Collusive Approaches to TAC SCM Customer Auctions

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Abstract

This paper considers the possibility of playing collusive strategies in customer order auctions in the Trading Agent Competition's Supply Chain Management game. In the first half, it describes the structure of the auctions and how agents should consider their valuations of the outcomes. In the second half, it describes ways of colluding based on strategies used in the FCC spectrum auction.

1 Introduction and problem specificaton

1.1 SCM and customer auctions

The Trading Agents Competition was created to encourage research into algorithms and techniques for autonomous agents in complex economic environments. In the Supply Chain Management game 6 agents compete, trying to run a profitable PC assembly business. To do this they have to compete for components and customer orders, both of which are determined by auctions, as well as managing their production and delivery schedules. Although these are all important, this paper will focus on the customer order auctions, which are the easiest to consider in isolation.

Each individual customer auction is a reverse first-price auction. Customers specify a Request for Quote describing the model and quantity of PCs as well as a delivery date and reserve price. The lowest-price bid that satisfies the requirements wins the order. These auctions are both simultaneous and sequential, with over 100 auctions per day, and all auctions being closed and replaced at the end of each day. When the auctions clear, each agent is informed of which auctions they won, as well as the lowest and highest price order for each type of PC. [2]

In addition to this information, agents receive 20-day market reports. For each component class (CPU, motherboard, RAM or hard-drive), these reports list the total quantity ordered as well as the production capacity of the suppliers. They also list the mean price paid for each component type. On the customer side, they list the total quantity of ordered and in RFQs, as well as mean price paid for each PC type. [2]

1.2 Value and Exposure in SCM

Exposure risks play a significant part in any SCM auction strategy. Every individual good in the supplier and customer auctions has negative valuation when taken in isolation: Every component ordered from a supplier has an associated cost to store, as well the cost of interest. Every customer order won includes penalty that will be charged for lateness or non-delivery.

There is a strong complementarity (or super-additive valuation [3]) in these auctions: Agents can only ever generate revenue by getting goods that "match", meaning they win a customer's order as well as all the parts needed to satisfy it. Of course, there's also a strong constraint on timing, where the agent requires a certain amount of time to receive components, assemble and deliver the computers.

There is also a strong substitutability (or sub-additive valuation [3]): agents have limited production capacity. Even if they win perfectly matched sets of components and auctions, there is a point at which they cannot assemble PCs fast enough to fulfill all their commitments. After this point, winning more auctions decreases utility as penalties and storage costs accumulate.

Computing the value of an order is a difficult task because of these exposure risks and the dynamic nature of the markets. Beyond that, there is a problem of externalities that arises from how the competition is run. Although the agents are supposed to maximize profit, the tournament ladder rewards relative performance rather than absolute profits, allowing the 3 highest scoring agents to advance in each group. Thus, agents can have powerful negative externalities with regard to any outcome that is profitable for another agent. These externalities will be strongest in situations where both agents are competing for third place.

2 Collusive approaches

2.1 FCC spectrum auction

In designing a collusive strategy for SCM auctions, it's useful to consider a real-world example of collusion in simultaneous auctions: the FCC spectrum auction. In this auction, companies were competing for the right to be cell-phone carriers in various US cities. This was a straightforward set of simultaneous English auctions, in which agents were permitted to use jump-bids. The auctions cleared simultaneously when there were no more bids in any of them. [4]

2.2 FCC-style collusion

In general, collusion in simultaneous auctions involves deciding on a distribution of goods outside of the mechanism, so they can reduce competition in the actual auction and by this, spend less. Although this distribution is chosen "outside" the mechanism, that doesn't necessarily mean that it can't be decided during the auction, even using the auction as a communication tool.

In the FCC case, agents used threat and retaliation bids to discourage each other from bidding on goods that they had "claimed". These bids are placed on goods that the target values highly, forcing them to pay more. Colluders can encode the object of their claim by timing it right after the target has bid on that good. They can also encode the good number into the trailing digits of their bid. Even without these, the target may be able to infer the contested good based on the identity of the bidder. [4]

Engaging in this type of collusion seems to be a trade-off between "freedom" and "competition-protection". If other members of the cartel avoid an agent's "claimed" goods, he faces less competition which lowers his expected costs. In exchange for this, he sacrifices a certain amount of freedom to bid on other auctions. Depending on the valuations of agents, this trade-off can often be profitable.

As it turns out, this style of collusion can be very successful. It is robust in the sense that it had a positive effect despite having relatively few participants (6 agents out of 153). It was very profitable in the sense that the agents that did participant in the cartel were far more successful than those that did not, paying $2.50/person compared with $4.34/person. (The value of a right to broadcast is generally measured by population of the area it covers.) They also won a significant portion of the goods: 476 out of 1479. [4]

2.3 Differences from SCM

Unfortunately for would-be colluders, SCM doesn't provide nearly as much information as the FCC auction and differs in some other important aspects. Firstly, auctions are sealed bid, which means that threatening and retaliating bids can't happen directly: if one agent wants to threaten another agent away from a good he wants, there is no way to do that directly within the auction. Secondly, the winner and winning bid aren't announced, agents would have a very hard time of knowing whether their threats had the intended effect. Thirdly, because auctions don't close simultaneously as in FCC, there is the chance that all the best auctions for retaliation have already closed.

2.4 Communication options for SCM

All these constraints make collusion much more difficult, but it is worth mentioning that communication in SCM is still possible. The format of the competition, with agents running at remote locations and connected through the internet, makes it possible for agents to communicate outside of the game. This would probably be taken very poorly by the TAC community because it violates the spirit of the rules. Also, in real-world situations where collusion is often illegal, direct communication is very risky.

Although it might be possible to communicate through actions in the supplier auction mechanism, this approach has many disadvantages. The first is that any message will have a significant noise component, as the sender will need to influence the going price in supplier-component auction, which is an aggregate statistic of the supply and the demand from all agents. The second is that there will likely be a considerable expense to the sender, who must significantly change their behavior in one of the 16 auctions in order to make an observable effect. Lastly, since these changes affect the actual price that other agents must pay, any agent who is able and willing can probably have a more significant effect from strategic market disruption than from collusion. Instead of trying to influence prices, the sender could try to communicate by influencing the aggregate statistics in the 20-day reports, but this would be even noisier and more expensive.

A more realistic scenario involves communicating through the minimum-bid reports on the customer side, which is the only commonly-visible value that any agent can directly manipulate. As in the FCC auction, they can use the dollar value of the bid to express other information. This method has several disadvantages however: Firstly, these messages involve a direct cost to the sender, who must sell goods at less than the going rate, or pay a non-delivery penalty. Secondly, there is a probabilistic, but very constrictive bound on the bandwidth: the more bits a message contains, the higher its value, making it more likely to be obscured by a real low-value bid. Thirdly, all agents must share this communication channel: all agents must pay the expense of sending, but only the numerically-lowest message (which is likely to cost most) will be broadcast.

This communication channel does have a few advantages however: Firstly, although the number of bits is limited, a SKU can be specified for "free" because the minimum bid is reported for each SKU. Secondly, ignoring the communication aspect bidding low is still sometimes rational, such as when trying to disrupt a market. A well-designed communication protocol would exploit both of these features.

2.5 Enforceability of FCC-style collusion in SCM

One concern when designing any method of collusion is whether or not there is any incentive for members of the cartel to defect. In this case, it seems that there would be: the defector could keep the rest of the cartel from his claimed auctions, while freely bidding on auctions claimed by other cartel members. The remaining members of the cartel would be at a disadvantage as they would be honoring the defectors claims while not gaining any benefits. This reduces to a Prisoner's Dilemma situation, finitely repeated. (Figure 1.) Therefore, backwards induction implies all members of the cartel would prefer to defect. [1] A small mercy is that the Nash Equilibrium (where everyone defects) is no worse than playing without colluding, modulo the cost of communicating.

> "Now I know what you're going to say, but stick with me, my story gets better." - Eddie Izzard.

It might be plausible to believe that agents could treat this as an infinitely-repeating game, and play a trigger or tit-for-tat strategy. (Human players often

		Player 2	
		Collude	Defect
Player 1	Collude	Protection, Protection	Nothing, Protection+Freedom
	Defect	Protection+Freedom, Nothing	Freedom, Freedom

Figure 1: Prisoner's Dilemma model of collusion: Protection+freedom > protection > freedom > nothing

act this way rather than playing the backwards-induced strategy, and actually earn more utility doing this.) This has nearly the same worst-case expected utility as always defecting and much better expected utility when played against itself. Unfortunately, to play such reactive strategies, the cartel members need to recognize defectors. An agent only ever finds out whether it won or lost an auction, not by how much or to whom. As such, the only way to figure out whether an agent has defected is by probabilistic inference in an extremely noisy environment. It would likely take several rounds of inference for the cartel to detect a defector with any confidence.

Although this seems to be incredibly damning, there is hope in the form of externalities. Firstly, as mentioned before multiple agents can win and advance to the next round. An agent that defects is more likely to advance, but at the expense of the cartel. In the next round, that agent won't be able to collude and will be in a more competitive scenario. This also functions as a form of trigger strategy, where agents defecting in this round decrease their odds of being able to collude in the next. Only in situations where two members of the cartel are competing for third place, is this relevant.

The second reason is that the agent developers might have good reason for wanting their agents not to defect, such as all agents being made by one team, or the developers wanting to co-author a paper on collusion in the SCM, which is likely to be a very publishable topic.

2.6 Set-your-own-hair-on-fire collusion

If we assume that multiple agents are representing a single interest, more extreme forms of collusion are possible. If one agent (the "martyr") is willing to sacrifice itself for the benefit of the other (the "champion"), the potential value – in the form of harm to other agents – is enormous. The champion behaves exactly as he did in the case of FCC collusion. The martyr honors all of the champion's claims, giving him the benefit of protection. In all auctions that the champion is avoiding, the martyr can be as disruptive as possible. Having no self-interest, the martyr can bid arbitrarily low denying the other agents revenue.

3 Conclusion

Although there are a number of significant obstacles not present in the FCC auctions, collusion in TAC SCM still seems feasible, particularly in the case where multiple agents are representing the interest of a single party (a quite plausible real-world situation). Future work should focus on implementing an agent to test these ideas in practice. There are a number of ways in which this research could be extended, such as extending the collusion to cover supplier side auctions. Also, more should be done to consider strategies another agent could use to exploit the cartel upon discovering it, and strategies the cartel could use to protect itself from this exploitation.

References

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