Folk Theorems in the Negotiation Game with Transaction Costs

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Even with complete information, two-person bargaining can generate a large number of equilibria and inefficiencies in (i) negotiation games where disagreement payoffs are endogenously determined (Busch and Wen 1995) and (ii) costly bargaining games where there are transaction costs (Anderlini and Felli 2001). This paper considers a model of negotiation with transaction costs. It is shown that, in contrast to the aforementioned analyses, full Folk theorems are obtained in our model.

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I. Introduction

Under well-defined property rights, rational economic agents are expected to bargain and fully exploit any mutual gains from trade. This "Coase theorem" (Coase 1960) provides an important benchmark for economists to consider the potential sources of inefficient outcomes of negotiation. Chief among many explanations for its failure is informational asymmetry, as documented by numerous papers in the literature on bargaining with incomplete information.[1]

Even with complete information, the Coase theorem can be invalid. First, inefficiencies can be sustained as equilibria in negotiation games

[1] For a survey of this literature, see Ausubel, Crampton, and Deneckere (2002).

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with complete information (Haller and Holden 1990; Fernandez and Glazer 1991; Busch and Wen 1995). These models can be regarded either as bargaining games in which disagreement payoffs at each stage of the bargaining are determined endogenously in some game or as repeated games in which an exit option is available at each stage *via* bargaining and contractual agreement. Inefficiencies in these games take the form of delay in agreement and even perpetual disagreement. Similar inefficiencies also arise in complete information bargaining models with small transaction costs (Anderlini and Felli 2001). In these models the players have to incur some (small) cost in order to participate in bargaining; such costs can induce sub-optimality for similar reasons as in the hold-up literature.[2]

In the negotiation model of Busch and Wen (1995) (henceforth, BW), two players bargain in each period — *via* Rubinstein's alternating-offers protocol — over the distribution of a fixed and commonly known *periodic* surplus. If an offer is accepted, the game ends and each player receives his share of the surplus according to the agreement in every period thereafter. After any rejection, but before the game moves to the next period, the players engage in a normal form game to determine their payoffs for the period. The Pareto frontier of this *disagreement game* is contained in the bargaining frontier.

In the bargaining model with transaction costs by Anderlini and Felli (2001) (henceforth, AF), two players bargain in the Rubinstein alternating-offers protocol to split a fixed surplus (which accrues only once and not periodically as in the negotiation game), but at the beginning of each period both players have a choice of whether or not to pay a participation cost. Bargaining in that period takes place only if both players pay the participation cost. If at least one player decides not to pay, the game moves to the next period without bargaining.

BW and AF characterize the set of subgame-perfect equilibria in their models, and show that indeed there can be multiple equilibria. Some of these equilibria involve delay in agreement (even perpetual disagreement) and inefficiency. Thus, the Coase theorem fails in the sense that it is

[2] There are other papers on the inefficiencies in two-person bargaining with complete information. For example, Perry and Reny (1993), and Sákovics (1993) derive the results in bargaining games with endogenous timing of offers. In Fershtman and Seidmann (1993), delay in agreement occurs until a deadline if a player that rejects an offer is subsequently committed not to accept any poorer proposal. A number of multi-person bargaining models also produce inefficiencies. For a recent contribution to this literature, see Chae (2009).

no longer guaranteed. However, in both BW and AF, the precise picture of the equilibrium set depends on the structure of the game considered. For instance, BW's negotiation model admits a unique efficient equilibrium payoff vector if each Nash equilibrium payoff vector of the disagreement game coincides with its minmax point; in AF, if the participation cost is sufficiently large (but still less in sum than the available surplus), the unique equilibrium is for the players never to pay the costs so that agreement is never reached.

In this paper, we extend Anderlini and Felli (2001) into BW's negotiation model by assuming that in order for the players to bargain in each period of the negotiation game (but not to play the disagreement game) both have to pay a participation cost; if at least one player foregoes the payment, they proceed directly to the disagreement game. It turns out that this "costly negotiation game" admits full Folk theorems. With any disagreement game structure, any transaction costs, and sufficiently patient players, not only there are multiple equilibrium outcome paths involving immediate agreement, delays in agreement and perpetual disagreement, one can also show the following: (i) any feasible and individually rational payoffs obtainable in the disagreement game and (ii) any positive payoff profile obtainable in an agreement can be sustained in equilibrium.

The costly negotiation game was in fact first analyzed by Lee and Sabourian (2007). Their objective, however, was to employ complexity considerations to sharpen equilibrium predictions, rather than to derive a full equilibrium payoff characterization without such complexity refinement. Their selection results suggest that transaction costs are a critical ingredient in a robust explanation of bargaining/negotiation inefficiencies with complete information.

The paper is organized as follows. In the next section, we describe BW's negotiation model and equilibrium characterization. Section 3 then introduces the costly negotiation game with the Folk theorem results.

II. The Negotiation Game

Let us formally describe the negotiation game, as defined by BW. There are two players indexed by $i=1,\ 2$. In the alternating-offers protocol, each player in turn proposes a partition of a *periodic* surplus whose value is normalized to one. If the offer is accepted, the game ends and the players share the surplus accordingly at every period indefinitely thereafter. If the offer is rejected, the players engage in a one-shot (normal form) game, called the "disagreement game," before moving onto the next period in which the rejecting player makes a counter-offer.

We index the (potentially infinite) time periods by $t=1, 2, \cdots$ and adopt the convention that player 1 makes offers in odd periods and player 2 makes offers in even periods. Let $\Delta^2 \equiv \{x=(x_1, x_2) \mid \Sigma_i x_i = 1\}$ be a partition of the unit periodic surplus. A period then refers to a single offer $x \in \Delta^2$ by one player, a response made by the other player — acceptance "Y" or rejection "N" — and the play of the disagreement game if the response is rejection. The common discount factor is $\delta \in (0, 1)$.

The disagreement game is a two-player normal form game, defined as

$$G=\{A_1, A_2, u_1(\cdot), u_2(\cdot)\},$$

where A_i is the set of player i's actions and $u_i(\cdot): A_1 \times A_2 \rightarrow R$ is his payoff function in the disagreement game. We denote the set of action profiles in G by $A=A_1 \times A_2$ with its element indexed by a.[3] Let $u(\cdot)=(u_1(\cdot), u_2(\cdot))$ be the vector of payoff functions, and assume that it is bounded. Each player's minmax payoff in G is normalized to zero. Also, we assume that, for any $a \in A$,

$$u_1(a)+u_2(a) \leq 1.$$

Therefore, bargaining offers the players an opportunity to settle on an efficient outcome once and for all.

Two types of outcome paths are possible in the negotiation game; one in which an agreement occurs in a finite time, and one in which disagreement continues perpetually. Let T denote the end of the negotiation game and $a^t \in A$ the disagreement game outcome (action profile) in period $t<T$. If $T=\infty$, we mean an outcome path in which agreement is never reached. Player i's (discounted) *average* payoff in this case is equal to

$$(1-\delta)\sum_{t=1}^{\infty} \delta^{t-1} u_i(a^t).$$

[3] The normal form may involve sequential moves. In this case, A_i represents player i's set of strategies, rather than actions, in the disagreement game.

If $T<\infty$, denote the agreed partition in T by $z=(z_1, z_2)\in\Delta^2$. Player i's payoff from such an outcome path amounts to

$$(1-\delta)\sum_{t=1}^{T-1}\delta^{t-1}u_i(a^t)+\delta^{T-1}z_i.$$

The negotiation game is stationary only every two periods (beginning with an odd one) or "stage." In specifying the players' strategies, we formally distinguish between the different *roles* played by each player in each stage game. He can be either the proposer (p) or the responder (r) in a given period. We index a player's role by k. The role distinction provides a natural framework to capture the structural asymmetry that the alternating-offer bargaining imposes on the repeated (disagreement) game.

In order to define a strategy, we first need to introduce some further notation. We use the following notational convention. Whenever superscripts/subscripts i and j both appear in the same exposition, we mean $i, j=1, 2$ and $i\neq j$. Similarly, whenever we use superscripts/subscripts k and l together, we mean $k, l=p, r$ and $k\neq l$.

We denote by e a history of outcomes in a period of the negotiation game, and this belongs to the set

$$E=\{(x^i,\ Y),\ (x^i,\ N,\ a)\}_{x^i\in\Delta^2,\ a\in A,\ i=1,2}$$

where the superscript i represents the identity of the proposer in the period.

We also need notation to represent the information available to a player *within* a period when it is his turn to take an action given his role. To this end, we define "partial history" (information within a period) d as an element in the following set:

$$D=\{\varnothing,\ (x^i),\ (x^i,\ N)\}_{x^i\in\Delta^2,\ i=1,2}.$$

For example, the null set $\varnothing$ here refers to the beginning of a period at which the proposer has to make an offer; (x^i, N) represents a partial history of an offer x^i by player i, followed by the other player's rejection.

Also, let us define

$D_{ik} \equiv \{d \in D \mid$ it is i's turn to play in role k after d in the period$\}$.

Thus, we have

$$D_{ip} = \{\varnothing,\ (x^i,\ N)\}_{x^i \in \Delta^2}$$

and

$$D_{ir} = \{(x^j),\ (x^j,\ N)\}_{x^j \in \Delta^2}.$$

We denote the set of actions available to player i in the negotiation game by

$$C_i \equiv \Delta^2 \cup Y \cup N \cup A_i.$$

Let us denote by $C_{ik}(d)$ the set of actions available to player i given his role k and a corresponding partial history $d \in D_{ik}$. Thus, we have

$$C_{ip}(d) = \begin{cases} \Delta^2 \text{ if } d = \varnothing \\ A_i \text{ if } d = (x^i, N) \end{cases}$$

and

$$C_{ir}(d) = \begin{cases} \{Y, N\} \text{ if } d = x^j \\ A_i \qquad \text{if } d = (x^j, N). \end{cases}$$

Let

$$H^t = \underbrace{E \times \cdots \times E}_{t \text{ times}}$$

be the set of all possible histories of outcomes over t periods in the negotiation game, excluding those that have resulted in an agreement. The initial history is empty (trivial) and denoted by $H^1 = \varnothing$. Let $H^\infty \equiv \cup_{t=1}^{\infty} H^t$ denote the set of all possible finite period histories.

For the analysis, we divide H^∞ into two smaller subsets according to the different roles that the players play in each stage. Let H^t_{ik} be the set of all possible histories over t periods after which player i's role becomes k. Notice that $H^t_{ik} = H^t_{jl}$. Also, let $H^{\infty}_{ik} = \cup^{\infty}_{t=1} H^t_{ik}$. Thus, $H^{\infty} = H^{\infty}_{ip} \cup H^{\infty}_{ir}$ ($i = 1, 2$).

A strategy for player i is then the function

$$f_i : (H^{\infty}_{ip} \times D_{ip}) \cup (H^{\infty}_{ir} \times D_{ir}) \rightarrow C_i$$

such that for any $(h, d) \in H^{\infty}_{ik} \times D_{ik}$ we have $f_i(h, d) \in C_{ik}(d)$. The set of all strategies for player i is denoted by F_i.

In the spirit of the Folk theorem, BW characterize the set of all subgame-perfect equilibrium (SPE) payoffs of the negotiation game. To this end, BW compute the lower bound of each player's SPE payoff in the negotiation game with discount factor δ.

Define

$$w_j = \max_{a \in A} \left\{ u_j(a) - \left[\max_{a_i' \in A_i} u_i(a_i', a_j) - u_i(a) \right] \right\}$$

which BW assume to be well defined. Note also that $w_i \leq 1$ given the assumption that $u_i(a) \leq 1 \ \forall a \in A$, and $w_i \geq 0$ if G has at least one Nash equilibrium.

Then, the infimum of player i's SPE payoffs in the negotiation game beginning with his offer (given δ) is not less than

$$\underline{v}_i(\delta) = \frac{1 - w_j}{1 + \delta}$$

while the infimum of the other player's SPE payoffs in the same game is not less than

$$\underline{v}_j(\delta) = \frac{\delta(1 - w_i)}{1 + \delta}.$$

BW show that, provided the players are sufficiently patient, there exists an SPE of the negotiation game (beginning with i's offer) in which the players obtain these lower bounds.

Define the limit of these infima as δ goes to unity by

$$\underline{v}_i = \frac{1-w_j}{2} \text{ and } \underline{v}_j = \frac{1-w_i}{2}.$$

We can now formally state BW's main theorem.

BW Theorem For any payoff vector (v_1, v_2) of the negotiation game such that $v_1 > \underline{v}_1$ and $v_2 > \underline{v}_2$, $\exists \overline{\delta} \in (0, 1)$ such that $\forall \delta \in (\overline{\delta}, 1)$, (v_1, v_2) is an SPE payoff vector of the negotiation game with discount factor δ.

The forces of bargaining thus restrict the set of feasible equilibrium payoffs in the negotiation game compared with the set of individually rational payoffs in the disagreement (repeated) game. However, if $\underline{v}_1 + \underline{v}_2 < 1$, the negotiation game has many inefficient subgame-perfect equilibria in a similar way that the Folk theorem characterizes the repeated game (even when the disagreement game payoffs are always uniformly small relative to agreement). The negotiation game has a unique (efficient) SPE payoff if $\underline{v}_1 + \underline{v}_2 = 1$ or $w_1 = w_2 = 0$ which implies that any Nash equilibrium payoff vector of the disagreement game has to coincide with its minmax point.

III. Costly Negotiation

Let us now introduce transaction costs to the setup. Consider the following "costly negotiation game." Extending AF, we assume that at the beginning of every period each player must pay a participation/ transaction cost $\rho \in [0, 1/2]$ to enter the bargaining but *not* the disagreement game. There are several ways to consider how this decision is made. The players can pay the cost either simultaneously or sequentially. This is immaterial. In order to remain synchronized with the sequential structure of the bargaining, we assume that at each period t the proposer first decides whether or not to pay ρ. If he makes the payment, the responder at t then decides whether or not to pay ρ. Bargaining in that period occurs if and only if both players sink the cost; otherwise the players move directly to the disagreement game before reaching the next period.

Let us now modify some notation for the costly negotiation game. Let $\mathcal{I}$ and $\mathcal{N}$ denote a player's decision to pay (participate) and not pay ρ, respectively. For each i, the set of partial histories within a period for a role is now one of the following:

$$D_{ip} = \{\varnothing,\ (\mathcal{I},\ \mathcal{I}),\ (\mathcal{N}),\ (\mathcal{I},\ \mathcal{N}),\ (\mathcal{I},\ \mathcal{I},\ x^i,\ N)\}_{x^i \in \Delta^2}$$
$$D_{ir} = \{(\mathcal{I}),\ (\mathcal{I},\ \mathcal{I},\ x^j),\ (\mathcal{N}),\ (\mathcal{I},\ \mathcal{N}),\ (\mathcal{I},\ \mathcal{I},\ x^j,\ \mathrm{N})\}_{x^j \in \Delta^2},$$

where, for example, $(\mathcal{I},\ \mathcal{I})$ represents the partial history of the sequential payment of the cost by both players. We similarly modify the definition of E, the set of outcomes in a period. The set of player i's actions is now given by $C_i \equiv \mathcal{I} \cup \mathcal{N} \cup \Delta^2 \cup Y \cup N \cup A_i$, and

$$C_{ik}(d) = \begin{cases} \{\mathcal{I}, \mathcal{N}\} & \text{if } k = p \text{ and } d = \varnothing \text{ or if } k = r \text{ and } d = (\mathcal{I}) \\ \Delta^2 & \text{if } k = p \text{ and } d = (\mathcal{I}, \mathcal{I}) \\ \{Y, N\} & \text{if } k = r \text{ and } d \in \{(\mathcal{I}, \mathcal{I}, x^j)\}_{x^j \in \Delta^2} \\ A_i & \text{if } k = p, r \text{ and } d \in \{(\mathcal{N}), (\mathcal{I}, \mathcal{N}), (\mathcal{I}, \mathcal{I}, x, N)\}_{x \in \Delta^2}. \end{cases}$$

With this set of modifications, all previous notation/definitions on histories and strategies also carry to the costly negotiation game.

Next, we define the payoffs. Let ρ_i^t be the (discounted) sum of participation costs that player i incurs between period t and the end of the game T under strategy profile f. Then, we can define player i's (discounted) average continuation payoff at t (given f) as

$$\pi_i^t = \begin{cases} (1-\delta)[\sum_{\tau=t}^{\infty} \delta^{\tau-t} u_i(a^\tau) - \rho_i^t] & \text{if } T = \infty \\ (1-\delta)[\sum_{\tau=t}^{T-1} \delta^{\tau-t} u_i(a^\tau) - \rho_i^t] + \delta^{T-t} z_i & \text{if } t < T < \infty \\ z_i - (1-\delta)\rho & \text{if } t = T < \infty. \end{cases}$$

We now present the main results. BW's Folk theorem-type characterization of the set of SPE payoffs in the negotiation game without transaction costs extends to one with transaction costs. In fact, here one can establish full Folk theorems. First, with transaction costs and sufficiently patient players, not only there are multiple SPE outcome paths involving immediate agreement, delays in agreement and perpetual disagreement, one can also show that any feasible and individually rational payoffs (obtainable by pure strategies) can be sustained in an SPE. With transaction costs the multiplicity problem is worse because of the coordination issue arising from the fact that bargaining can occur if and only if *both* players decide to participate.

Let $m^i = (m_1^i,\ m_2^i) \in A$ denote the pure strategy minmax profile against player i in G (the disagreement game) and define $m=(m_1^2, m_2^1)\in A$ to be the mutual minmax profile; thus $u_i(m)\leq 0$ for all i (recall that each player's minmax payoff in G is zero). Further, let $V=\{u(a)\mid a\in A\}$ be the set of feasible payoffs associated with pure strategy profiles in the disagreement game G.

***Proposition* 1.** *Consider the costly negotiation game. For any $\rho>0$, $\exists\bar{\delta}$ such that, for any $\delta\in(\bar{\delta}, 1)$ and for any $v\in V$ with $v\gg 0$, $\exists$ an SPE with payoffs v.*

Proof. Fix any $\rho>0$ and consider any $v\in\{u(a)\mid a\in A\}$ with $v\gg 0$. Let $a^*\in A$ be such that $u(a^*)=v$.

For any N, let

$$\pi_i(N,\delta)=(1-\delta)\sum_{t=1}^{N}\delta^{t-1}u_i(m)+\delta^N v_i.$$

Fix any N, δ, and $\varepsilon>0$ such that

$$0<\pi_i(\mathrm{N},\ \delta)<\varepsilon<\min\{v_1, v_2, (1-\delta)\rho\}\ \text{for each}\ i. \tag{1}$$

Now, we construct equilibrium strategies with payoffs v. First, let us define the following:

- "Norm": never pay ρ and always play a^* in G.
- "Punishment": never pay ρ and play m for N periods followed by a^* in every period. (Notice that i gets $\pi_i(\mathrm{N},\ \delta)$ in "punishment.")

The strategy profile then is as follows:

(i) Play "norm" unless there is a deviation.

(ii) While playing the "norm," change to "punishment" if the partial history $d=\mathcal{I}$ or $d=(\mathcal{N},\ \mathcal{I})$ is observed (*i.e.*, if exactly one player deviates and pays ρ).

(iii) While playing "norm," change to "punishment" in the next period if a disagreement outcome other than a^* occurs (*i.e.*, if there is a deviation in the disagreement game from a^*).

(iv) While playing "punishment," go back to the beginning of "punishment" if the partial history $d=\mathcal{I}$ or $d=(\mathcal{N},\ \mathcal{I})$ is observed (*i.e.*, if exactly one player deviates and pays ρ).

(v) While playing "punishment," go back to the beginning of the "punishment" next period if there is a deviation in the disagreement game (*i.e.*, if a disagreement outcome other than m occurs in the first N periods of "punishment" or if an outcome other than a^* occurs after the first N periods of the punishment).

(vi) While playing "norm" or "punishment," if both players pay ρ, and i is the proposer, then

(a) i offers $z=(1-\varepsilon, \varepsilon)\in\Delta^2$
(b) j accepts $z'\in\Delta^2$ if and only if $z'_j\geq\varepsilon$
(c) if i makes another offer z' such that $z'_j\geq\varepsilon$ and j rejects, go to "punishment"
(d) if i makes another offer z' such that $z'_j<\varepsilon$ and j rejects, go to "norm."

Let us check for subgame-perfectness of the above profile.

First, note that, by part (ii) and (iv) of the above strategy profile, neither player has an incentive to deviate and pay ρ alone in "norm" or "punishment."

Second, by part (iii) and (v), it is obvious that there is no incentive to deviate from a^* in the disagreement game in "norm" or "punishment."

Third, given part (v), in the first N periods of "punishment" neither player has an incentive to deviate from the mutual minmax profile m in the disagreement game. This is because $\max_{a_i} u_i(a_i, m^i_j)=0<\pi_i(N, \delta)$ for each i, and therefore, such a deviation yields at most $\delta\pi_i(N, \delta)$.

Fourth, given part (vi), if the proposer, say i, pays ρ first then the other player, j, is better off activating "punishment" than following suit and paying ρ. This is because if the game enters punishment then j gets $\pi_j(N, \delta)>0$; if j also pays ρ and then follows the equilibrium strategy (the best he can do) he ends up accepting z and his payoff will be $\varepsilon-(1-\delta)\rho<0$ (by condition (1)).

Finally, consider the behavior in any subgame after both have paid ρ. Assume that i is the proposer in this subgame. If i offers $x\in\Delta^2$ such that $x_j\geq\varepsilon$, then, by (1), it is optimal for j to accept. On the other hand, if i makes a deviating offer z' such that $z'_j<\varepsilon$, then j rejects because, by (1), the payoff he obtains from "norm" v_j exceeds ε. Finally note that it does not pay i to make a deviating offer z' such that $z'_j<\varepsilon$ because i obtains v_i after j's rejection but we have $v_i\leq 1-v_j<1-\varepsilon$.

Notice that this is a Folk theorem for the set of payoffs V associated with only pure strategy profiles in the disagreement game G. In the standard way we can also generalize the statement to the *rational convex hull* of the set V.

Furthermore, we can extend the above result to show that, with sufficiently patient players, any strictly positive payoff profile that can be obtained in an agreement can be supported as equilibrium payoffs. To this end, let $\Delta^2(\rho,\ \delta) \equiv \{x = (x_1 - (1-\delta)\rho,\ x_2 - (1-\delta)\rho) \mid \Sigma_i x_i = 1\}$.

***Proposition* 2.** *For any* $\rho > 0$, *there exists* $\bar{\delta}$ *such that, for any* $\delta \in (\bar{\delta},\ 1)$ *and for any* $v \in \Delta^2(\rho,\ \delta)$ *with* $v \gg 0$, $\exists$ *an SPE with payoffs* v.

Proof. To show this claim, fix any $x = (x_1,\ x_2)$ such that $\Sigma_i x_i = 1$, and modify the Proof of Proposition 1 above by only changing the strategy profile in the Proof such that

- "Norm": both players pay ρ and if i is the proposer
  (i) i offers $x \in \Delta^2$
  (ii) j accepts $z' \in \Delta^2$ if and only if $z'_j \geq x_j$
  (iii) if either player does not pay ρ or if i makes an offer $z' \neq x$ and j rejects, go to "punishment."
- "Punishment": it is the same as in the Proof of Proposition 1 except that we fix N, δ, and $\varepsilon > 0$ such that

$$0 < \pi_i(N,\ \delta) < \varepsilon < \min\{x_1 - (1-\delta)\rho,\ x_2 - (1-\delta)\rho,\ (1-\delta)\rho\}.$$

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