A Modified Vickrey Auction with Regret Minimization for Uniform Alliance Decisions

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Overview

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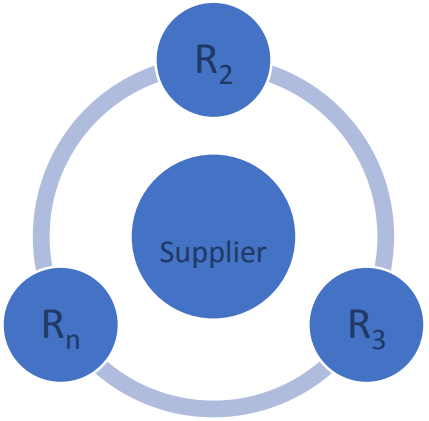
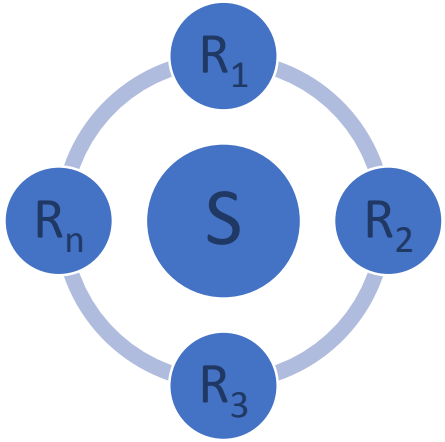


Introduction

Supply chain management problem

- Selecting **a unique large supplier** for a group of **multiple small retailers**.

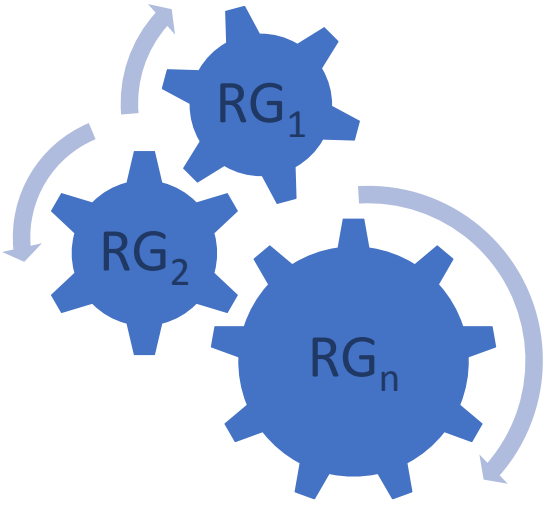


Assumptions

- Self-interested retailers grouped based on the similarity of their utility functions;
- More large size suppliers, each endowed with complementary or substitutable products;
- Suppliers deliver only large size shipments.
- Self-interested group members have no insight into the preference orders of each other

Introduction (cont.d)

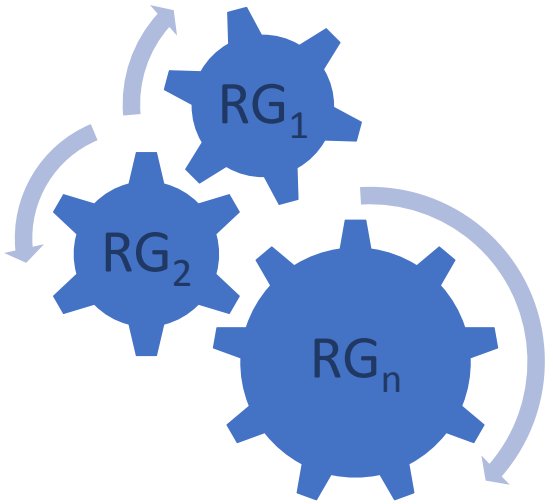
- Unfair group supplier assignment: an incentive for unsatisfied retailers to give up the group commitment.
- Required: Mechanisms showing favoritism towards the least happy alliance members, thus resulting in the favorable conditions for alliance stability.



- Classical coalition formation and matching algorithms inappropriate: **system focus**
- Collective choice problem, similarities with the election of a president through citizens voting.

Scientific question

- Given that alliance members want to hide sensitive information from each other, we consider the following question in selecting a unique large supplier for an alliance of small retailers:



Should the alliance members reveal cardinal information or revealing the ordinal preferences over alternatives is sufficient to achieve a fair and efficient assignment of a uniform task to the alliance?

Solution approach

- Proposed market-based method: **modified Vickrey auction** with regret minimization.
- Scope of regret minimization: a **fair solution** achievement.

Research objective:

- Investigate fairness and the efficiency of Vickrey, modified Vickrey and voting method in this setting
- Compare the results in terms of **utilitarian**, **egalitarian**, **elitist** and **Nash** social welfare.

Vickrey auction (VA)

- Essentially the only design to provide dominant strategy incentives and yield efficient auction outcomes. Theorems in Green and Laffont [8] and Holmstrom [10]
- Bidders have an incentive to bid truthfully in this type of auction,
- It is the quickest and most likely to achieve **Pareto efficiency** and profit maximisation as a result. Furthermore, in the jargon of game theory, bidding truthfully is **a dominant strategy.**
- If all players bid truthfully, then the VA maximizes the social surplus.
- VA is **computationally tractable** and it can be implemented in **polynomial time**.

Vickrey auction (VA)

- VA resolving this problem in a distributed way for self-interested agents.
- **Two stages**: bidding and assignment.
- **Bidders**: retailers within the alliance.
- Objective: minimize their total individual costs.
- In a bidding phase, bidders $a_i \in A$ submit to the auctioneer in **a sealed bid** their full list of costs $c_{ai,\,\Theta A}$ for a set of suppliers Θ_A without knowledge of other bids.
- In the assignment phase, auctioneer calculates **alliance total cost** $c_{A,\,\vartheta}$ for every supplier in the alliance, and assigns the alliance to the supplier with the least total cost.
- Alliance total cost $c_{A,\,\vartheta}$ is measured as a sum of the individual bidders' costs for each bidder $\vartheta \in \Theta$.

- The lowest cost bidder wins, paying a price equal to **the second-lowest bid**.

Vickrey rules

- For the services of the assigned supplier to the alliance, each member of the alliance $a_i \in A$ pays an individual price p_i which is calculated based on the **Vickrey rules**.

$$p_i = c_{a\vartheta} + (C - C^{-i})$$

- C^{-i} - the total cost that could be generated if a_i did not participate, and the auctioneer allocated (not necessarily the same) supplier to the rest of the bidders to minimize total group assignment cost.
- β-unsatisfied agents: individual cost exceeds the best assignment cost by more than ratio $\beta > 1$.

Regret

- **Regret**: calculates the difference between the utilities of two choices or outcomes.
- **Regret theory** models how choices can be made under uncertainty by minimising the maximal possible regret that can be incurred by a choice.

- We propose the modification of Vickrey rules by the integration of regret which is seen here as an opportunistic cost of

  β -unsatisfied agents for the alliance assignment.

Alliance is stable if all the members are β -satisfied with the assignment and the alliance profit is strictly positive.

Modified Vickrey Rules

Regret: an opportunistic cost of β-unsatisfied agents:

$$r(a_i, \vartheta_A) = c_{ai,\, \vartheta A} + (C - C^{-i}) - c_{ai}^{q}$$

where $c_{ai}^{q} = \beta_i\, c_{ai,\, \vartheta imin}$ is a qualifying supplier cost for agent a_i and

$c_{ai,\, \vartheta imin} = \min c_{ai,\, \vartheta A}$ is the cost of individually optimal supplier for agent a_i

Payment $p(a_i)$ for each β -unsatisfied agent a_i is lowered by the value sufficient to reach **its minimally acceptable group assignment** solution,

$$p(a_i) = c_{(ai,\, \vartheta A)} + (C - C^{-i}) - r(a_i, \vartheta_A)$$

The total regret of unsatisfied agents is *distributively* paid by satisfied ones as an **additional cost** to their **Vickrey payment** $p(a_i)$ controlling that satisfied agents don't become unsatisfied due to the additional payments .

Voting with Borda count

- Voting is a general group option-choosing method for societies of self interested agents
- Formally, a voting problem is specified by a non-empty set of social options *O* and a set $A=[a_1, \ldots, a_n]$ of at least two agents.
- Each agent $a \in A$ reports his/her preferences over elements in *O*, which are represented by **a complete, transitive preference relation**.
- The choice of voting rule is determined by the nature of the problem.

Voting with Borda count (cont.d)

- We use **the Borda count scoring rule** that considers not only who the top ranked candidate is, like the plurality rule and the fallback bargaining rule, but also how strongly a candidate is preferred in respect to other candidates.

- An additional advantage of the Borda count rule is the **low computational complexity** of the winner determination

Simulation setup

- Experiments performed for the group of *100* retailer agents and *100* suppliers
- Costs based on **Euclidian distances** from their to the suppliers positions
- **Initial agent positions** generated **uniformly randomly** in the range $[0,100]^2$
- The average values for 10 different instances are presented

Experiment Results

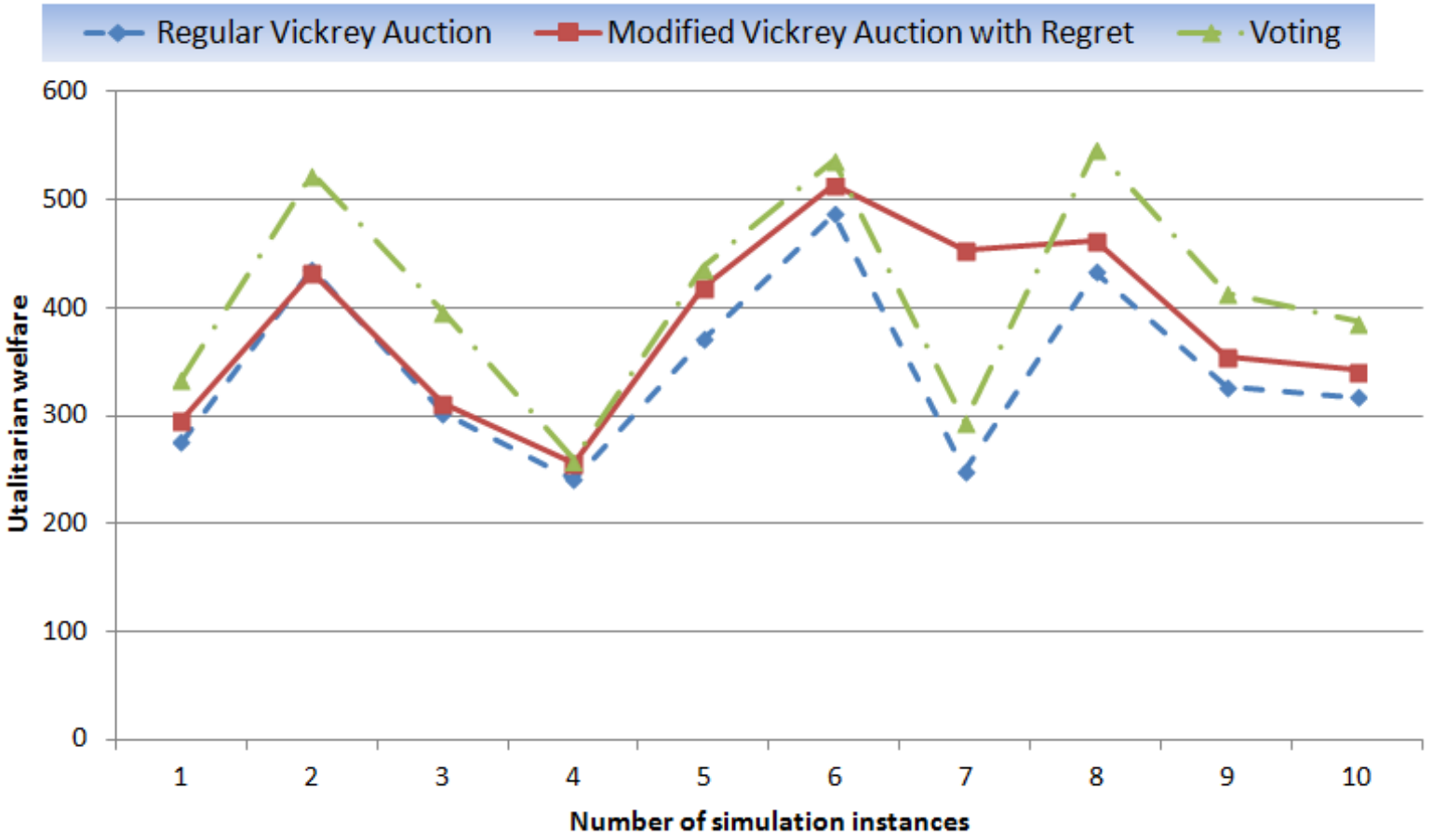


Figure 1. Utilitarian welfare

Experiment Results

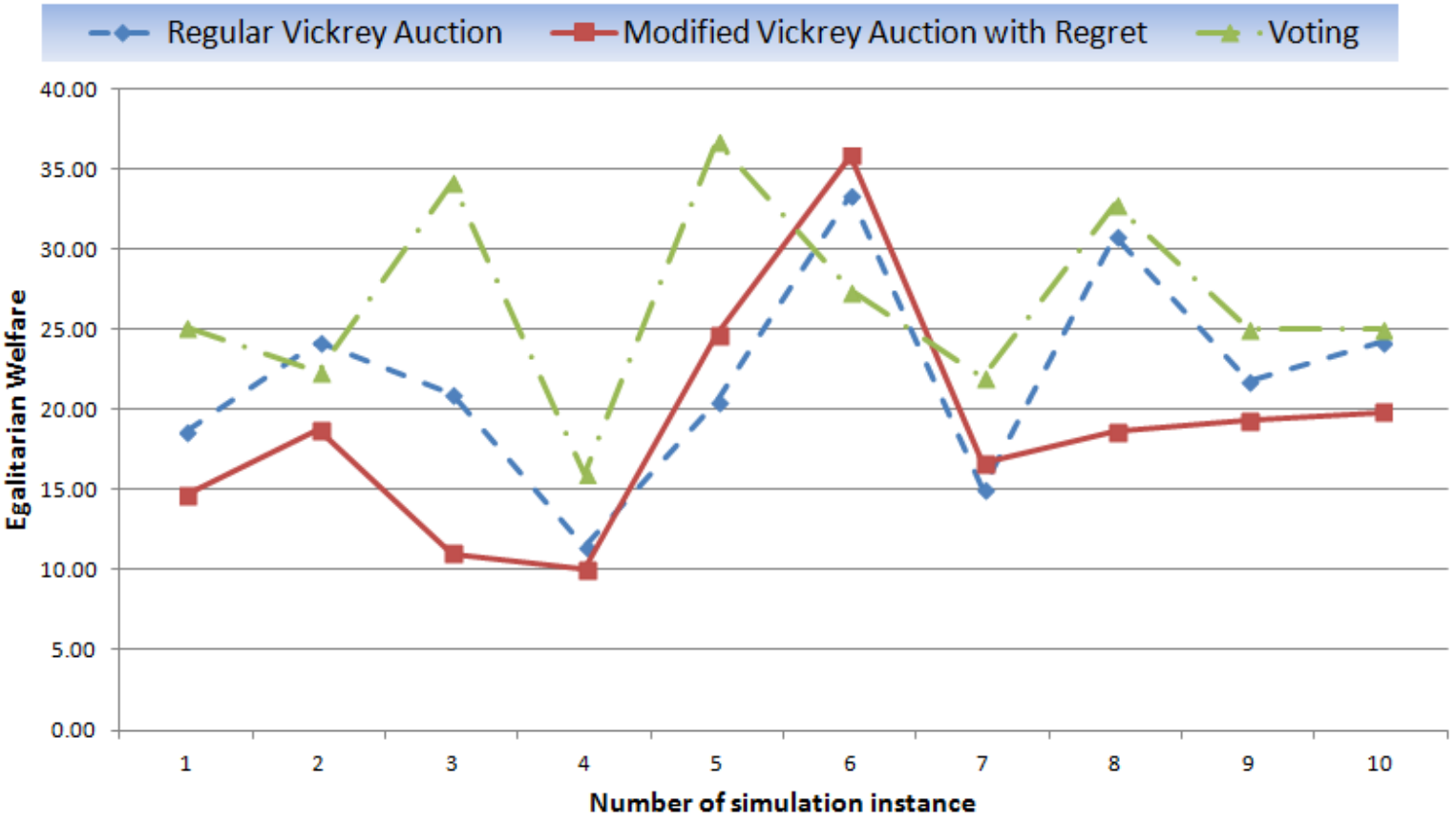


Figure 2. Egalitarian welfare

Experiment Results (cont.d)

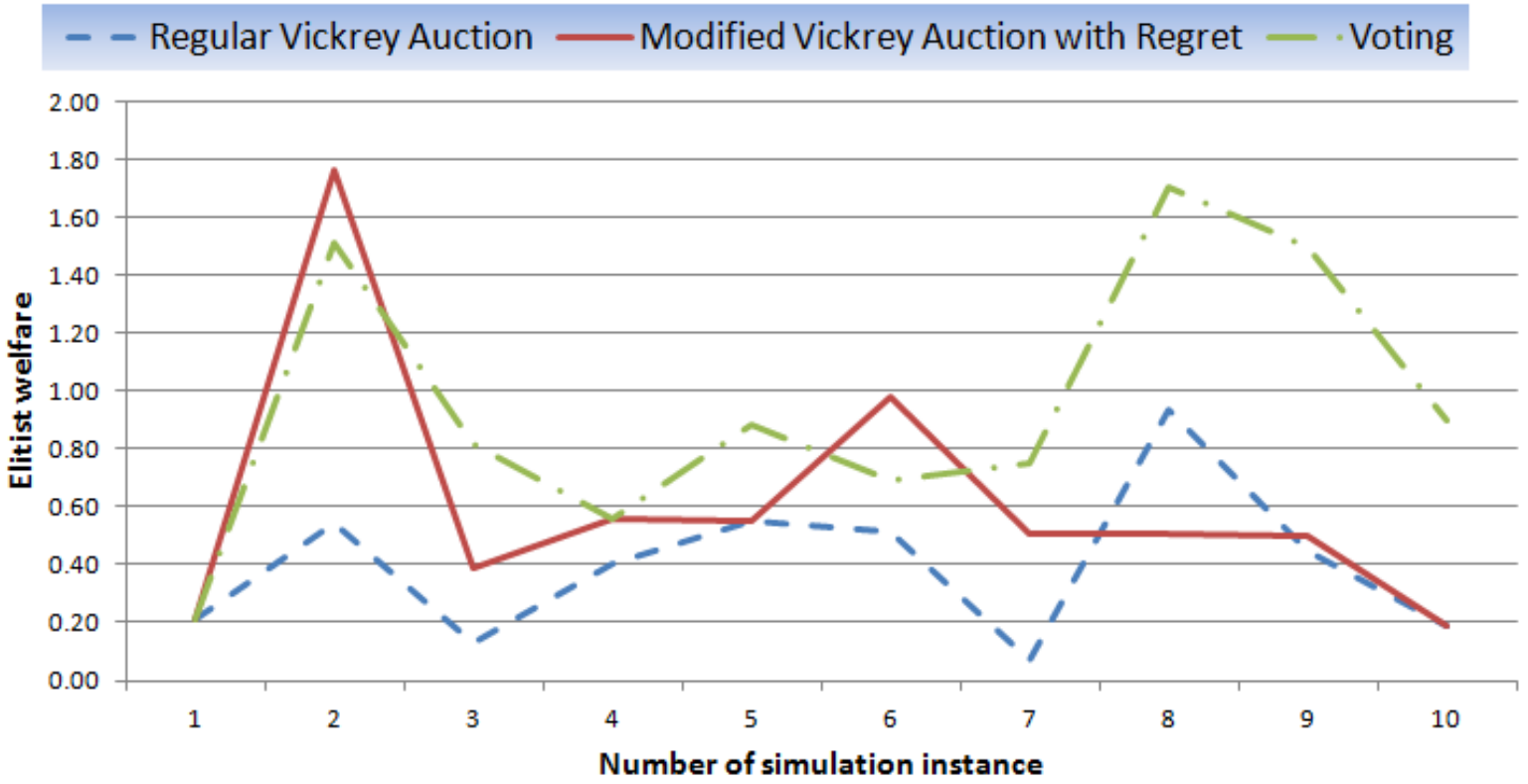


Figure 3. Elitist welfare

Experiment Results (cont.d)

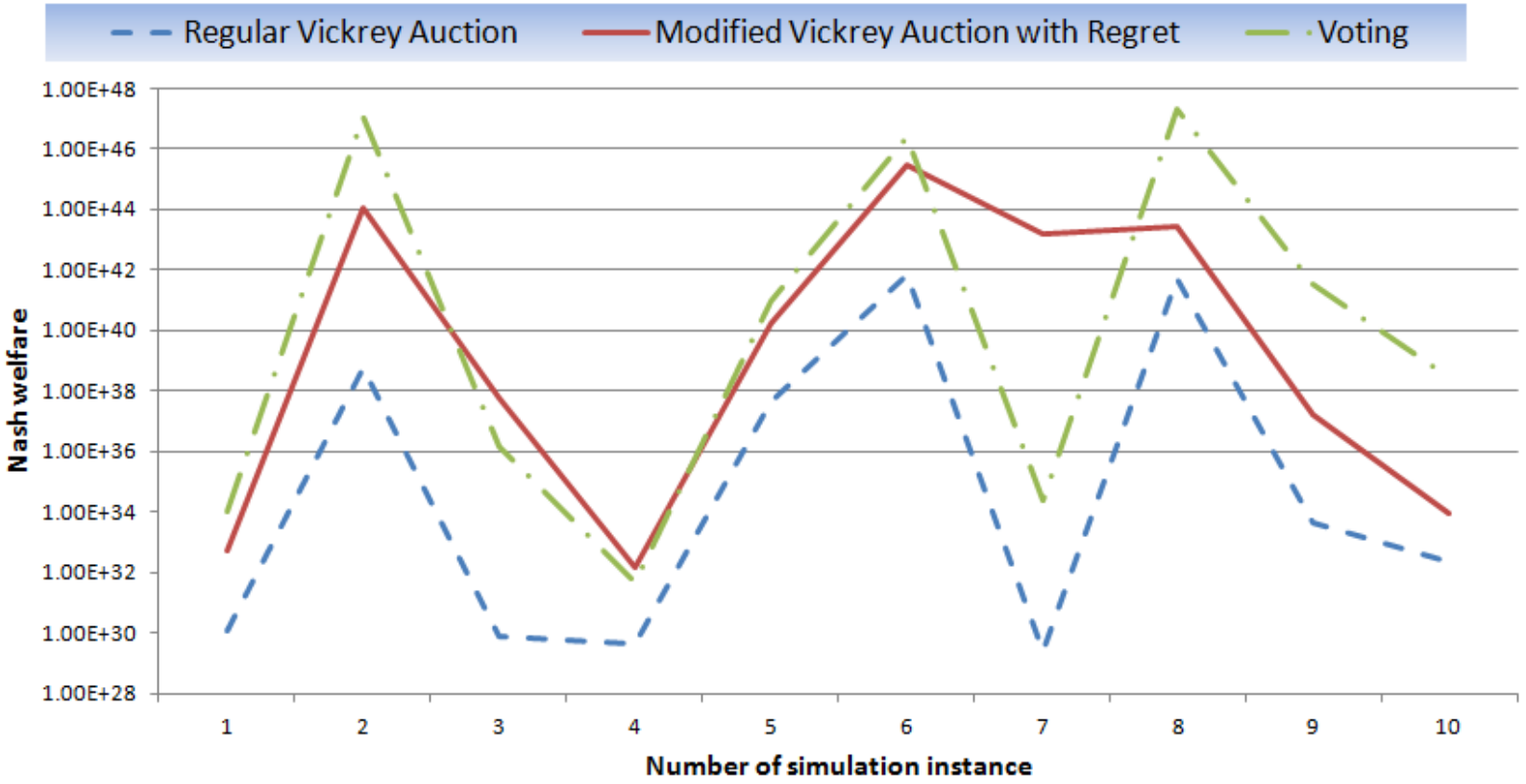


Figure 4. Nash welfare

Conclusions

- Due to the inclusion of regret in the bid calculation, the egalitarian welfare of the Vickrey auction with regret is in average better than the one of the original Vickrey auction.
- Other social welfares of the Vickrey and the modified Vickrey auction are on average similar
- Voting method requesting ordinal preference values has inferior behavior on average in respect to the other two methods

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Thank You for your attention!