Games and Economic Behavior ••• (••••) •••–•••

Contents lists available at ScienceDirect

Games and Economic Behavior

www.elsevier.com/locate/geb

A one-period memory folk theorem for multilateral bargaining games

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ARTICLE INFO

Article history:
Received 8 November 2013
Available online xxxx

JEL classification:
C72
C78

Keywords:
Dynamic games
Bargaining
Folk theorem
Subgame perfect equilibrium
One-period recall

ABSTRACT

We study strategies with one-period recall in the context of a general class of multilateral bargaining games. A strategy has one-period recall if actions in a particular period are only conditioned on information in the previous and the current period. We show that if players are sufficiently patient, given any proposal in the space of possible agreements, there exists a subgame perfect equilibrium such that the given proposal is made and unanimously accepted in period zero. As a corollary we derive that also perpetual delay can be sustained as a subgame perfect equilibrium. Our strategies are pure and have one-period recall, and we do not make use of a public randomization device. The players' discount factors are allowed to be heterogeneous. We also construct a finite automata representation of our strategy profile.

1. Introduction

One of the most important problems in economic theory is the bargaining problem. The bargaining problem studies how agents make an agreement when they can achieve a particular set of feasible payoffs by collaborating. A bargaining game consists of a sequence of proposals and responses to the proposals. If a proposal is accepted by all the players, the game ends. If a proposal is rejected by at least one player, the game continues and the next proposal is made.

We provide a folk theorem for a general class of multilateral bargaining games. The main result of the paper is that any feasible payoff vector can be sustained as a subgame perfect equilibrium outcome using strategies with one-period recall, provided that the players are sufficiently patient. A strategy profile is said to have one-period recall if the players' actions in any given round of bargaining may only be conditioned on actions in the previous and the current rounds. The constructed strategy profile is pure and we do not rely on a public randomization device to establish our folk theorem. As a corollary we derive that also perpetual delay can be sustained as a subgame perfect equilibrium outcome using strategies with one-period recall. We allow the players to have heterogeneous discount factors.

Folk theorems constitute a class of theorems which state that any individually rational outcome can be sustained as an equilibrium. Early contributions to the folk theorem literature are by Friedman (1971) and by Rubinstein (1979). Fudenberg and Maskin (1986) have proved a folk theorem in repeated games with discounting, where subgame perfect equilibrium is used as the solution concept. Since bargaining games do not belong to the class of repeated games, they are not covered by these results.

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http://dx.doi.org/10.1016/j.geb.2015.11.006
0899-8256/

Fudenberg and Yamamoto (2011) prove a folk theorem for stochastic games generalizing an earlier result by Dutta (1995). A crucial assumption in both contributions is that of irreducibility: starting from any given state, any other state is visited with a positive probability, irrespective of the moves of any particular player. In bargaining games, some of the states are terminal, and the irreducibility condition is clearly violated. Moreover, both Dutta (1995) and Fudenberg and Yamamoto (2011) assume the set of states and the set of actions to be finite, whereas a large part of the bargaining literature studies infinite action sets. The existing folk theorems for repeated games and for stochastic games therefore do not cover the bargaining model.

One of the main results in the field of bargaining has been proved in Rubinstein (1982). Rubinstein (1982) studies two-person alternating offers bargaining and shows that there is a unique subgame perfect equilibrium in this model. In the unique subgame perfect equilibrium, the proposal of the first proposer is immediately accepted by his opponent. The folk theorem does evidently not hold for two-player bargaining games. We therefore study bargaining games with at least three players in this paper.

The proof of Rubinstein (1982) does not work for bargaining problems with more than two players. As reported in Binmore et al. (1992), one of the first extensions to the three-person case was made by Shaked. In Shaked's example, Player 1 starts by making a proposal which describes each player's share of a unit surplus. The other players must accept or reject this proposal sequentially. If the proposal is accepted by all players, it is implemented and the game ends. If the proposal is rejected by one of the players, the next period begins and Player 2 makes a new proposal. Negotiation continues in this way. It is shown that any efficient payoff vector can be supported by a subgame perfect equilibrium if the common discount factor is sufficiently high.

Herrero (1985) obtains a result similar to Shaked for the case with three or more players, though we will explain that the construction used in Herrero (1985) is not complete. Haller (1986) also considers the case with three or more players in a game where players vote simultaneously on a proposal. Haller (1986) shows that any efficient division of a unit surplus can be supported as a subgame perfect equilibrium irrespective of the value of the discount factor. While these papers have identified that the driving force for the multiplicity of equilibrium payoffs is that a responder can be compensated by rejecting a deviating offer, the extent of such multiplicity of equilibrium payoffs in a general setting and the key factors that drive such multiplicity are less clear. It is here that our paper contributes.

All constructions used in the literature so far rely on strategies which require infinite recall for all players. The action of a player in a given time-period depends on the whole history of play. In particular, the strategy of every player at any given time-period depends on the actual play in period zero. Infinite recall allows for the punishment of a player, who has deviated from his strategy only once, during the whole remainder of the game. Several authors have questioned the plausibility of such behavior.

Aumann (1981) discusses some of the options to narrow down the definition of equilibrium to avoid unreasonable predictions and mentions bounded recall as a way of modeling bounded rationality in repeated games. Sabourian (1998) characterizes the set of bounded recall pure subgame perfect equilibria in a repeated game setting without discounting. His results indicate that the equilibrium set expends fast in the length of recall. Cole and Kocherlakota (2005) show in a repeated game context with imperfect public monitoring that for some parameter settings the assumption of bounded recall may reduce the set of equilibrium payoffs to a singleton. To obtain such a result, however, they also make strong symmetry assumptions with respect to the strategies under consideration. Bhaskar et al. (2013) study subgame perfect equilibria in stochastic games that are purifiable and have bounded recall. Equilibrium strategies are purifiable if they also constitute an equilibrium of a perturbed game with independent private payoff perturbations in the sense of Harsanyi (1973). They show that only Markovian equilibria have bounded recall and are purifiable. Barlo et al. (2009) prove that the folk theorem in repeated games continues to hold even if one restricts attention to strategies with one-period recall.

We consider a general specification of the multilateral bargaining model and explore the existence of subgame perfect equilibria under the strong bounded recall restriction that players' actions may only be conditional on actions in the previous and the current period. Our bargaining protocol covers many existing models as special cases. At the beginning of each round of bargaining, nature chooses the proposer and the order of responses as summarized by a permutation of the set of players. We do not place any restrictions on the moves by nature. These moves could be random and depend on the entire history of play. In particular, the bargaining protocol is allowed to have infinite recall. We make only weak assumptions on the set of feasible payoffs and allow for sets that are non-convex or discrete.

Special cases of our bargaining protocol with alternating or rotating proposers are described in Rubinstein (1982) and Herrero (1985). We cover protocols with time-invariant recognition probabilities as studied in Binmore (1987) and Banks and Duggan (2000). Models where the proposer is selected by means of an underlying Markov process generalize these approaches, see Merlo and Wilson (1995), Kalandrakis (2006), and Herings and Predtetchinski (2010), and are also special cases of our bargaining protocol. Part of the literature studies endogenous bargaining protocols, where a player who rejects becomes the next proposer, a bargaining protocol introduced in Selten (1981) and also used in Chatterjee et al. (1993) in coalitional bargaining theory. Our set-up allows for endogenous protocols as well, where not only rejections affect the choice of the next proposer, but also the contents of previous proposals may influence this choice, something which is not covered in the bargaining literature so far.

We allow for heterogeneous discount factors. Unlike the classical folk theorem in Fudenberg and Maskin (1986), where players have identical discount factors, Lehrer and Pauzner (1999) find that in two-player repeated games with heterogeneous discount factors, not all feasible individually rational payoffs can be supported by an equilibrium, even when both

Please cite this article in press as: Herings, P.J.J., et al. A one-period memory folk theorem for multilateral bargaining games. Games Econ. Behav. (2015), http://dx.doi.org/10.1016/j.geb.2015.11.006