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Dynamic Economic Game Theory and Asian Free Trade Agreements

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Abstract

The purpose of this paper is to use fairly standard game theory elements and apply them to free trade agreements (FTA) made within ASEAN countries and between ASEAN countries and outside countries and the rest of the world (ROW). The applications use some mathematics, but it is not my intent to burden unnecessarily the reader with the mathematics. My intent is to make the applications appeal to the practitioners who are directly or at least indirectly engaged in the process of making FTA's and who are interested in a theoretical basis for FTA's. The intent then could be described as being largely pedagogical. The main contribution of the paper is to show the structure and behavior of the backward solution method used in dynamic game theory.

An earlier version of this paper was presented at the 18th conference of the American Committee of Asian Economic Studies (Gander, *et al.*, 2008).

Introduction:

The present paper will address primarily micro economic topics related to n-person game theory and bargaining among the members of an ASEAN FTA or between ASEAN and other countries. Both static and dynamic game theory will be considered. The bargaining issues will be treated generally in an abstract way with the intent of showing the problems associated with the complexity of an n-player bargaining game of the Nash type. The approach is similar to a Cournot game where, for example, the ASEAN players allocate the net excess demand for a product by the ROW or by the set of extended countries, net of their (ASEAN) own domestic demand. Practical bargaining considerations will guide the theoretical discussion. In particular, the formation and effect of coalitions on the bargaining outcome will be discussed. Some of the results of this game treatment will be critical of the likelihood of the success of negotiations within a full ASEAN FTA over a many-commodity field (or range) of choices.

First, some general remarks will be made to set the context of the paper. The symbol (FTA) is used in two contexts, one a geographic context and the other a reference to a free trade agreement. The goal of the geographic context, or ASEAN for short, is to further economic growth within ASEAN by the liberalization of trade within ASEAN. A free trade agreement is usually bilateral between two ASEAN members or between one member and an outside country. Free trade agreements may also be multilateral, involving several countries within and between members and non-members. The ASEAN countries are Thailand, Singapore, Malaysia, Indonesia, the Philippines, Vietnam, Brunei, Laos, Cambodia, and Burma or Myanmar. In the applications, I limit the examples to only a few countries for ease of presentation.

Of particular note is the content of a FTA when using a dynamic game model. In theory, it is assumed that an FTA can be quantified in a scalar fashion, so there is a sense of the agreement increasing quantitatively along a linear scale. This assumption is not unrealistic. In modern operations research (OR), humans are being digitized in terms of skills, knowledge, background training, personality traits and many other traits. Then, using the equivalent to linear (or non-linear) programming, the optimum collection of personnel is selected that minimizes cost and other objectives for a given project (see, Baker, 2008).

The actual existing FTA's (agreements) today within ASEAN itself and between ASEAN and the other countries usually entail a maze of details (See, Baldwin, 2006 and Wawai and Wignaraja, 2007). For purposes of simplicity and manageability, some game applications will use only two or three ASEAN members. Regardless of the size of the ASEAN used, I treat it as an integrated economy consisting of member countries as players in a within-ASEAN bargaining game. A bargaining game between ASEAN and the ROW will be treated in an extended footnote. Basically, it is assumed that within ASEAN, free trade exists, although this is a goal and not a full realization, yet.

In the context of the present paper, what is important is the size (number of members) of ASEAN and the number of additional countries that may be brought into any FTA (agreement). As indicated earlier, in practice as size or the number of players (given by n) increases, the likelihood of a successful FTA decreases. However, related to size, is the degree of economic diversity (given by d) in production and consumption that can characterize an agreement. As more and more countries are added to the FTA (agreement), thus effectively increasing the geographical FTA (area), more economic

diversity is possible. From more economic diversity (and other diversities), more economic benefits will be forthcoming.[1] It can be argued that while size itself is adverse to the likelihood of agreement success, if economic diversity occurs, then the likelihood of a successful FTA will increase. While economic diversity is an important consideration in analyzing FTA's, a more detailed discussion, however, is beyond the limited scope of this paper.

The main point is that in terms of practical considerations, as the size or number of members to the overall FTA increases, the likelihood of a successful agreement in general and in particular for such significant products as oil, rice, rubber, motor vehicles, electronic products, and transportation equipment, gets smaller. The practitioner is well aware of the problems encountered in bargaining as the number of countries (players) increases. Here, I simply give a theoretical basis for the awareness.

With these general remarks, the paper will proceed as follows. First, some mechanics of number formation and coalitions will be reviewed. Then, a 3-country static bargaining game will be presented. Then, a dynamic bargaining game between two countries will be presented. Then, some concluding remarks will be made.

The Mechanics of Number Formation and Coalitions:

ASEAN can function as a single entity and as such make bilateral or multilateral free trade agreements (FTA's) or other types of agreements with other countries not part of ASEAN. Also, individual ASEAN members can form FTA's with members and non-member countries. The many forms or configurations of FTA's are well documented in Kawai and Wignaraja (2007). As a result of the many forms FTA's can and have taken, they argue for the need of a single East Asia FTA consolidation to eliminate the "Noodle

Bowl" effect of the proliferation of FTA's. In light of the proliferation problem, our presentation in this section and elsewhere will have to be simple and limited.

In the case of ASEAN as a single entity, the number of players can be ten or less depending on what kind of free trade agreement (or other types of agreements) is being considered. As the number of players in ASEAN increases, the number of pair-wise coalitions increases very rapidly. For example, if n=3 players, there are 3 possible pair-wise coalitions. If n=6, then there are 15 possible pair-wise coalitions, or in general, #C=n(n-1)/2. But, for n=>4, #C(pairs) = 6 and #C(triplets)=3, or in general, #C(r)= C^n_r = n!/r![n-r]!, where r is the size of the coalition. Thus, as n increases the complexity of the bargaining process within ASEAN itself increases very rapidly, reducing for practical considerations the likelihood of an equilibrium solution and particularly one that is stable. The bargaining process becomes even more complex when many commodities are involved in trade among the ASEAN members, when rules of origin (ROO) are part of the agreement, and also when foreign direct investment and technology transfer are involved. It is no wonder that when FTA's are held to one or a few commodities and one or a few country members, proliferation results.

Oligopoly-Type Static Bargaining Games:

To keep the game presentation manageable, I will consider an n=3-member ASEAN acting as a single entity vis-à-vis the net excess demand of the ROW (or some single non-member country) for a single product, net of any within-ASEAN consumption of the product. In other words, each of the three ASEAN countries is a player in a bargaining process aimed at allocating the net ROW excess demand fairly in the Nash sense. The form of the FTA among the three ASEAN members could be something like

this. Each agrees to free trade within the group. Each agrees that they will act jointly as a single entity vis-à-vis the ROW. The agreement could involve preferential treatment for the product they export to the ROW. As such, rules of origin (ROO) on both sides may be involved. I only focus on the exports to the ROW and not on any reciprocal trade issues (imports from the ROW). This focus is to limit the scope of the game. In a more macro setting, the three ASEAN members can be one country and the ROW can be another country.[2]

The equilibrium in static bargaining theory is described as being one that maximizes the product of the three utility (profit or trade gains) functions, subject to the constraint set consisting of all possible equal pair-wise marginal rates of substitution between any two members and their corresponding outputs (q1,q2,q3) and the sum of the three outputs. In symbolic form, generalizing on Nash (1950)'s bargaining product formula, let

(1) $\text{Max } W = U1(q1,q2,q3)*U2(q1,q2,q3)*U3(q1,q2,q3)$

(2) $\text{Subject to (S.T.)} \quad q1 + q2 + q3 = Q$

(3) $\text{S.T.} \quad MRS^{1}_{1,2} = MRS^{2}_{1,2}$

(4) $\qquad MRS^{2}_{2,3} = MRS^{3}_{2,3}$

(5) $\qquad MRS^{1}_{1,3} = MRS^{3}_{1,3}$,

where Q is the total export of the product to the ROW. In words, the MRS's say that players 1 and 2, for example, have no incentive to change the allocation between them, given 3's output, players 1 and 3 have no incentive to do likewise, and players 2 and 3 have no incentive to do likewise. The resulting allocation gives a maximum to W, the bargaining pay-off.

In Jacobian determinant form, the MRS conditions are implicitly given by

$$(6) \qquad \begin{vmatrix} U_{11} & U_{12} & U_{13} \\ U_{21} & U_{22} & U_{23} \\ U_{31} & U_{32} & U_{33} \end{vmatrix} = 0,$$

where a typical sub-minor (for example) is given by

$$(7) \qquad \begin{vmatrix} U_{11} & U_{12} \\ U_{21} & U_{22} \end{vmatrix} = 0,$$

which upon rearrangement results in the Pareto Optimum condition $(U_{11}U_{22} - U_{12}U_{21}) = 0$ or $U_{11}/U_{12} = MRS^{1}_{1,2} = U_{21}/U_{22} = MRS^{2}_{1,2}$. Further, it can be shown that the Jacobian is the basis of the sum triplet of outputs in (2).

As n increases, the Jacobian becomes more and more complex. While in theory, the nature of an n-person game solution can be described in algebra (see, Friedman, 1986), in practice the solution may be quite difficult to achieve. Thus, the likelihood of achieving a Pareto Optimum condition decreases as n increases.

Another aspect of the within ASEAN bargaining game given by (1) to (5) is the concept of sub-games and sub-game perfect. I use this concept in a slightly different way than it is commonly used in non-cooperative games. Since there are three possible pair-wise coalitions for n=3, there are three sub-games, (1, 2), (2, 3), and (1, 3). In terms of the Jacobian approach given before, each of the three sub-games refers to a sub-minor Jacobian equal to zero along with the overall Jacobian equal to zero. The sub-games Pareto Optimum conditions are given by the respective MRS equalities in (3) to (5).

When individual ASEAN members make FTA's with other non-member countries, but still within the overall context of ASEAN itself, then the sub-games must be in equilibrium along with the overall game equilibrium, so the bargaining game is sub-game perfect. In other words, there is no incentive for any subset of players to change its structure, so the overall structure remains in equilibrium. Considering the potential number of individual ASEAN members (ten) and the many possible coalitions within ASEAN itself and the opportunities for bilateral and multilateral FTA's between ASEAN (or any subset of members) and other countries (particularly, with China, Japan, Korea, Australia, and New Zealand) and the broad range of commodities traded, the structure of the overall agreement set is perhaps beyond comprehension. It is no wonder that Kawai and Wignaraja (2007) argue for some consolidation of agreements.

On the other hand, Baldwin (2006) appears to accept the complexity and argues for better management of the trade agreements. The "Noodle Bowl" is still present, but it is not as "wormy."

As a result of the above complexity, for practical considerations, given that free trade is achieved within ASEAN itself, a single entity agreement between ASEAN as a whole and various non-members seems to be the best strategy. To expect otherwise that all the individual sub-games will be in equilibrium along with the overall set of agreements for ASEAN as a whole might be unreasonable.

The n-person game becomes greatly more complex when additional constraints are placed on the feasibility set of possible bargaining outcomes, due to the nature of the FTA's undertaken. These constraints may originate from country-specific economic, cultural, and political forces which define the feasibility set and thus determine the scope

of a bargaining agreement. For example, using n=2 to simplify the presentation and still assuming a net excess demand from the ROW facing the two countries of ASEAN engaged in an agreement over how the output supply will be shared, each member country may for political (or policy) considerations set a minimum to the output share it wants as a status-quo (say, for local employment considerations). Other possible constraints limiting the size of the feasibility set could involve FDI and technological transfer considerations with the ROW and defined in terms of a minimum output share. The MRS or Pareto Optimum condition determines the initial feasibility set as we showed before with the Jacobian treatment. The status-quo is initially without the policy constraints the output origin (0, 0).

Using a Cournot-type two-country game model, in Figure 1, R1 and R2 are the non-cooperative reaction functions. The Pareto Optimum (PO) set is given by the line PP'. The Nash product formula, $W(q1, q2)= \Pi1(q1, q2)*\Pi2(q1, q2)$, is usually maximized subject to the initial feasibility set, PP'. The added constraints defined in terms of the outputs are labeled q1^ and q2^. The new feasibility set is now given by the shaded area, whose extreme boundary is SS', a subset of PP'. As drawn in the figure, the product formula equilibrium is in the set SS', so the constraints are not binding. But, this need not necessarily be the case. Depending on the shape of the product formula function W(.), the equilibrium could be binding at point S or at point S' or both outputs could be binding if SS' is a minimum point in the set PP'.

As the number of players in ASEAN increases and the initial feasibility set expands as we showed earlier, then increasing the number of players with each one adding an additional constraint, the FTA agreement becomes very complicated. Finding

an equilibrium point (in other words, an agreement) that satisfies the Nash formula and Pareto Optimum condition will be very difficult in practice. In any case, given such difficulty, Baldwin's (2006) argument for a need for better management of the FTA's process is well taken. The point to note from the figure is that as n increases and the number of constraints increases, the size of the feasible bargaining set of possible solutions gets smaller, limiting the potential outcomes to an area that may not be compatible with maximizing W(.) subject to the PO condition.

Dynamic Bargaining Game:

Up until now, the game theory discussion has been in terms of a static game. To correspond more closely to real world bargaining, a dynamic game approach should be used. Such an approach, however, is very complicated and I will only just briefly outline its structure here.

The outputs in the utility functions in (1) are modified to include explicitly all three of the free trade agreement parameters Ai (i = 1,2,3) in each output, qi. But, since the Ai's will change over the course of the dynamic bargaining process, the equilibrium outputs in (1) will also change over time. There is a two-stage relationship at each instant of time, t, between the equilibrium qi* and all Ai's, where each qi* depends on all the Ai's, the bargaining outcome at each instant of time, t. So, at each instant of time, t, the sub-equilibrium bargaining outcomes, Ai*, are determined in the first stage, and then the corresponding sub-equilibrium outputs, qi* are determined in the second stage to optimize (1). I will focus only on the first stage and implicitly take for granted the outcomes of the second stage to simplify the discussion.

The essence of a dynamic game (in reference to the first stage) is contained in the backward solution method. With this method, the content of the end (target) bargaining agreement must be known and specified first. I use two countries making an FTA as an example. The end (time-wise) result agreement, say, is given by $A1^*(\ldots)_T$ and $A2^*(\ldots)_T$, where A1 agrees or proposes ultimately to do certain actions given by (…) and A2 does likewise at the end of the terminal date, T, of the bargaining session. As discussed earlier, (…) stands for the digitization of the agreement. The backward solution method finds a "path" backwards in terms of the contents of A1 and A2 that minimizes the cost of bargaining in terms of the time spent achieving the contents. The idea is that each player needs to find the best subset of actions or proposals to put forward that ultimately leads to the final set of actions or proposals given by $A1^*(\ldots)_T$ and $A2^*(\ldots)_T$. All along the way, of course, the second-stage outcomes are also being determined as discussed before. The only way to solve this first-stage problem is to begin backwards.

In other words, to use an analogy from auto traveling, say, you want to drive from San Francisco to New York by the best route possible in terms of time. You begin with the target, New York, first. Select a small radius of distance from New York and select the route that minimizes the travel time from the radius to New York. Then, from that radius, you select another radius further towards San Francisco, and choose the best route from that second radius to the selected target on the first radius. You continue to work backwards by repeating this process of selecting a radius and then the route that minimizes travel time. Finally, at the T-r radius, you select the best route from San Francisco to that radius. The resultant path found backwards then is the equilibrium path you actually take from San Francisco.

In terms of the structure of the final FTA, you want to select a subset of actions and/or proposals previous to the final FTA that in a backward sequence minimize the bargaining cost (say, in terms of time). In other words, one does not put all his/her cards on the table at once. The trick is to decide which cards to play at which time. You find which subset of actions is best to as it were put on the table and then work up from there. But, to find which is best, you need to begin backwards.

In Figure 2, the essence of a two-player dynamic game is presented. The note to the figure summarizes the backward solution method. Suffice it to say here, that once the optimal path (in effect, a vector of digitized elements that changes along the path) is found, then the players can proceed forward. How realistic this summary is remains to be argued. In any case, it can be argued that players proceed forward in a bargaining session as if they have some notion of what is the optimal content of the agreement to place on the table at any point in time.

Summary and Conclusions:

As the number of players within ASEAN increases, the number of potential coalitions increases very rapidly. The FTA's multiply and become very complex. The same potential complexity holds for FTA's between ASEAN as a single entity and non-member countries.

Game theory is a useful analytical methodology to define the bargaining problem. It does not instruct us on how to achieve a bargaining solution. It only describes or defines a solution. We know what constitutes a bargaining solution, but we do not know how to achieve it, in any practical sense. Nevertheless, descriptions are useful devices to shed some light on the contents of a bargaining process. The literature is clear about the

existing "Noodle Bowl" effect of the proliferation of FTA agreements of all sorts. Game theory applications provide the logic and consequences of the proliferation of FTA and other types of agreements.

Footnotes:

[1]Kawai and Wignaraja (2007) make a different argument about size. They argue propose adding Australia and New Zealand to obtain ASEAN + 6. They argue with no a priori basis that as n increases, the economic benefits to a larger FTA (area and agreement) will increase. Presumably, at least implicitly, economic diversity has also increased. They use size n as the breadth of an FTA and L as the depth or scope of FTA, my symbols. The depth of an FTA is in terms of (say) value-added content (VA), change in tariff classification (CTC), specific production process (SP), and other ROO's elements, like safety of toys.

[2]It can be shown (see, Gander, 2005) in a more detailed presentation that the two country's respective national income form reaction functions, Y1=F1(Y2, A1), and Y2=F2(Y1, A2), where the A's are policy shift parameters. The Y1 depends on its exports X1 to country 2 and Y2 depends on its exports X2 to country 1. Thus, when Y2 increases, it buys more from country1, whose income Y1 goes up. When Y1 increases, it buys more from country 2, whose income increases. Thus, Y1 and Y2 are complementary outcomes. A non-cooperative game has an equilibrium where F1(.) intersects F2(.). A cooperative game defines U1(Y1, Y2)*U2(Y1, Y2) as the Nash product formula. The MRS's define the core set of potential equilibria (Y1*, Y2*). In effect, the FTA between ASEAN and the ROW (acting as a single entity) will determine the equilibrium within the core set. Thus, the Nash product formula solution must be

consistent with the FTA between ASEAN and the ROW (or some single non-member country). In effect, the FTA is over the respective volume of reciprocal exports, which determines (cetarius paribus) the respective income levels, subject to the Pareto Optimum condition (the core set).

References:

Baldwin, R. E. *East Asian Regionalism: Managing the Noodle Bowl.* A talk to ADB, Manila, December 11, 2006, available from web site, http://hei.unique.ch/baldwin.

Baker, S. *The NumCrati*, New York, New York: Houghton Mifflin Harcourt, 2008. Reviewed in *Business Week*, "Management by the Numbers," September 8, 2008, pp. 32-38.

Friedman, J.W. *Game Theory with Applications to Economics*. New York, New York: Oxford University Press, 1986.

Gander, J. P. "*A Two-Country Trade Model and Nash Bargaining*." Working Papers, Economics Department, University of Utah, 2005.

Gander, J. P., Reynolds, S., Ratanakomut, S., and Ariyasajjakorn, D. (Tew). *Micro Economic Game Theory Applications Within ASEAN and Between ASEAN and Other Countries: Issues Involving Globalization."* The 18th conference of the American Committee of Asian Economic Studies (ACAES) held jointly with the Rimini Centre of Economic Analysis (RCEA) at Rimini, Italy, August 29-31, 2008.

Kawai, M. and Wignaraja, G. *ASEAN+3 or ASEAN+6: Which Way Forward?* ADBI Discussion Paper 77, 2007. Tokyo: Asian Development Bank Institute. Available: http://www.adbi.org/discussion-paper/2007/09/13/2359.asean.3.asean6./

Nash, J.F. *"The Bargaining Problem." Econometrica,* 1950, 18(2), pp. 155-62.

Nash, J.F. *"Two-Person Cooperative Games," Econometrica,* 1953, 21(1), pp. 128-41.

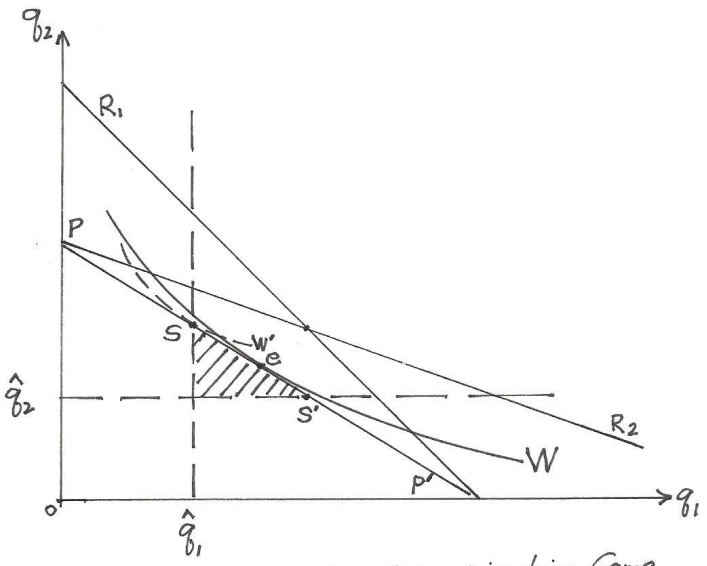
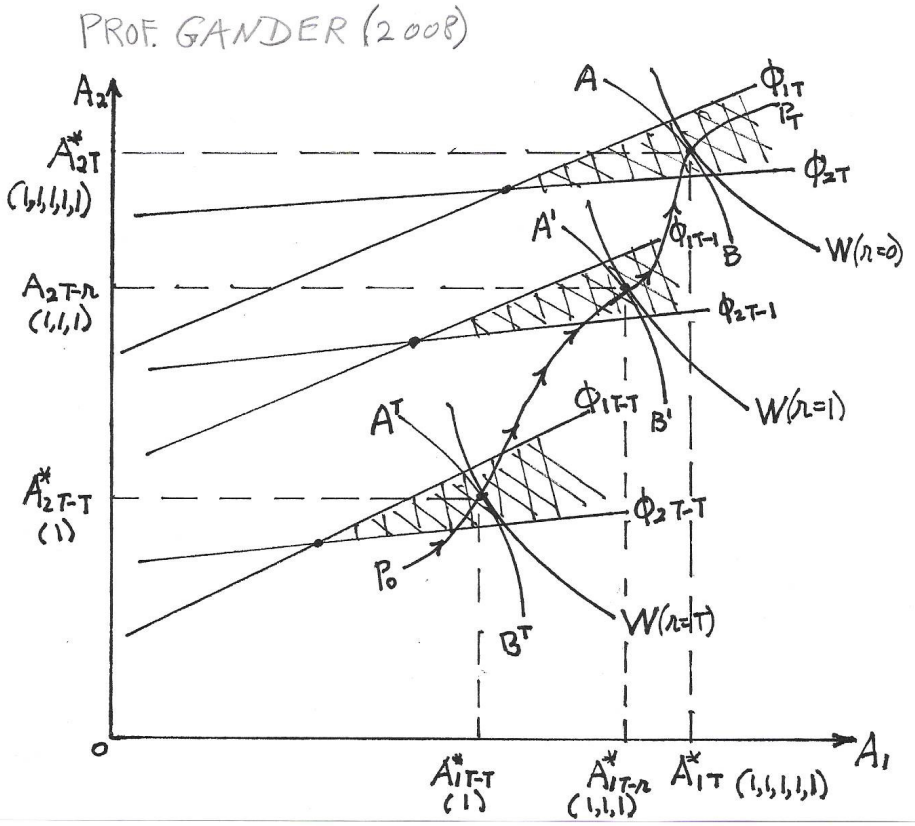


Figure 1. Constraint Maximization Game


PROF. GANDER (2008)
A2
A*2T (1,1,1,1,1)
A2T-n (1,1,1)
A*2T-T (1)
A
Φ1T
PT
Φ2T
A'
Φ1T-1
B
W(n=0)
Φ2T-1
AT
Φ1T-T
B'
W(n=1)
Φ2T-T
P0
BT
W(n=T)
O
A*1T-T (1)
A*1T-n (1,1,1)
A*1T (1,1,1,1,1)
A1

PROGRESSIVE SEQUENCE OF BILATERAL AGREEMENTS---

Let, A_{iT} = {full ideal agreement with, for example, five elements, treated as a scalar bundle based on some preference function tied to the country's income level desired at time T}

BACKWARD SOLUTION PROCESS—

Given the full ideal agreement, A^*_{iT} , find the first previous optimal subset Agreement, A^*_{iT-r} , then the next previous subset, etc. to the initial optimal starting agreement, A^*_{iT-T} . The dynamic path from start to finish is given by P_o to P_T .

EQUATIONS---

Reaction functions at sequence "r", r= 0,1,2,…T:

$A_{iT-r} = \Phi_{i,r}(Aj_{T-r} ; A^*_{iT} , r)$ when i=1, j=2 and reverse, for rth sequence.

Objective function for first stage (second stage is implicit):

$W= U1[Y1(A_{1T-r} , A_{2T-r} , r), Y2(A_{1T-r} , A_{2T-r} , r)]*U2[Y1(A_{1T-r} , A_{2T-r} , r), Y2(A_{1T-r} , A_{2T-r} , r)]$, the Nash bargaining product formula $=W(A_{1T-r} , A_{2T-r} , r)$.

A^r- B^r curve gives the Pareto Optimum equal MRS's condition for "r".