  1

[nperiods]            ' Number of periods per game (T)
9

[nrepetitions]        ' Maximal number of times we play the whole game
1

[time]                ' Maximal number of seconds per period
120

[shuffle]             ' Shuffle players from game to game ("yes" or "no")
yes

[path]                ' Path for all messages (this is system-specific)


[solver]              ' Call to GAMS solver
gams

[government]          ' Indicate whether or not there is a Government
yes
```

```
==> AGWAR3.CNF ... configuration file for AGWAR game with strong GATT

[nagents]          ' Number of agents, including Government
 5

[agents]           ' Names of agents (up to 60 characters).
gatt
agec
nonagec
agus
nonagus

[npolicies]        ' Number of policy dimensions
 2

[policies]         ' Names of policy dimension (up to 60 characters)
ecreform
usreform

[nplayers]         ' Number of experimental subjects (live + simulated)
5

[players]          ' Player ID's, with an asterisk for simulated players
1
2
3
4
5

[ngroups]          ' Number of experimental groups (or clones)
1

[simulated]        ' Agent or player ID and an asterisk if simulated
gatt     *
agec     *
nonagec  *
agus     *
nonagus  *

[voting power]     ' Agent or player ID and number of votes
gatt     1.0
agec     0.5
nonagec  0.5
agus     0.5
nonagus  0.5

[access]           ' Agent or player ID and access probability
gatt     1.0
agec     0.36
nonagec  0.14
agus     0.305
nonagus  0.195

[matched proposals]  ' Have proposals from the same agents over replications
no

[u-default]        ' Agent or player ID and default utility level
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-default] values

[u-squo]           ' Agent or player ID and status quo utility levels
gatt     0
agec     0
nonagec  0
agus     0
nonagus  0

* NOTE: alternatively, user can enter the [p-squo] values

[u-ideal points]   ' Ideal points of Euclidean Utility function
gatt      0    0
agec      100  -75
nonagec   -100  100
```

```
agus     -100  100
nonagus   100  -100

[u-intercept]       ' Intercepts of Euclidean Utility function
gatt     0
agec     1000
nonagec  1000
agus     1000
nonagus  1000

[u-coefficient]     ' Coefficients of Euclidean Utility function
gatt     0
agec     1
nonagec  1
agus     1
nonagus  1

[nperiods]          ' Number of periods per game (T)
29

[nrepetitions]      ' Maximal number of times we play the whole game
1

[time]              ' Maximal number of seconds per period
120

[shuffle]           ' Shuffle players from game to game ("yes" or "no")
yes

[path]              ' Path for all messages (this is system-specific)


[solver]            ' Call to GAMS solver
gams

[government]        ' Indicate whether or not there is a Government
yes
```

APPENDIX B: The Cooperative Nash Bargaining Solution

Nash [1951] proposed a "solution" to a class of cooperative bargaining problems. The solution is obtained as the unique outcome that satisfies a series of plausible axioms involving, among other things, economic efficiency. Agents are assumed to be able to communicate and write down some binding agreement to implement this solution, which is widely referred to as the Nash Solution (NS).[37] In the absence of an agreement each agent faces a specified disagreement outcome. The particular disagreement outcome that is selected can have dramatic consequences for the negotiated agreement, which is intuitive enough. This turns out not to be the case in our study, however.

Computationally, the NS is straightforward to calculate. One simply evaluates the product of the utility gains of each agent, where a "gain" is measured by the difference between the utility that the agent receives at the tentative agreement point and the fixed disagreement outcome. The strategy combinations that generate a maximum for this "Nash Product" constitute the agreement point.

More formally, Nash [1950] characterized a cooperative negotiation situation in terms of a bargaining environment and a bargaining process. The environment is a pair (S,d) defined over a set of outcomes $x = \{x_1, x_2\}$, where x_i denotes the outcome to agent i, S is the set of feasible outcomes, and d is the disagreement outcome. We require that S be compact and convex, and that there exists at least one point $x \in S$ s.t. $x \succ d$ (i.e., $x_1 \succ d$ and $x_2 \succ d$). The first two requirements on S are satisfied by allowing mixed strategy combinations of all pure strategies in S, for x finite. The third requirement on S is readily verified by inspection of S. It is assumed that the pair (S,d) is common knowledge.

We will interpret S as consisting of the set of outcomes attainable by mixtures of the pure strategy combinations evaluated in each payoff matrix we generate.

Two possible disagreement outcomes d can be considered. One is the Status Quo, and corresponds to zero

[37] Readers that are not familiar with game theory should take some care to distinguish the notions of Nash *Equilibrium* and the Nash *Solution*. The fact that they were developed by the same John Nash leads many readers to confuse them. To add to the risk of confusion, Nash [1953] demonstrates that the NE and the NS coincide for certain classes of non-cooperative games. Many game theorists sniff at the direct use of axiomatic solution concepts such as the NS unless they can be shown to emerge as NE of interesting classes of non-cooperative bargaining models.

welfare improvements for each country. An alternative disagreement point is the non-cooperative NE for the (non-cooperative) game generated by the same sets of pure strategies. This has the natural interpretation of a "threat point", in the spirit (if not the letter) of Nash [1953]. Harrison and Rutström [1991a] demonstrate in the context of several trade war simulations that the choice of either of these interpretations of the disagreement point can have a major quantitative impact on the outcome of the bargaining process.

The bargaining process is modelled as a function f(S,d) that selects a solution $z = f(S,d)$ for $z \in S$. This solution must possess four properties:

(1) Pareto Optimality: if $f(S,d) = z$ then there does not exist an $x \in S$, $x \neq z$, s.t. $x \succ z$.

(2) Symmetry: if $x_1 = x_2$, for all x, and $d_1 = d_2$ then $z_1 = z_2$.

(3) Independence of Irrelevant Alternatives: if $T \subset S$ and if $f(S,d) \in T$, then $f(T,d) = f(S,d)$.

(4) Independence of Equivalent Utility Representations: if ' denotes a given positive affine transformation, and if $z = f(S,d)$ and $y = f(S',d')$, then $y = z'$.

Nash [1950] established the remarkable result that there exists a (unique) solution that possesses these four properties and that it can be computed as the set of feasible outcomes that maximize the product of the gains relative to d. Formally, z is the solution to

$$\max_{x_1,\, x_2} \quad (x_1 - d_1)\,(x_2 - d_2).$$

This solution generalizes naturally to n-person negotiation situations, providing one does not permit coalitions or sidepayments.

Note that no particular "extensive form" bargaining process is modelled by the NS. However, there is an implicit requirement buried in the definition of the bargaining environment that if S does not contain any feasible outcome that (strictly) Pareto-dominates d then each player has a final "veto power" over any proposed agreement. Viewing this as a final sub-game in the overall negotiation game, one is naturally led to adopt the non-cooperative NE as the only credible outcome of this "disagreement sub-game".

We make one simplification when actually computing the NS. Rather than evaluate the set of mixed strategies to determine the unique NS, we evaluate only the set of pure strategies. This discrete approximation to the true NS should be satisfactory for our purposes.

REFERENCES

Brooke, Anthony; Kendrick, David, and Meeraus, Alexander, **GAMS: A User's Guide** (Redwood City, CA: Scientific Press, 1988).

Cummings, Ronald G., and Harrison, Glenn W., "Valuing Environmental Goods: Can the Contingent Valuation Method Elicit Real Economic Commitments?", **Natural Resources Journal**, 1992 forthcoming.

Harrison, Glenn W.; Jones, Richard; Kimbell, Larry J., and Wigle, Randall, "How Robust is Applied General Equilibrium Analysis?", **Journal of Policy Modelling**, v. 13, 1992, forthcoming.

Harrison, Glenn W.; McCabe, Kevin A.; Rausser, Gordon C., and Simon Leo, "Multilateral Bargaining in Spatial Environments", **Unpublished Draft Manuscript**, Department of Economics, College of Business Administration, University of South Carolina, 1992.

Harrison, Glenn W.; Rutherford, Thomas F.; and Wooton, Ian, "The Economic Impact of the European Community", **American Economic Review (Papers & Proceedings)**, v. 79, May 1989, pp. 288-294.

Harrison, Glenn W.; Rutherford, Thomas F., and Wooton, Ian, "Liberalizing Agriculture in the European Community", **Economics Working Paper B-90-03**, Division of Research, College of Business Administration, University of South Carolina, October 1990.

Harrison, Glenn W.; Rutherford, Thomas F.; and Wooton, Ian, "An Empirical Database for a General Equilibrium Model of the European Communities", in J. Piggott and J. Whalley (eds.), **Applied General Equilibrium** (Heidelberg: Physica Verlag, 1991).

Harrison, Glenn W., and Rutström, E.E., "Trade Wars, Trade Negotiations, and Applied Game Theory", **The Economic Journal**, v. 101, May 1991a, pp. 420-435.

Harrison, Glenn W., and Rutström, E.E., "Who Are The Friends and Enemies of The Common Agricultural Policy?", **Unpublished Manuscript**, Department of Economics, College of Business Administration, University of South Carolina, 1991b.

Harrison, Glenn W., and Rutström, E.E., "Trade Wars and Trade Negotiations in Agriculture", **Unpublished Manuscript**, Department of Economics, College of Business Administration, University of South Carolina, 1991c.

Harrison, Glenn W.; Rutström, E.E.; and Wigle, Randall, "The Costs of Agricultural Trade Wars", in A. Stoeckel, D. Vincent and S. Cuthbertson (eds.), **Macroeconomic Consequences of Farm Support Policies** (Durham: Duke University Press, 1989).

Harrison, Glenn W., and Vinod, H.D., "The Sensitivity Analysis of Applied General Equilibrium Models: Completely Randomized Factorial Sampling Designs", **The Review of Economics and Statistics**, v.73, 1992, forthcoming.

Myerson, Roger, "Refinements of the Nash Equilibrium Concept", **International Journal of Game Theory**, v.7, 1978, pp.73-80.

Nash, John F., "The Bargaining Problem", **Econometrica**, v.18, 1950, pp.155-162.