State Trading Companies, Time Inconsistency, Imperfect Enforceability and Reputation

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Strategic trade in international markets is important for agricultural and other basic commodities. Distribution systems for these commodities are dominated by agents that have the potential for exclusive monopoly power. State trading companies (STC) and large private firms control most of the trade volume. For agriculture in particular, the seasonal nature of the production process compared to a relatively constant demand for the commodities brings into play as well concepts of timing in trade contracting and time consistent behavior.

Some of the earliest papers that investigate issues of time consistency in trade are Lapan (1988), Maskin and Newbery (1990) and Staiger and Tabellini (1987). Melkonian and Johnson (1996) have explored a model in which an STC, which has monopsony power, cannot credibly commit to a particular policy or contract. An annual trading cycle was considered. In the sequence of economic decisions, the STC moves first and announces a planned level of import. Producers in the exporting countries make their decisions on the allocation of the more fixed inputs (e.g., land) based on related price expectations. However, before they make decisions on the allocation of the more variable inputs (e.g., labor or fertilizer), the STC has the opportunity to revise the announced level of imports. Then, the labor or variable input allocation decisions of the producers are made, given the revised (and predetermined) level of imports and the previous allocation of the more fixed inputs. Finally, trade takes place.

A standard monopsony argument can be used to obtain the optimal level of import, if the STC can commit itself to the announced import level. But, when the STC cannot be held to the precommitted or the ex-ante optimal level of import, it has an incentive to set a lower ex post level, once the land allocation decision has been made (the STC will face an ex post supply that is less elastic than the ex-ante supply). In standard terminology, the ex-ante optimal level of import is not time-consistent. If foreign producers are assumed to know the rule used in setting ex post level of import, they will use this information when making their land allocation decisions. We showed that both the importer (STC) and the exporting countries are worse off as a result of the inability of the importer to precommit to the optimal level of import. It is shown that forward contracts support the ex ante optimal level of import as a time-consistent equilibrium. We also considered the case when the importer is better informed than the exporter and showed that under some scenarios the importer cannot benefit from the superiority of its information.

In this paper, we use a standard game theoretic formulation to model the strategic behavior we have described, and to explain apparent anomalies in trade performance. The same game theoretic formulations can be used to examine the impact of mechanisms with the potential for dealing with time inconsistency. In particular, precommitment penalties that might be enforced by bonding or other types of trade management systems are evaluated. These mechanisms can result in Pareto superior trade (and investment) patterns. An alternative is to consider the trading strategies in a sequential game context. The implications of signaling and reputation effects are at issue in this sequential or multi-stage trading context. This formulation opens the possibility of behavior that avoids the suboptimal elements of the single period game. As well, the strategies that emerge suggest alternative mechanisms that dominate the unregulated outcomes for the simple sequential game, even if they involve contracts that are imperfectly enforceable.

The Perfect Information Game

We consider a sequential game between two players. The game has three periods. In the first period, player 1 (the STC) announces the policy she intends to implement in the third period. That is, player 1 makes one of two announcements: "benevolent" or "nonbenevolent." This announcement becomes known to player 2 (the STC's trading partner). After either of the two announcements is made, players 1 and 2 play the game depicted in Figure 1 (numbers at the decision nodes in the game tree represent the player whose turn it is to move; the first of the pair of numbers at terminal nodes represents payoff of player 1, and the second, the payoff of player 2). As will be clear, the "cheap talk" of player 1 does not affect the future strategic interaction between the players.

Specifically, in the subgame following player 1's initial announcement, player 2 moves and chooses one of two levels of investment, "high" or "low" (**h** and **l** in Figure 1). After observing the level of investment, player 1 makes her choice of policy to be implemented: "benevolent" or "nonbenevolent" (**b** and **nb** in Figure 1). The complete (with the policy announcement) game form and the payoffs to the players, depending on the history of the game, are shown in Figure 2. Note that the two proper subgames starting at the nodes where it is player

2's turn to move are equivalent (the game forms and the payoffs are the same). This reflects the noncredible cheap talk announcement of player 1.

Now, consider in more detail payoffs to the players for different strategy profiles. For both of the possible levels of investment selected by player 2, player 1's payoff is higher if she chooses to implement nonbenevolent compared to the benevolent policy; $x_1 < 0$ and $x_2 < x_3$. In contrast, player 2's payoff, given that the investment decision has been made, is higher if the benevolent policy is implemented by player 1; $y_1 > 0$ and $y_2 > y_3$. If an investment decision is followed by a benevolent policy, player 2's payoff is higher when he chooses high; $y_2 > y_1$. While if an investment decision is followed by a nonbenevolent policy, player 2's payoff is higher when he chooses low; $y_3 < 0$. Player 1's payoff is higher when high investment is followed by a benevolent policy than in the case when low is followed by nonbenevolent; $x_2 > 0$. We also assume that $x_3 + x_1 > 0$ (the importance of this assumption will be clear in a later section). With this assumption, the sign restrictions on the payoffs can be easily summarized; $x_1 < 0$, $0 < x_2 < x_3$, and $x_3 + x_1 > 0$; $y_3 < 0$ and $0 < y_1 < y_2$.

Consider either of the two proper subgames following initial policy announcement, i.e. the game depicted in Figure 1. If player 2 chooses low, player 1 chooses between x_1 if she plays benevolent and 0 if she plays nonbenevolent. Thus, obviously player 1 will play nonbenevolent. The same reasoning leads us to conclude that when high investment is chosen by player 2, nonbenevolent policy will be implemented (in that case, player 1 chooses between x_2 and x_3). That is, nonbenevolent is the ex post (after the investment decision) optimal policy. Anticipating that either level of investment will be followed by implementation of nonbenevolent policy, player 2, when making his investment decision, chooses between 0 if he plays low and y_3 if he plays high. Obviously, he will choose the low investment. When making her initial announcement, player 1, anticipating that she and her opponent will play optimally at later nodes, chooses between 0 if she announces benevolent and 0 if nonbenevolent, and she is indifferent between the two.

This argument is just a simple application of backward induction to the solution of a game of perfect information.[1] Thus, we have shown that this game has two subgame perfect equilibria: (1) player 1 initially announces benevolent and implements nonbenevolent policy for all levels of investment, and for either of the initial announcements, player 2 chooses low investment no matter what the initial announcement; and (2) player 1 initially announces nonbenevolent, and the actions at all other information sets are the same as for the first strategy profile (the second equilibrium differs from the first only by the move of player 1 at her first information set). The equilibria payoffs of both players are the same for both of the strategy profiles. Both yield a payoff of 0.

Now, suppose that there is a mechanism that allows player 1 to credibly precommit to a policy or announcement. One possible mechanism can be described as follows: suppose that before the game player 1 signs a perfectly enforceable (binding) agreement saying that she is going to burn $\$c$ $(c > x_3)$ if she does not implement the announced policy. The tree for this game is presented in Figure 3. Note that the game form is unchanged and only the payoffs to player 1 at the terminal nodes, corresponding to histories where the announced and implemented policies differ, have been modified. There is also another interpretation of the extensive form game presented in Figure 3. Suppose that player 1 is known for sure to be a "commitment" (or an "honest") type, that is a player who gets a very high negative payoff ($\$c$) from reneging on her announcement in the first period. In other words, player 1 incurs very high cost from being inconsistent.

We solve the game with this commitment mechanism. Consider the proper subgame starting with the node following player 1's initial announcement of benevolence. If player 2 chooses low, player 1 chooses between x_1 if she plays benevolent and $(0-c)$ if she plays nonbenevolent. Thus, obviously player 1 will choose benevolent. The same reasoning leads us to conclude that benevolent policy will be implemented by player 1 when high investment is chosen by player 2 (in this case, player 1 would choose between x_2 and $(x_3 - c)$). Hence, when player 2 makes his investment decision after the announcement of benevolence and anticipates the above characterized response (implementation of the benevolent policy), he chooses between y_1 if he chooses low and y_2 if he chooses high. Surely, he will choose high investment.

Applying the same reasoning (backward induction) to the proper subgame starting with the node following a nonbenevolent announcement, we find that in the subgame either investment decision will be followed by the implementation of the nonbenevolent policy and player 1 (anticipating the nonbenevolent response) will choose low investment. Thus, rolling back the payoffs of the players (when the strategies obtained by backward induction are followed) to the nodes that follow initial announcement, we see that player 1 chooses between x_2 if she chooses benevolent announcement and 0 if she chooses nonbenevolent. And hence, she will choose benevolent. Thus, we have shown that this game has unique subgame perfect equilibrium, where: player 1 announces benevolent in period 1 and at the node following a particular announcement, she implements the policy that was announced; player 2 chooses high if benevolent was announced and low if nonbenevolent. The subgame perfect equilibrium payoffs to the players are (x_2, y_2).

We could consider yet a larger game where player 1 chooses in period 0 whether to play the game described in Figure 2 or the game of Figure 3 (the first interpretation (burning money) will be chosen for Figure 2, since it is not sensible to assume that people choose to be honest or not) and that decision is made known to player 1. In this game player 1 will choose the game with the precommitment mechanism. There are two subgame perfect equilibria of this game: player 1 in period 0 chooses to play the game with commitment mechanism and the choices of both players after the choice in period 0 are exactly the same as equilibria strategy profiles of players 1 and 2 for the games presented in Figures 2 and 3.

The multiplicity of equilibria arises from the fact that the proper subgame following the choice of player 1 not to choose a commitment mechanism has two subgame perfect equilibria (as described above). The payoffs for both the equilibria described are (x_2, y_2). Thus, if player 1 has an option of a commitment mechanism, she will use that option and the payoffs of both players are higher in the game when this option is available $(x_2 > 0, y_2 > 0)$, as compared with the case when it is not.

The Finitely Repeated Version of the Game Without Commitment

Consider the strategic situation when player 1 does not have access to the commitment mechanism and there are finitely many trading cycles after policy announcement is made. Again, there are two players. The game has *N*+1 stages (*N* is a positive integer). We index time backwards; i.e., the first stage of the game is *N*+1, second *N*, and so on. At the stage *N*+1, player 1 makes one of two announcements, benevolent or nonbenevolent. After the announcement is made and observed by player 2, the game depicted in Figure 1 is played *N* times. We assume that the announcement in stage *N*+1 is noncredible in a sense that it does not affect the moves available to the players and the payoffs for each strategy profile (the two proper subgames, following the announcement, are exactly the same).

The sign restrictions for different strategy profiles are the same as in the previous section.[2] The payoffs of players 1 and 2 are the sums (undiscounted) of their respective payoffs in the stages of the game. This is a finite game with perfect information, which again can be solved by application of backward induction. First, let us conjecture how the game might progress. We might expect that player 1 will announce benevolent in stage *N*+1, and then will implement benevolent policy no matter what the level of investment, to convince player 2 that she is honest (committed to her announcement), and that she will continue to implement the announced policy. In other words, player 1 will try to establish a reputation for being a “commitment” type. Observing this kind of choice by player 1, player 2 will become convinced that player 1 will keep to the announced policy (benevolent) and will choose high investment level. Thus, we would expect benevolent policy to be implemented and high investment for player 2 in the first stages of the game. However, we also expect that this kind of behavior will not be observable at very late stages in the game, since later in the game there is not much benefit from demonstrating commitment (the reputation value is low). That is, we would expect nonbenevolent policies to be implemented at later stages of the game. Though the behavior we have just described seems likely to develop and is very intuitive, the game theoretic prediction discards it.

To solve for the subgame perfect equilibrium, consider a proper subgame starting with the node following either of the two announcements. Within that subgame consider the last stage. In this stage, player 1 will implement the nonbenevolent policy for both levels of investment by player 2, since there are no gains left to maintain her reputation. Anticipating this response, player 2 will choose low investment. In the next to the last stage, player 1 will implement nonbenevolent policy whatever level of investment, since it is more beneficial in the short-run and does not affect the play in the last stage. Anticipating this, player 2 will choose low investment in the next to the last stage. Carrying this argument to the beginning of the subgame, we find that player 2 chooses low investment in all stages, and player 1 always implements the nonbenevolent policy. Again, as in the Section 2, the game has two subgame perfect equilibria, which differ only by the initial announcement and have low investment and nonbenevolent policy implementation for each possible history. The equilbrium payoffs for both strategy profiles are (0,0).

Now, suppose we consider the game which consists of *K* stages (*K* is finite positive integer), where each stage is exactly the game described above (announcement of a policy followed by *N* repetitions of the game in Figure 1). Again, we reach conclusion that the subgame perfect equilibria will have low investment and nonbenevolent policies implemented for all information sets (Recall that all information sets are singletons in this game). Thus, even in the case when there are multiple (and finite) subperiods of announcements followed by investment choice-implementation sequences, the reputation effect does not “come alive.”

In summary, we showed that although it is intuitive and plausible for player 1 to try to maintain a reputation for being a commitment type by implementing the policy announced to persuade player 2 to make a high investment, in none of the subgame perfect equilibria is this an optimal strategy.

Imperfect Enforceability, Pooling and Reputation Effects

We have shown that, for the basic game, if there is an option of commitment mechanism that is also perfectly enforceable then high investment is chosen and the ex ante optimal policy is implemented. This results in payoff increase for both players. Then, we turned to the case when the trading game is repeated finitely many times, but with the commitment mechanism absent. We showed that no matter how many (finite) times the game is to be played, reputation effects do not come alive and the payoffs to the players are the same as in the one-period version of the game (0,0).

In this section we investigate a model with an imperfectly enforceable commitment mechanism. As before, the commitment mechanism obliges the party (player 1), reneging on announcement, to pay a penalty of $*c*.

First, consider the game where announcement of the policy is made followed by N repetitions of investment choice-implementation sequence. As previously, we assume that the game has two players. Before the game is played, player 1 makes a contract with the third party, which obliges her to implement the announced policy. The information, on whether the commitment contract is going to be honored is, however, the private information of player 1. That is, the commitment contract with the third party is "imperfectly enforceable." We assume that player 2 has prior probability belief r that player 1's payoffs are the same as in Figure 3, each time she reneges on her announcement. That is, r is the probability of player 1's being commitment type. With probability $(1-r)$ player 1's payoffs are as in Figure 2. That is, $(1-r)$ is the probability of player 1 being a noncommitment type, for whom the policy announcement is a cheap talk (for a noncommitment type it does not cost anything to renege on the announced policy). In other words, player 2 is uncertain about player 1's cost of reneging on her announcement. This is a game of incomplete information Harsanyi (1967-68), which can be transformed into a game of imperfect information where nature moves first and chooses player 1's payoff structure, player 1 observes nature's move but player 2 does not. The game when there is only one investment choice-policy implementation stage is depicted in Figure 4. We denote by q_c the commitment type player 1, and by q_N the noncommitment type.

We first analyze the game depicted in Figure 4 and then move on to solve the case of an arbitrary number (finite) of investment choice-policy implementation stages. Note, that for the commitment type it is a strictly dominated strategy to renege on the announcement made in the first stage. Thus, we can eliminate the strategies where commitment type implements policy different than the one announced as possibilities for equilibrium behavior. Given an initial announcement and either investment level, implementation of the nonbenevolent policy is optimal for the noncommitment type (by application of backward induction). In other words, it is a strictly dominated continuation strategy for the noncommitment type to implement nonbenevolent policy at any information set. Eliminating the strictly dominated strategies for different player 1 types, it is easy to show that the best response for player 2 at the information set following nonbenevolent announcement is to choose low investment for any beliefs about the type of player 1 (commitment type implements the policy announced, and the noncommitment type always implements nonbenevolent policy).

Thus, the choice of the low investment after the announcement of the nonbenevolent policy is justified. Given these rounds of elimination of the strictly dominated continuation strategies, the strategies in which the noncommitment type of player 1 announces the nonbenevolent policy are weakly dominated by the strategy where she announces the benevolent and implements the nonbenevolent policy for either investment level. To eliminate weakly dominated strategies, we invoke Kohlberg and Mertens (1986) requirement that the equilibria set be stable. Elimination of weakly dominated strategies corresponds to setting their admissibility condition. The above described elimination of dominated strategies has allowed us to reduce the set of possible modes of behavior for the two players. Now, we can move on to finding the Nash equilibria of the game in Figure 4.

Note, that no matter what the value of r in the interval (0,1), the following strategy profile is a Nash equilibrium of the game in Figure 4:

i. The commitment type of player 1 announces nonbenevolent policy and at the information sets following a particular announcement implements that promise; the noncommitment type announces benevolent policy and implements nonbenevolent policy given either level of investment and either announcement;

ii. Player 2 chooses low investment following either announcement by player 1.

It is easy to note that the equilibrium just described is sequential if we specify beliefs at the two information sets of player 2 using Bayes' law to update prior beliefs, given player 1's equilibrium strategy. We denote this equilibrium by (*). Using the terminology of signaling games, this equilibrium is separating in a sense that the signal (the announcement) sent by player 1 in the first stage reveals her type. This equilibrium set (singleton) is also stable. To find all possible equilibria, we consider two possible cases differentiated by the magnitude of r and relative values of player 2's payoffs for different strategy profiles:

(1) $r \geq \dfrac{-y_3}{y_2 - y_1 - y_3}$

(the case in which the relative likelihood of player 1's being a commitment type is high).

Consider the strategy of player 1 where her both types announce benevolent with probability 1. Then Bayes' updating yields posterior which is equal to prior beliefs about type of player 1. That is, probability that player 1 is of commitment type, given that both types announce benevolent with probability one, is equal to r. Then, given updated beliefs and player 1's optimal strategies following the investment decision, player 2's expected payoff from high investment is equal to $r\,y_2 + (1-r)\,y_3$ and from low investment to $r\,y_1 + (1-r)\,0$. Hence, if the inequality (1) is satisfied and player 1 uses the strategy described above, player 2 will choose high investment. Thus, following strategy profiles and beliefs of player 2 about player 1 constitute a sequential equilibrium (also stable as a set):

i. Both player 1 types announce benevolent policy in the first stage; at the information sets following a particular announcement commitment type of player 1 implements the announced policy (implementation of benevolent policy after announcement of benevolence, and similarly for non-benevolent policy), the noncommitment type chooses to implement nonbenevolent strategy at all of her information sets;

ii. Player 2 chooses low investment at the information set following nonbenevolent announcement, and chooses high investment at the information set following benevolent announcement.

iii. At the information set following the benevolent announcement, the probability (posterior) that player 1 is of commitment type is equal to the prior r (Bayesian updating is invoked using equilibrium strategy of player 1); at the information set following the nonbenevolent announcement the posterior probability that player 1 is of commitment type is equal to q, where q is any real number in the segment [0,1].

It is easy to observe that (strategy profile, beliefs) pair is consistent and sequentially rational (requirements of a sequential equilibrium). This is a pooling equilibrium in the sense that both player 1 types choose to send the same signal (announcement of benevolence). The equilibrium payoffs of the noncommitment type of player 1 and of player 2 are x_3 and $r\,y_2 + (1-r)\,y_3$ respectively. Payoffs of both players are higher than in the case when player 1 does not have a reputation for being a commitment type (that is, when $r = 0$).

Recall, that for the values of r satisfying inequality (1) the (strategy profile, beliefs) pair (*) also represents a sequential equilibrium. But, the outcome payoffs of both players for this equilibrium are Pareto dominated by the equilibrium payoffs for the just described pooling equilibrium. We use the coalition-proof Nash equilibrium[3] concept of Bernheim, et al. (1987) to discard the equilibrium (*). We argue that the pooling equilibrium is more likely to be played than separating one, because if preplay communication were possible then both players would have an incentive to agree to play pooling equilibrium (which is a self-enforcing mode of behavior).

When the initial reputation for credibility is low,

(2) $$r < \frac{-y_3}{y_2 - y_1 - y_3} \ ,$$

the only sequential equilibrium, which also survives the elimination of dominated (strictly as well as weakly) strategies, is separating where the noncommitment type chooses the benevolent announcement and the commitment type chooses the nonbenevolent announcement (that is, equilibrium (*)). The equilibrium payoffs of both player 1 types and player 2 are equal to zero, i.e. they are the same as in the case when player does not have a reputation for being commitment type.

Our conclusions can be easily summarized: For the game where there is only one investment choice-policy implementation stage after the policy announcement, if the prior probability of player 1 being a commitment type is not sufficiently large the resulting equilibrium is the one where the different player 1 types separate in the first stage (announcing different policies) and the equilibrium payoffs of both players are equal to zero (same as when there is no reputation for being a commitment type). When reputation of being commitment type is sufficiently large, the pooling equilibrium is the only one that survives all the criteria that we have imposed and payoffs of both players are higher than in the case where reputation is absent.

Now, we consider a more general game in that we allow the announcement stage be followed by arbitrary but finite number of investment choice-policy implementation stages.

Again, there are two players in the game: player 1 and player 2. The game has *N*+1 stages (*N* is a positive integer). As previously, we index time backwards. Again, the first stage of the game is *N*+1, second *N*, etc. At the stage *N*+1 player 1 makes one of two announcements:

benevolent or nonbenevolent. After the announcement is made and observed by player 2, the investment choice-policy implementation game form is played *N* times. But in contrast to the game described in the third section, player 2 is uncertain about the payoffs of player 1, and holds a prior probability r that player 1 incurs a cost each time she (player 1) reneges on the announcement (her payoffs are as in Figure 3). With probability $(1-r)$ the payoffs of player 1 for each stage game are those given in Figure 2. That is, $(1-r)$ is the probability of player 1 being a noncommitment type. The payoffs of players 1 and 2 are the expected sums (undiscounted) of their respective payoffs in the stages of the game. In the following we will be interested in the payoffs for the noncommitment type of player 1 and payoffs of player 2.

Before trying to determine how this game will be played, note that commitment type of player 1 will implement the announced policy along each equilibrium path of this game. That is, there are two possibilities for commitment type's behavior in equilibrium: announce and then in all stages implement benevolent policy, or announce and then in all stages execute nonbenevolent policy. Note, that our model differs from other reputation models since we allow the type, whose reputation to be maintained, to be strategic, i.e. that player type is not restricted to a single strategy along the equilibrium path.

Let h_j denote the history of the game up to stage *j*. Player 2 will update his beliefs about the player 1 type conditional on the previous moves of both players (h_j). We denote these beliefs at the beginning of stage *j* by p_j. As indicated above, p_j is a function of h_j. For any value of r (the initial reputation for being the commitment type) between 0 and 1, the following strategy profile and belief structure constitute a sequential equilibrium:

i. The commitment type player 1 announces nonbenevolent policy and at the information sets following a particular announcement implements the promised policy; the noncommitment type announces benevolent policy and implements nonbenevolent at all of her information sets;

ii. Player 2 chooses low at all of his information sets.

iii. At all information sets following the announcement of nonbenevolent policy, player 2's belief that player 1 is commitment type is equal to 1; at all information sets following the announcement of benevolent strategy, player 2's belief that player 1 is commitment type is equal to 0.

It is possible to show that the equilibria set (a singleton) just described is stable. Using terminology of signaling games, this is a separating equilibrium, because the signal (in this case, the signal is an announcement of policy) sent in the first stage of the game reveals sender's type. Subsequently, we term this a separating equilibrium.

This game also has another sequential equilibrium for large enough r and/or N. To solve for this equilibrium of the finite game of imperfect information, we first find the sequential equilibrium when there is only one investment choice-policy implementation stage after the announcement. Then we solve when there are two stages, and then invoke mathematical induction to find the solution for arbitrary (finite) number of stages. The following strategies and beliefs constitute a sequential equilibrium[4] if: $r \geq \left(\frac{-y_3}{y_2 - y_1 - y_3}\right)^N$.

<u>Beliefs:</u>

i. $p_{N+1} = r$

ii. For any $j \leq N$, probability that player 1 is of commitment type at each information set of player 2 following announcement of nonbenevolent policy is equal to one.

iii. $p_N = r$ at the information set following benevolent announcement

iv. If the history of the game up to stage $j<N$ includes benevolent announcement and any instance of implementation of nonbenevolent policy then $p_j = 0$.[5]

v. If $p_{j+1} = 0$ then $p_j = 0$.

vi. If $j>1$, $p_j < \left(\frac{-y_3}{y_2 - y_1 - y_3}\right)^{j-1}$ and the investment decision is followed by implementation of the benevolent policy, then $p_{j-1} = \left(\frac{-y_3}{y_2 - y_1 - y_3}\right)^{j-1}$.

The strategy of player 1 is described as follows:

i. the commitment type announces benevolent policy in stage N+1 and at information sets following an announcement of benevolence she implements benevolent, at information sets following nonbenevolent she implements nonbenevolent;

ii. the noncommitment type announces benevolent policy in stage N+1; at all information sets following a nonbenevolent announcement she implements nonbenevolent policy; the choice of the noncommitment type at the information sets following benevolent announcement (nodes following both high and low investment) depends on p_j and j:

If j=1 then she implements the nonbenevolent policy, given any investment choice;

If j>1 and $p_j \geq \left(\frac{-y_3}{y_2 - y_1 - y_3} \right)^{j-1}$ then she implements the benevolent policy.

If j>1 and $p_j < \left(\frac{-y_3}{y_2 - y_1 - y_3} \right)^{j-1}$ then she implements the benevolent policy with probability $\frac{(A-1)p_j}{(1-p_j)}$ (where $A = \frac{y_2 - y_1 - y_3}{-y_3}$) and the nonbenevolent with complementary probability.

The strategy of player 2 can be described using related conditions:

Player 2 chooses high investment in stage j if $p_j > \left(\frac{-y_3}{y_2 - y_1 - y_3} \right)^{j}$, he chooses low investment if $p_j < \left(\frac{-y_3}{y_2 - y_1 - y_3} \right)^{j}$. If $p_j = \left(\frac{-y_3}{y_2 - y_1 - y_3} \right)^{j}$, then player 2 randomizes between his choices, playing high with probability $\frac{x_3 - x_2}{x_3}$ in case when high investment was chosen in the previous stage and with probability $\frac{-x_1}{x_3}$ if low investment was chosen in the previous stage.

The nature of the equilibrium is the following: for every $r > 0$ there is a number $n(r)$ such that, if there are more than $n(r)$ investment choice-policy implementation sequences remaining to be played, the noncommitment type will implement the benevolent policy and player 2 will choose high investment. The noncommitment type chooses nonbenevolent in the last stage and mixes between benevolent and nonbenevolent in stages $n(r)$,.....,2. Accordingly, player 2 mixes between high and low or chooses high with probability, which depends on the relative magnitudes of r and the players' payoffs. Thus, in each of the stages $n(r)$,.....,1, reputation breaks down with positive probability.[6] Reputation breaks down in the later stages, since long-run value from having reputation for commitment is outweighed by the (opportunity) cost of pretending to be a commitment type. Note, that for large enough N, payoffs of both players converge to 3. For large enough r and/or *N* this equilibrium outcome dominates the separating outcome. Hence, applying the coalition-proof Nash equilibrium concept, we discard the separating equilibrium.

If we consider a larger game consisting of *K* stages, where each stage is the game just described, then the equilibrium (that survives the refinements we pose) will have the following properties: In *K*-1 first stages, both types of player 1 announce the benevolent policy and subsequently implement benevolent in all periods of the stage; player 2 chooses high investment in all periods of the first *K*-1 stages; the play in the last stage is the same as for the single stage game described above (that is, the game with announcement followed by *N* repetitions of investment choice-policy implementation sequence).

The Canadian Wheat Board As an Example

The results developed can be directly applied to modern issues on the performance and welfare impacts of STCs. We select the Canadian Wheat Board (CWB) as an illustration. The wheat Board makes to farmers "an initial or partial payment upon delivery, which is guaranteed by the Government of Canada" (Canadian Wheat Board 1998). This initial payment, which is announced prior to planting, has been historically at about 80-90% of the total payment. It has been argued by many authors that the presence and the level of the guaranteed initial payment have a considerable impact on farmers' planting decisions and on the trading practices of the Canadian Wheat Board. Various explanations for the effects of these policies and Board management have been provided (a recent discussion can be found in Carter and Wilson (1997)). We recapitulate the essentials of these arguments.

First, the initial payment is a signal to the farmers on what the final price is likely to be. But, producers are unaware of the exact level of final price that will be realized with the final payment. This uncertainty for the farmer arises due to a lack of information on the share of the crop that will be sold at different grades, and on the decisions of the CWB on levels of exports in the various segments of the international market. Thus, this initial signal to producers might not reflect the real intentions of the CWB, or the CWB may not be able to fulfill its plan which lead to the initial payment, i.e., the payment scheme is time inconsistent. This will likely distort resource allocation decision of farmers, and in turn lead to decrease in their welfare.

Second, high initial payment announcement (even compared to US border prices) diminishes the incentive of the Canadian farmers to by-pass the CWB, and secures a larger and more predictable supply. This in turn, increases control of the CWB in marketing domestic stocks. Countries, in which the highest priority is food security, will be more likely to contract with the CWB than with other grain traders. This will occur because dealing with the CWB assures the country of a consistent grain supply. Thus, we can view a high guarantee as a credible commitment of the CWB to honor agreements with its trading partners. If this commitment mechanism really works, then it will likely result in welfare increases for Canadian producers. The later follows due to the simple fact that the CWB is presumed to be optimizing in trade and that a mechanism is in place to assure honoring of ex ante commitments (which, since they are optimizing, contributes to the welfare of Canadian farmers).

The orders of magnitudes of these two effects are questions for empirical analysis. The value of the game theoretic framework is to show that the welfare trade-offs are much more subtle than they may at first appear. Clearly, simply taking averages over time of export prices is at best a most crude approximation of the impact of the CWB. Perhaps this is the reason for the different conclusions of available analyses. Added structure will be necessary if there is to be an analysis of the STCs that can stand the light of day in terms of modern economic theory.

Concluding Comments

We have used concepts of modern game theory to treat time inconsistency issues associated with strategic trade. The results are particularly applicable to trade in commodities with production periods that are lengthy, as in agriculture. A game with a sequence of decisions is envisioned, in which an importing firm or country might announce its planned level of import. The producer or suppliers then “invest” by perhaps allocating land to the commodity to be exported. The importer may then change the first decision or be credible and follow through as planned. Clearly, the investment decision of the exporter will be different depending on whether or not the importer’s announcement is believed (high or low in our stylized model). From the results on time consistency, we know that revision or noncommitment can lead to an outcome that is suboptimal compared to the initial (ex ante) decision on announcement. Mechanisms are then explored that impose a “cost” for the failure to honor the initial commitment. An example of such a mechanism in actual trade might be the posting of a bond by one of the parties. Both parties (the STC and its trading partner) gain, if these mechanisms are perfectly enforceable.

We investigated the game in which the parties are assumed to trade for more than one period, and where enforcement mechanisms are absent. Results show that the optimality problems are similar to those for the single stage game, in terms of their time inconsistency implications. Then the sequence of trading decisions or games is examined in which the commitment mechanism is present, but imperfectly enforceable (we represent this by assuming that information on whether a commitment contract will be honored is private information of the STC). This opens the signaling possibilities and the use of experience with previous trading actions to establish reputations. We show that if the parties trade for sufficiently many periods and/or the initial reputation for being commitment type is sufficiently high, then reputation effects dominate the play of the game. Both players gain compared to the case in which the commitment mechanisms are absent. The major applied implication is for a role of some type of authority that could “enforce” announced intentions.

The concepts developed for understanding STC behavior and strategic trade were applied to a stylized version of the CWB policies. Even this cursory application suggests areas of major concern relative to the available assessments of the welfare impacts of the CWB and other STCs. There are two clear welfare impacts, and of opposite sign. The obvious conclusion is that much more sophisticated economic analysis will be required to determine the natural benefits of STCs. Current results simply do not take advantage of the available theory on strategic trade and time inconsistency.

Finally, we observe that the model of strategic trade has required innovations in the game theoretic formulation. The most important of these follow from the personality of the commitment type.

The model provides an important context for exploring impacts of signaling, reputation, and third party interventions that approximate the institutions and authorities that govern international trade.

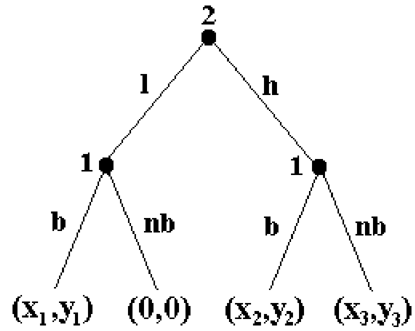

Figure 1. Investment choice - policy implementation sequence.

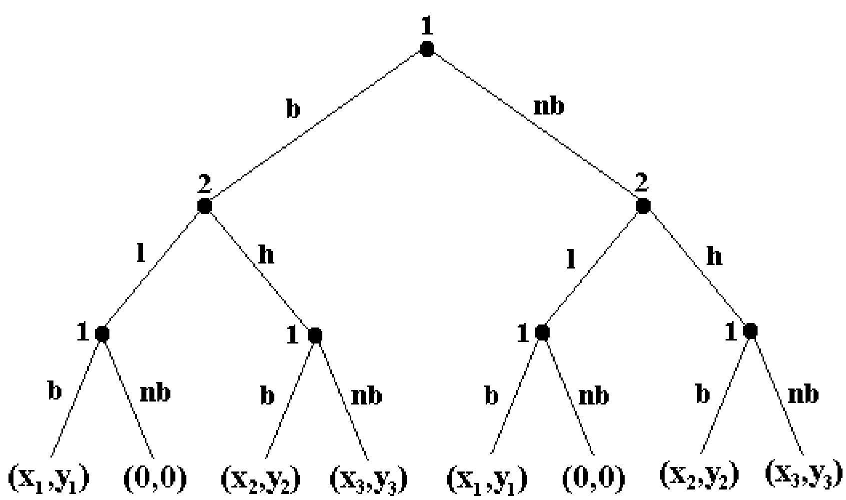

Figure 2. The basic model.

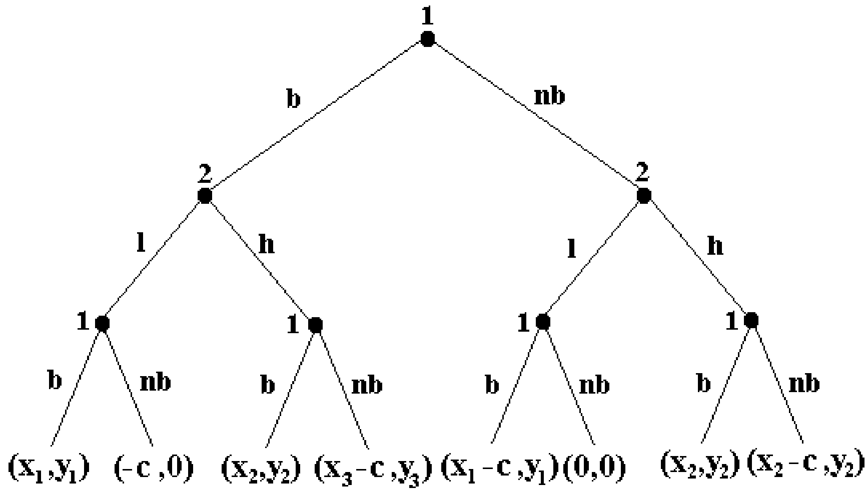

Figure 3. The game with perfectly enforceable commitment mechanism.

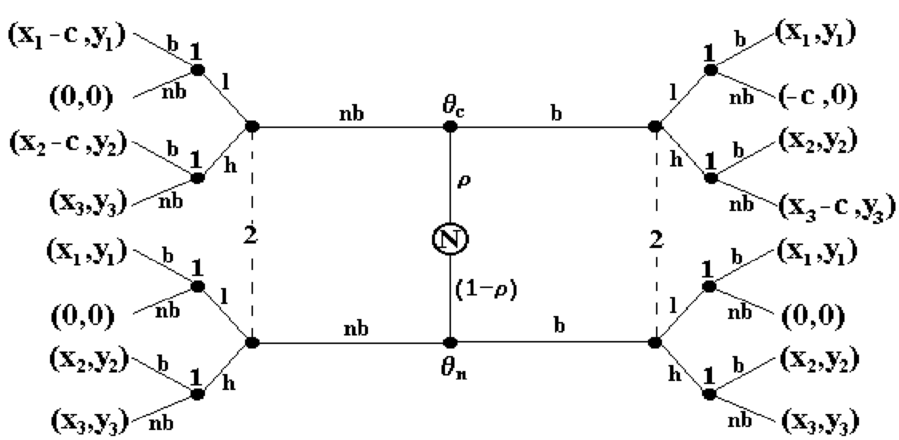

Figure 4. The game with imperfect information.

ENDNOTES

1. In a game of perfect information, players move sequentially and each player knows all previous moves when making his decision, that is, all information sets are singletons. The backward induction argument is: solve for the optimal choice of the last player depending on each possible history of the game, and then solve for the optimal choice of the next to the last mover given that the last mover will make his/her optimal choice.

2. When N=1, this game coincides with the one depicted in Figure 2.

3. For two player games, the sets of coalition-proof and Pareto-undominated equilibria coincide.

4. We do not present an algorithm for finding sequential equilibria of the game since it is similar to the one used to find equilibria of multiple versions of the “chain-store” game (Kreps and Wilson (1982), Milgrom and Roberts (1982)).

5. Beliefs of player 2 about player 1 are such that any failure to implement the policy announced is perceived as a sure sign of noncommitment.

6. Compare our findings with conjectures about what would be the intuitive outcome of the game.

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