The Effects of Dynamics and Information Structures on the Solution of Conflicts in the Global Economic and Trading System*

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Abstract

This article exemplifies the application of mathematical (game theoretic) modeling to describe economic phenomenon, i.e., conflicts within the global trading system. The main proposition of this article is that broadening time horizon and promoting information exchange between the parties in conflicts will result in cooperative solution.

1 Introduction

The world has made remarkable progress during the past five decades in lowering the barriers on goods and investment that were erected before World War II. Increased integration has contributed to an unprecedented period of growth and prosperity. But as border barriers have been lowered, differences in national domestic policies have been exposed to international scrutiny. These domestic policies are creating new tension and conflicts (Lawrence et al, 1995).

By employing the so-called Analytic Hierarchy Process (AHP), Azis (1995) developed a stylized model of the conflicts and analyzed it in a game theoretic framework[1]. He predicted, among others, that the solution of the conflicts would likely be non-cooperative unless the parties in conflicts made some special efforts.

This paper views the potential conflicts more optimistically. We will show that if dynamic aspects are incorporated in the game theoretic framework, a more optimistic solution can be predicted. Furthermore, we will show that a better quality of information structure will ensure the existence of a more stable cooperative equilibrium.

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[1]A long list of reference on Analytic Hierarchy Process, including those written in seven languages, can be found, among others, in Saaty (1994).

In the next section we will give a quick review on how to model the conflicts using AHP in a game theoretic framework. The dynamic models of the game with imperfect and perfect information structures will be discussed in Section 3 and 4 respectively. We conclude this paper by providing some discussion on the policy implications and suggestions for further study in Section 5.

2 Modeling the Conflicts by using AHP

Following Azis (1995), we set a premise that there are two parties (players) in the game, i.e. the developed countries party (DC) and the less developed countries party (LCD)[2]. In the global economic and trading system LCD has four targets, i.e.

(1) Increase market access to developed countries,

(2) Maintain high economic growth,

(3) Improve industrial efficiency by reducing import cost, and

(4) Sustain economic and political stability nationally and regionally.

To meet targets LCD has two strategies, i.e.

(1) Continue the trade liberalization, and

(2) Improve the domestic structure (human right, environment, labor practice, etc.)

On the other hand, DC has three levels of decision making process, i.e. setting objectives, targets, and strategies. Her objectives are

(1) Achieve strong economic growth,

(2) Impose her value system (e.g. human right and democracy) worldwide, and

(3) Insure an environmental resources.

Strategies available to DC are

(1) Implementation a quiet diplomacy to improve social and political conditions in LCD,

(2) Support GATT/WTO rules to open markets in LCD, and

(3) Implement protection measures (tougher stance) but still within the GATT rules.

Considering the two sets of strategies available to the players, we can conduct a series of steps in AHP which will result in the following payoff bimatrix.

[2] To avoid confusion we refer LCD as a male and DC as a female.

Matrix 1.
Payoffs to the players with respective joint strategies
(The first and the second entries in the cell are payoffs to LDC and DC respectively)

	DC's Strategies		
LDC's Strategies	Quiet Diplomacy	Support GATT	Benign Protection
Change in Structure and Trade Liberalization	(.298;.258)	(.176;.211)	(.074;.250)
Trade Liberalization Being Continued	(.143;.071)	(.205;.043)	(.104;.067)

We can observe in Matrix 1 that no Nash Equilibrium (Nash, 1950) exists in this static game with pure strategies[3]. A tentative conclusion which can be drawn from this fact is that no stable solution exists in this game. In the following sections we will alter the conclusion by incorporating dynamics and perfect information structure into the model.

3 A Dynamic Model with Complete but Imperfect Information

It can be figured out that the game discussed in the previous section has the following characteristics: (1) *static,* i.e. the game is played only once (single stage game, no dynamic aspect involved), (2) *complete,* i.e. the payoff of each joint strategy is common knowledge, and (3) *imperfect,* i.e. strategies are played simultaneously.

In this section we will analyze the same game but with incorporating dynamic aspect. The information structure remains the same, i.e. complete and imperfect. In the next section we will modify the game by assuming perfect information structure.

To start the analysis notice that the DC's second strategy is strictly dominated by the third strategy (see Matrix 1). Therefore, from now on we will exclude DC's second strategy from our analysis.

To incorporate dynamic aspect into the model, we will consider a multistage game, i.e. we will repeat the game N times, where N is a sufficiently large integer. It is reasonable to assume that no player exactly knows when the game will end. Consequently, for the sake of tractability but without loss of generality we analyze an infinitely repeated game. We are inspired by the Folk Theorem (Friedman, 1971), but we face a rather different situation. We have a kind of Prisoners' dilemma with an asymmetric payoff matrix but with no single Nash Equilibrium exists.

In a static game a strategy is simply a single action. In a dynamic game, however, a player's strategy specifies the action the player will take in *each* stage, for *each* possible history of play through the previous stage. Accordingly, we will use the

[3]For a discussion on Nash Equilibrium and other elementary concepts in Game Theory mentioned in this paper, see any standard textbook in Game Theory, e.g. Gibbons (1992).

term *action* to refer a row or a column of the payoff matrix. We will call the LDC's strategy in Matrix 1 Player I's *action-1* and *action-2*. Analogously, we will DC's strategies Player II's *action-1* and *action-3*.

Definition 1 ***(Cooperative Joint Actions)*** *If Player I plays action-1 and Player II plays action-2, and accordingly result in payoff pair (.298;.258), then this joint actions (action-1,action-1) is called the cooperative joint actions.*

We call this joint actions *cooperative* because if the players were in cooperative game they would certainly choose *(action-1,action-1)*. This pair of actions gives the maximum total (combined) payoff. Notice that in a cooperative game payoffs are assumed transferable among the players, i.e. players maximize the combined payoffs and they may redistribute it in a way that satisfies them (e.g. with side payments). We will show that even in a cooperative game, under a mild assumption, the cooperative joint actions will be considered by the players as their best choice.

Definition 2 ***(Present Value)*** *Given the discount factor $\delta = \frac{1}{1+r}$, where r is the interest rate per stage, the present value of $\pi_1, \pi_2, \pi_3, \ldots$ is*

$$PV = \pi_1 + \delta\pi_2 + \delta^2\pi_3 + \ldots = \sum_{t=1}^{\infty} \delta^{t-1}\pi_t.$$

Let us now formalize our repeated game:

(1) At stage-1 players simultaneously choose actions from their feasible sets of actions respectively. Each player receives π_1 according to Matrix 1.

(2) At stage-t, $t = 2, 3, 4, \ldots$, players observe the outcome of all previous stages and then simultaneously choose actions from their feasible sets of actions respectively. Each player receives π_t according to Matrix 1.

(3) Each player maximizes his present value of the infinite sequence of payoffs.

For Player 1 the best joint actions is the cooperative joint actions. It will give him the maximum payoff. He knows, however, that the cooperative joint actions is only second best for Player II. The best joint actions for Player II is *(action-1, action-3)* which will give her a payoff .350. Player II's *action-3*, however, is very risky, because if it is combined with Player I's *action-2* then Player II receives the worst payoffs (.067).

Player I is in position to offer *promise* to play his *action-1* in the hope that Player II at the same time plays her *action-1*. This combination of actions will result in the cooperative joint actions. Yet Player I realizes that his promise will tempt Player II to play her *action-3* in which Player I must *threaten* to punish Player II if the latter deviates from the cooperative joint actions. Player I will punish Player II by playing *action-2* **forever**, in which case Player II will receive payoff at most .071 per stage.

Claim 1 ***(Player I's Commitment to Cooperate)*** *If both players choose the cooperative joint actions, then Player I does not have the incentive to deviate from it.*

Proof. The maximum payoff Player I can receive from playing non cooperative action is less than the payoff he receives from the cooperative joint action, i.e. $.143 < .298$ per stage. ∎

Definition 3 ***(The Trigger Strategy)*** *The specification of the trigger strategy is as follows. At stage-1 play the cooperative action. At stage-*t*, where* $t = 2, 3, 4, ...$*, if at stage* $t-1$ *the cooperative joint actions occurs then play the cooperative action; otherwise play the non-cooperative action forever.*

Claim 2 ***(The Advantage of Playing Non-Cooperative Action at the First Opportunity)*** *If a player believes that playing non-cooperative action is more profitable than otherwise, then he (she) will play it at his (her) first opportunity.*

Proof. This claim is only relevant to Player II. Let π_t be the payoff of a player receives at stage-t. Let u be the maximum of π_t, i.e. $u \geq \pi_t$, for all t. Let PV_t be the present value whose t^{th} term of π is substituted by u, i.e.

$$PV_t = \pi_1 + \delta\pi_2 + ... + \delta^{t-2}\pi_{t-1} + \delta^{t-1}u + \delta^t\pi_{t+1} + ...$$

Then $PV_i \geq PV_j$ if and only if $i \leq j$ since $\delta \leq 1$. ∎

Illustration of Claim 2:

$$\begin{aligned} PV_1 &\geq PV_2 \geq PV_3 \Longleftrightarrow \\ u + \delta\pi_2 + \delta^2\pi_3 + ... &\geq \pi_1 + \delta u + \delta^2\pi_3 + ... \geq \pi_1 + \delta\pi_2 + \delta^2 u + ... \end{aligned}$$

Claim 3 ***(The Credibility of Player I's Promise and Threat)*** *Player I's promise is to cooperate forever unless Player II at stage-*t *deviates from the cooperative joint actions in which case Player I will execute his threat at stage* $t+1$ *and at all stages that follow. Player I's threat is to play non-cooperative action forever. The promise is credible because it will give the maximum benefit to Player I. The threat is credible because - if it is executed - it will hurt Player II much more severely than it will hurt Player I.*

Proof. See Claim 1 for the proof of credibility of Player I's promise. To prove the credibility of the threat, compare the present values Player II will receive in the cooperative and the non-cooperative scenarios.

$$\begin{aligned} PV(\text{cooperative}) &= \sum_{t=1}^{\infty} \delta^{t-1}(.258) \\ &= .258 \sum_{t=0}^{\infty} \delta^t \\ &= \frac{.258}{1-\delta}. \end{aligned}$$

From Claim 2 we know that the **maximum** payoff to Player II in the non-cooperative scenario is

$$\begin{aligned}\mathsf{PV}(\text{non-cooperative}) &= .350 + \delta(.071) + \delta^2(.071) + \ldots \\ &= .350 + .071 \sum_{t=1}^{\infty} \delta^t \\ &= .279 + \frac{.071}{1-\delta}.\end{aligned}$$

Obviously, $\mathsf{PV}(\text{cooperative}) > \mathsf{PV}(\text{non-cooperative})$ for any $\delta > .3297$ or equivalently for any $r < 203.31\%$. On the other hand, if Player II is non-cooperative, the best response of Player I is to punish player II by playing *action-2,* because at least he will receive a payoff of .104 per stage instead of only .074 in case where he (irrationally) keeps on playing *action-1.* ∎

Claim 4 ***(The Existence of Cooperative Equilibrium)*** *In the dynamic game (infinitely repeated game) with complete but imperfect information with payoff structure shown in Matrix 1, there exists a cooperative equilibrium for any δ sufficiently close to one.*

Proof. Since the promise and the threat of Player I are credible (see Claim 3), the best strategy of Player II is to cooperate at each stage of the game. ∎

To conclude this section, notice that in our context the meaning of discount factor simply measures the players' patience. If a player sets $\delta = 1$, then for him (her) it is indifference to receive a benefit today or to receive it next year (and those this player is very patience). The interest rate measures the players' impatience, since it is inversely related to the discount factor.

4 A Dynamic Model with Complete and Perfect Information

In this section we will show that if we can improve the quality of information structure (to become perfect instead of imperfect), then we can guarantee the existence equilibrium without any condition on the discount rate. Furthermore, the cooperative equilibrium is in a sense more stable than the one discussed in the previous section. Our model is similar to the Stackelberg (1934) duopoly model. The difference is that our strategy spaces are discrete, where as the strategy spaces in his model are continuous.

We will analyze two dynamic games with *perfect information,* by which we mean that at each move in the game the player with the move knows the full history of the play of the game thus far. For the payoff structure we will again refer to Matrix 1. The sequence of the game is as follows.

(1) A player (the leader) chooses an action from his (her) feasible set of actions.

(2) The other player (the follower) observes the leader's actions and then chooses an action from his (her) own feasible set of actions.

(3) Each player maximizes his (her) payoff which depends on the two chosen actions.

We will analyze two scenarios. In the Scenario I we assume that LDC is the leader, where as in the Scenario 2 DC will be the leader.

A sequential game of this kind is best represented in an extensive form (game tree). For Scenario 1, see **Tree 1**. The numbers in the brackets are payoffs to the players the values of which are exactly the same as the corresponding entries in Matrix 1. The first and the second entries are payoffs to LDC and DC respectively.

As a consequence of the information structure, LDC knows exactly that if he plays *action-1*, then DC's best response is to play *action-3*, in which case the solution gives payoff pair (.074;.350). On the other hand if LDC plays *action-2*, then DC will surely respond with playing *action-1*, in which case the solution payoff pair is (.143;.071). Being the leader, LDC can choose the best alternative, i.e. the action that gives the greater payoff to him. Obviously, the equilibrium of this game is that LDC plays *action-2* and DC responds with playing *action-1*, in which case the equilibrium payoff pair is (.143;.071).

For Scenario 2, see **Tree 2**. With the same argument it can be shown that the underlined payoff pairs are potential solutions the best of which the leader (DC) will choose. Clearly, the leader will choose payoff pair (.298;.258) which gives DC a payoff of as much as .258 which is much better than that given by the other alternative, i.e. .067. We can conclude therefore that the equilibrium of this game is that DC plays *action-1* and LDC responds with playing *action-1*, in which case the equilibrium payoff pair (.298;.258). In the previous section we called this the cooperative solution.

Some facts are worth noting here. In both scenarios DC's best action is *Quiet Diplomacy* (DC's *action-1*). Both players prefer Scenario 2 which gives them better payoffs. Therefore, DC has incentive to lead the game, and on the other hand LDC prefers being the follower. Thus perfect information structure leads the players to the cooperative solution which is more stable than the cooperative equilibrium we claimed in the previous section. We need to define what we mean by a *stable* equilibrium before claiming our finding in this section.

Definition 4 *(Stable Equilibrium in Stackelberg Game) An equilibrium in a Stackelberg game is said to be stable if only if all the players prefer this equilibrium to any other equilibria in any possible scenarios of the game.*

Claim 5 *(The Existence of Stable Cooperative Equilibrium) In the dynamic games with complete and perfect information there exists a stable cooperative equilibrium.*

Proof. The number of possible scenarios in the dynamic games is only two, i.e. Scenario 1 where LDC is the leader, and Scenario 2 where DC is the leader. As shown in the text, in Scenario 1 the equilibrium gives a payoff pair (.143;.071);

where as in Scenario 2 the equilibrium gives a payoff pair $(.298;.258)$. Clearly, both players prefer Scenario 2 to Scenario 1, and therefore the equilibrium in Scenario 2 is stable. According to Definition 1, this stable equilibrium is called the cooperative equilibrium. ∎

5 Concluding Remarks

This paper has provided an example of the effects of dynamic aspects and information structures on the solution of possible conflicts in the global economic and trading system. While the model can be considered as highly stylized and heavily dependent on the result of the so called Analytic Hierarchy process, it has casted some light on the possible cooperative solution of the conflicts. Our results support the idea of broadening time horizon (i.e. avoiding myopic time horizon) in dealing with conflicts which have potentially important impact. They also support the idea of promoting information exchange between the parties in conflicts, the example of which are envisaged by Lawrence et al (1995).

For further study, some aspects of uncertainty (incomplete information structure) can be incorporated into the model. The idea of *infinitely* repeating the game like the one we discussed in this paper may seem unappealing. But it is also we known that *finitely* repeating the game (e.g. Prisoners Dilemma) will not basically alter the solution of the single stage game. By changing the structure of information (i.e. incorporating uncertainty) we may find some interesting results (Kreps et al, 1982).

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Tree 1. Scenario 1 of the Dynamic Game with Complete and Perfect Information

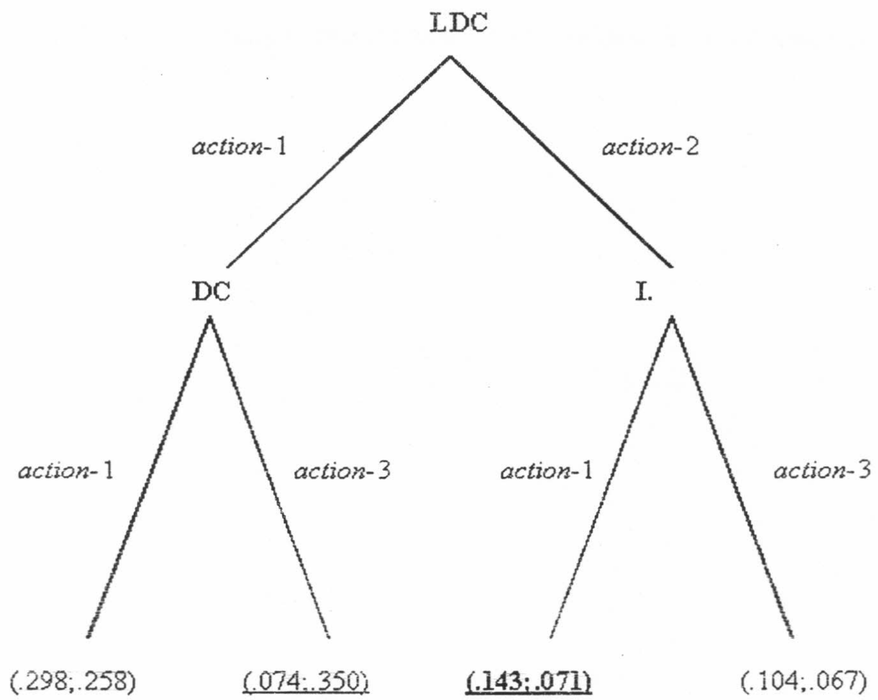

Figure 1: *LDC is the Leader, DC is the Follower*

Note: The numbers in the brackets are payoffs to LDC and DC respectively.
The underlined payoff pairs are the potential solutions.
The payoff pair printed in bold characters is the equilibrium.

Tree 2. Scenario 2 of the Dynamic Game with Complete and Perfect Information

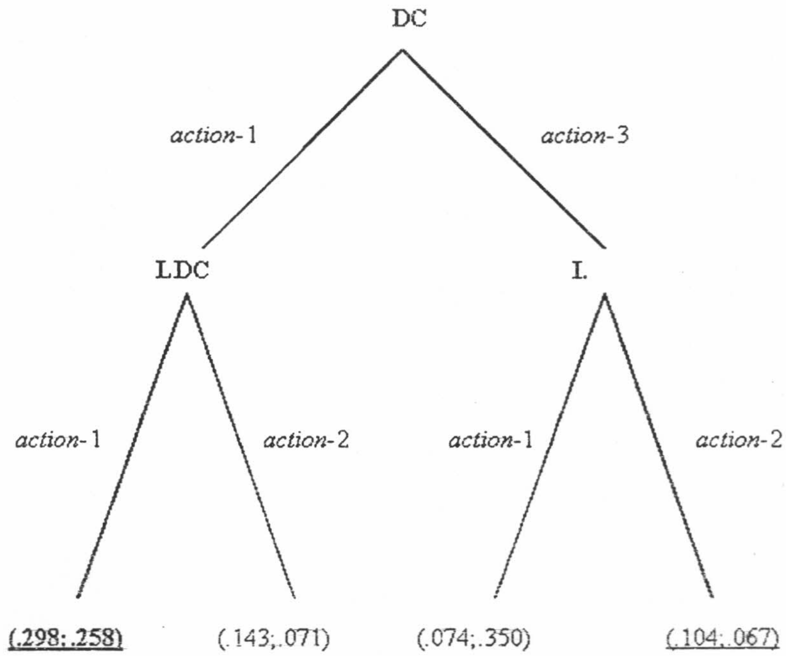

Figure 2: *DC is the Leader, LDC is the Follower*

Note: The numbers in the brackets are payoffs to LDC and DC respectively.
The underlined payoff pairs are the potential solutions.
The payoff pair printed in bold characters is the equilibrium.