

# Bilateral Bargaining in a One-to-Many Bargaining Setting

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## 1. Introduction

Electronic markets are becoming increasingly transparent with low search cost, strong price competition, and low margins. Automated negotiation enables a business to go beyond price competition. Through the use of autonomous agents, which negotiate on behalf of their owners, a business can obtain flexibility in prices and goods, distinguish between groups of buyers based on their preferences, and even personalize complex goods according to the demands of individual buyers without significantly increasing transaction costs.

We focus here on one-to-many bargaining, where a seller agent negotiates, on behalf of a seller, with many buyer agents individually in a bilateral fashion. In many cases, auctions can be used to effectively organize one-to-many bargaining. For various situations, however, auctions may not be the preferred protocol for bargainers. In situations of, for example, flexible or virtually unlimited supply, multiple issues, and/or continuous sale the appropriate auction protocol becomes, at best, much more complex. Consequently, businesses may opt for the intuitive and flexible bilateral bargaining protocol, where the seller agent negotiates bilaterally with one or more buyers simultaneously by exchanging offers and counter offers.

Only little work has been done to study actual strategies for one-to-many bargaining. For the case of virtually unlimited supply, as for information goods, we present a number of one-to-many bargaining strategies for the seller. These strategies take into account a “fairness” norm whereby buyers are treated in a similar fashion. Preventing unfair outcomes is important for maintaining customer satisfaction, which in turn may be important for a business’ long-term profitability. We compare the performance of the bargaining strategies using an evolutionary simulation, especially for the case of impatient buyers. Several of the developed strategies are able to extract almost all the surplus given sufficient time pressure; they utilize the fact that the setting is one-to-many, even though bargaining is bilateral.

## 2. Bargaining protocol

The seller agent negotiates with many buyer agents simultaneously by alternating proposals and counter proposals. A proposal just states the price for which a bargainer is willing to buy/sell the good, although it can easily be extended to include multiple issues, e.g. see [1, 2]. The bargaining protocol also allows for bargainers to set a delay before responding to a proposal.

## 3. One-to-many bargaining strategies

The challenge is to develop bargaining strategies for the seller that maximize overall revenue by utilizing differences in buyers’ willingness to pay indirectly through their time impatience. The strategies as developed also take into account a notion of fairness: the seller should be indifferent between offers made to different buyers within a reasonable time interval.

The developed seller strategies determine a threshold level which sets the price for new offers and the minimal price for accepting buyer offers. We consider *fixed threshold strategies*, *time-dependent threshold strategies*, and *responsive threshold strategies*. The first type of strategy is introduced for comparison and is unable to utilize a buyer’s time pressure. In case of the second type, on the other hand, the threshold is changed from one period to the next, allowing for indirect price discrimination based on the buyers’ time impatience. The responsive threshold strategy is inspired by the first-price auction. With this strategy, the threshold is set to the highest offer that is submitted within a certain time interval. Unlike the previous strategies, this strategy does not rely on (a-priori) knowledge of buyer preferences. It may become vulnerable, however, whenever groups of buyers experience very little time pressure. To prevent very low prices in case of little or no time pressure, we also introduce combined strategies with either a fixed or time-dependent reservation value (i.e., minimum price level).

In order to benefit from time pressure all the seller strategies introduce a (fixed) delay before responding in case an

offer is below the threshold. If the offer is above the threshold, on the other hand, a seller responds without delay.

## 4. Simulation and results

We apply an evolutionary simulation environment as in [1] to evaluate the performance and robustness of the above negotiation strategies against many learning buyers in case of flexible (or unlimited) supply. The strategy parameters, i.e. a value in case of a (combined) fixed threshold or a piece-wise linear function in case of a (combined) time-based threshold, are learned using an evolutionary algorithm (EA). EAs are a class of search algorithms based on Darwin's theory of variation and natural selection, and are increasingly being used for modeling economic behavior. The strategies of each buyer agent *type* (see below) and the seller agent evolve in a separate EA population to allow heterogeneity of their behavior. Note that the responsive threshold strategy (without reservation value) does not require any learning by the seller agent.

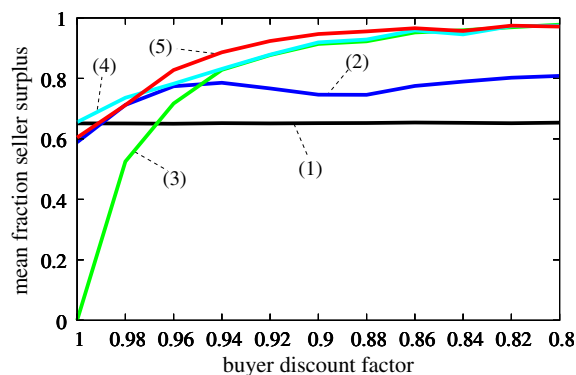
### 4.1. Buyers and their agents

A buyer in the simulation is interested in at most one unit of the offered good in each bargaining game. We consider the case where buyers are impatient and prefer an early agreement. Time pressure is a common assumption in bargaining. The seller agent is simultaneously and continuously negotiating with many buyers and is therefore less concerned with immediately reaching an agreement for a particular bargaining game. Buyers can have different preferences regarding their time pressure and valuation of the good, which together characterize the buyer *type*. For the simulation we have 3 types. The number of buyer agents in a negotiation of each type is randomly determined for each game by a Poisson distribution with average  $\lambda = 10$ .

A buyer agent of type  $i$  tries to maximize the utility  $u_i = (v_i - p)\delta_i^t$  with valuation  $v_i$  of the good, price  $p$ , discount factor  $\delta_i$  and period  $t$ . Negotiations move to the next period whenever the seller agent applies a delay before responding. We assume that, because of the time pressure, buyer agents respond without delay. Buyer agents use a time-dependent threshold strategy as described in Section 3 with an adaptive piece-wise linear function.

### 4.2. Results

The results measure the fraction of the seller's surplus, i.e., the seller's total profit as a fraction of the maximum obtainable profit, after a learning process of 500 generations of the EA, with 200 negotiations per generation. Each negotiation takes up to 40 periods. Results are averaged over the last 1000 negotiations and 30 experiments. Figure 1 shows



**Figure 1. Fraction of seller surplus for different seller threshold strategies: (1) fixed, (2) time-dependent, (3) responsive, (4) combined (3) and (1), and (5) combined (3) and (2).**

the results for various buyer discount factors  $\delta$  (where  $\delta$  is equal for all buyers) and seller threshold strategies.

As shown in Fig. 1, the fixed threshold strategy (1) is able to extract around 65% of the surplus. The time-based threshold strategy (2), however, can obtain higher profits by utilizing the buyers' time pressure. Buyers with a high valuation will purchase relatively early, since waiting for a better deal does not compensate the loss due to time discounting. Note that with no time discounting (i.e., when  $\delta = 1.0$ ) the fixed threshold strategy performs better because of the difference in strategy complexity: a single value is more easily learned than a piece-wise linear function.

Outcomes using the responsive threshold strategies (3), (4) and (5) show an impressive increase in the fraction of surplus when buyers are impatient. For sufficiently high time pressure, the seller obtains almost all surplus, indicating that buyers submit and/or accept offers close to their reservation value. Note that this is achieved while respecting our notion of fairness. The results also show superior performance of the combined responsive strategies if buyers have very little time pressure. This makes the combined strategies very versatile.

## References

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