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On the use of surplus division to facilitate efficient negotiation in the presence of incomplete information

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Abstract

Classic results in game theory state that private information is a cause for a negotiation to end with suboptimal outcome. Subsequently, private information is a compelling explanation for the frequent occurrence of negotiation breakdowns or costly delays. In this paper, we propose a mechanism for improving efficiency of negotiation outcome for multilateral negotiations with incomplete information (i.e., negotiators holding private information). This objective is achieved by introducing biased distribution of the resulting surplus created by the negotiators' joint offers to prevent negotiators from misrepresenting their valuations of the negotiation outcomes. Our mechanism is based on rewarding concession-making agents with larger shares of the obtainable surplus. We show that the probabilities that the agents with private information make concession are accordingly increased. This allows for better efficiency to be achieved.

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1. Introduction

Conducted experiments have shown that more often than not negotiations reach inefficient compromises[1,2]. In relation to this phenomenon, a central question in research in economics and political science is to understand the difficulties the parties have in reaching mutually beneficial agreements. The classic result discovered by Myerson and Satterthwaite[3] indicates that uncertainty about whether the gains from trade are possible necessarily prevents

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full efficiency. More precisely, their result states that, given two parties with independent private valuations, *ex post* efficiency is attainable if and only if it is common knowledge that gains from trade exist[4].[1]

The above-mentioned theoretical analyses are also consistent with empirical findings by Raiffa[6] and Sebenius[7], in which they provide analyses on the negotiators failure to achieve efficient agreements in practice and their unwillingness to disclose private information due to strategic reasons. For this reason, private information is a compelling explanation for the frequent occurrence of bargaining breakdowns or costly delays. Inefficiencies are a consequence of the incentives to misrepresent a bargainers' valuations between those with private information. The mechanism proposed in this paper aims to remove such incentives by devising ways to distribute the resulting gains from trade in such a way that the bargainer who can still make a concession becomes more willing to actually make that concession.

Most games with incomplete information, i.e., where some or all of the players have private information that is not known to other players, are modeled using some particular information structures and strategic devices to allow agents with private information to perform some action to send out a signal indicating their types.[2] Upon observing the action by the agent with private information, other agents can decide their own best course of actions. In various models of the bargaining problem, several mechanisms have been used to allow negotiators to communicate their private valuations with other parties.[3] These mechanisms include the use of costly delays (i.e., time delays when there are discount factors)[8,9], transaction costs[10], or bargaining deadlines[11,12]. Our approach, on the other hand, applies a mechanism of biased distribution of the observable gains from trade to encourage the parties with private information to truthfully reveal their types. To facilitate this mechanism we employ a negotiation protocol to allow the bargainers to concurrently submit their proposals.

The paper is organised as follows. Section II gives an overview of the multilateral negotiation model, including the negotiation protocol. In Section III, we describe the use of biased surplus division as a strategic device for negotiation with incomplete information, focussing on the case of bilateral negotiation. Our results are extended for the case of multilateral negotiation in the Section IV before we conclude the paper with a discussion.

2. A multilateral negotiation model

Consider the multilateral negotiation as an allocation problem with n agents. Given the set of all possible allocations A, agent i has a valuation $v_i(a, t_i)$ for the allocation $a \in A$ when its type is t_i. Assume that the status quo allocation $\tilde{a} \in A$ defines the agents' reservation utilities. We will normalise each valuation function v_i such that $v_i(\tilde{a}, t_i) = 0$. Assume also that the maximum amount of resource available for this allocation is R. Thus, an allocation $(a_1, \ldots, a_n)$ is ***feasible*** iff $\sum_{i=1}^{n} a_i \leq R$.

If the status quo allocation $\tilde{a} = (\tilde{a}_1, \ldots, \tilde{a}_n)$ is feasible then, gains from trade are possible: $\tilde{G} = R - \sum_{i=1}^{n} \tilde{a}_i$. Because each agent's status quo allocation $\tilde{a}_i$ is her private information, whether or not gains from trade are possible is not common knowledge. According to Myerson and Satterthwaite's[3] result, this source of uncertainty is the cause for negotiation inefficiency. Throughout this paper, we assume that each agent's utility is independent of the allocations received by other agents, and that $\tilde{a}_i < R$; otherwise, agent i would not participate in the negotiation in the first place.

2.1. The negotiation protocol:

The negotiation protocol used in our model is similar to the *Monotonic Concession Protocol*[13,14] which proceeds in rounds. In each round, all agents make simultaneous allocation claims for themselves, i.e. they each claims an allocation a_i ($0 \leq a_i \leq R$). The combination of all claims makes up a potential allocation $a = (a_1, \ldots, a_n)$. If a is a feasible allocation, i.e. $\sum_{i=1}^{n} a_i \leq R$, then an ***agreement*** is reached with each agent being allocated what it claims during this round and the ***observable surplus*** $\sigma = R - \sum_{i=1}^{n} a_i$ will be divided between the agents.

Remark: The surplus to be distributed once an agreement is reached is the *observable gains from trade* based on the agreement which could be smaller than the actual gains from trade $\tilde{G}$.

[1] For a modern development of this result, the reader is referred to[5].
[2] The "type" of a player embodies any private information that is relevant to the player's decision making.
[3] The literature of automated negotiation usually uses the agents' reserve prices to indicate their valuations.