An Experimental Study of House Allocation Mechanisms*

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Abstract

We report an experiment on three house allocation mechanisms under complete information: the random serial dictatorship with squatting rights, and two variants of the top trading cycles mechanism. Results show that the latter two are significantly more efficient than the former.

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1 Introduction

A house allocation mechanism assigns a set of houses to a set of agents, allotting at most one house to each agent. Rents are exogenously given and there is no medium of exchange, such as money. The canonical examples are dormitory room allocation for college students and public housing. In general some houses have existing tenants, some houses are empty. Some applicants will be new, for example, freshmen.

Many universities in the U.S. employ some variant of a mechanism called the *random serial dictatorship with squatting rights* (RSD) to allocate dormitory rooms. Each existing tenant can either keep her house or enter the applicant pool. Each applicant is randomly given a priority and each is assigned, in priority order, her top choice among the houses that remain. This mechanism is strategy-proof: for each applicant, reporting her true preferences is a dominant strategy. An existing tenant who enters the lottery may end up with a house less preferred than her current house and therefore this mechanism is not individually rational. Consequently not every existing tenant will join the applicant pool and potential gains from trade is lost. Therefore RSD is not Pareto efficient.

Abdulkadiroğlu and Sönmez [1999] propose a simple alternative, the top trading cycles (TTC) mechanism. Applicants are again prioritized and are given their top choice in priority order. This continues until someone requests an existing tenant's house. In this case, the existing tenant is moved to the top of the priority queue, directly in front of the requester. This is repeated any time an existing tenant's house is requested. If a cycle of requests is formed (e.g., I want John's house, John wants your house, and you want my house), all members of the cycle are given what they want, and their new houses are removed from the system. The key innovation is that an existing tenant whose current house is requested is upgraded to the first place at the remaining of the line before her house is allocated. As a result the TTC mechanism is individually rational. It is also strategy-proof and Pareto efficient.

In theory TTC has better efficiency properties than RSD when all agents are perfectly rational. However, it is not clear whether it remains superior in practice with boundedly rational agents. We use laboratory experiments to evaluate the performance of the mechanisms.

Since the solution concept is dominant strategy, it is robust to the information specifications. In a companion paper, Chen and Sönmez (forthcoming) implement RSD and a variant of TTC under *incomplete information*. This paper serves as a robustness check, where we conducted a series of experiments to evaluate the performance of RSD, TTC, and a variant of TTC called TTC-opt under *complete information*. The latter environment is important, as in some real world applications, agents might know each other's preferences well.

2 Experimental Design

We design the simplest possible environment which captures the key aspects of the house allocation problem. We consider an environment with three agents: an existing tenant and two newcomers. There are two houses to allocate: House A and House B. The existing tenant currently occupies House A. House B is vacant. Preferences are induced by the following payoff table:

	A	B	No house
Existing Tenant	\$10	\$15	\$3
Newcomer 1	\$10	\$4	\$3
Newcomer 2	\$10	\$15	\$3

These payoffs are chosen for the following considerations. First, there are four Pareto efficient house allocations for the chosen problem. In general the aggregate utility can differ at different Pareto efficient allocations. In our case, however, the aggregate utility is 28 at each of these allocations. This conveniently gives us a reference point for full efficiency. Second, the environment slightly favors the RSD mechanism. If the existing tenant is an expected payoff maximizer then she has a slight preference for entering the lottery. Since the inefficiency of RSD results from the possibility that the existing tenant opts out, this design choice is favorible for RSD. Our results suggest that RSD causes significant efficiency loss even under this preferential treatment.

In this environment we test three mechanisms: RSD and two versions of TTC. In the first version, the existing tenant is explicitly given an option to keep her house and not enter the lottery (TTC-opt). In the second version, the existing tenant is not given such an option, but of course she can rank her house as her top choice and receive it with certainty (TTC). Since TTC guarantees each existing tenant a house that is no worse than her current house, in theory the outcomes of TTC and TTC-opt should be the same.

We conducted a total of twenty-six independent sessions in February and March 1999 at the University of Michigan. These include nine sessions for RSD, nine for TTC and eight for TTC-opt. All sessions were conducted by hand. Our subjects were undergraduate students from introductory economic principles' class at the University of Michigan with one exception. Newcomer 2 in Session 3 of RSD was a graduate student. No subject was used in more than one session. This gives us a total of 78 subjects.

Each session consisted of one round only. All three mechanisms were implemented as one-shot games of complete information. Subjects knew the complete payoff table as well as the mechanisms used to allocate the houses. The sessions lasted for about half an hour, with the first fifteen minutes being used for instructions. The conversion rate was \$1 for all sessions. Each subject also received a participation fee of \$3 in addition to their earnings from the experiments. The average earning (including participation fee) was \$11.70 for 30 minutes.

3 Results

Two questions are important in evaluating the mechanisms. The first is the efficiency of the mechanisms. The second is whether individuals play their dominant strategies.

To evaluate the aggregate performance of the mechanisms, we compare the efficiency generated by the three mechanisms. Efficiency is calculated by taking the ratio of the sum of the actual earnings of all subjects in a session and the Pareto-optimal earnings of the group. The qualitative result stays the same if expected efficiency is considered instead of observed efficiency.

RESULT 1 (Efficiency) : *The efficiency of either TTC or TTC-opt is significantly higher than that of RSD.*

SUPPORT. All sessions of TTC and TTC-opt generate 100% efficiency. Under RSD, five sessions generate 100% efficiency, while four sessions generate 61% efficiency. Permutation tests show that the efficiency of TTC (or TTC-opt) is significantly larger than the efficiency of RSD ($p = 0.0147$, one-tailed).

The reason for the loss of efficiency in RSD is the existing tenants who opted out. For RSD participation is not a dominant strategy for the existing tenant although our choice of parameters slightly favors participation for risk neutral agents. For TTC-opt, however, opting out is a dominated strategy.

RESULT 2 (Participation) : *Existing tenants under TTC-opt are significantly more likely to participate than those under RSD.*

SUPPORT. The existing tenants' participation rate is 100% under TTC-opt, but only 33.3% under RSD. A t-test of proportions yields $z = 3$, $p < 0.01$ (one-tailed).

Once the existing tenant decides to participate, then truthful preference revelation is a dominant strategy for each of the three mechanisms considered. However, as many experiments have shown that subjects do not always play dominant strategies.

RESULT 3 (Truthful Preference Revelation) : *The differences in the proportions of truthful preference revelation under each of the three mechanisms are not statistically significant.*

SUPPORT. Under RSD 100% of the subjects revealed their preferences truthfully. Under TTC, 100% of the existing tenants and newcomer 1's revealed their preferences truthfully, while 78% of the newcomer 2's revealed their preferences truthfully. Under TTC-opt, 89% of the existing tenants (newcomer 1's), 75% of the newcomer 2's revealed their preferences truthfully. Let T_i be the probability that agents reveal their preferences truthfully under mechanism i. T-tests of proportions yield the following statistics: $H_0 : T_r = T_t$ against $H_1 : T_r > T_t$ yields $z = 1.27$ ($p > .10$); $H_0 : T_r = T_y$ against $H_1 : T_r > T_y$ yields $z = 1.41$ ($p > .05$); and $H_0 : T_t = T_y$ against $H_1 : T_t > T_y$ yields $z = 0.92$ ($p > .10$).

4 Conclusion

In theory TTC has better efficiency properties than RSD whether the environment is complete information or incomplete information. Chen & Sönmez (forthcoming) show that even with boundedly rational agents TTC remains more efficient provided that the environment is incomplete information. This experiment completes this program by showing that all qualititative results of Chen & Sönmez (forthcoming) remain the same in a complete information environment as well. We now have added reason to believe that replacing RSD with TTC in practice might significantly improve allocation efficiency.

References

Abdulkadiroğlu, A. & T. Sönmez [1999]. "House Allocation with Existing Tenants," *Journal of Economic Theory* 88, 233-260.

Chen, Y. & T. Sönmez [forthcoming]. "Improving Efficiency of On-Campus Housing: An Experimental Study." *American Economic Review.*

Reviewers' Appendix. Experimental Instructions

The complete instructions for RSD (Mechanism R) are shown here. For TTC-opt (Mechanism Y) and TTC (Mechanism T), only the parts of the instructions, which differ from those of RSD, are shown here.

Instructions - Mechanism R

This is an experiment in the economics of decision making. The instructions are simple, and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you in cash at the end of the experiment. In this experiment we are going to simulate a house allocation process. The procedure, allocation method, and payment rules will be described in detail below. The Decision Sheet in your envelope is for your own private use. Do not reveal it to anyone. Do not communicate with each other during the experiment. If you have any questions, raise your hand and the experimenter will come and help you.

Procedure

- There are three participants in each group:
  - An Existing Tenant
  - A Newcomer 1
  - A Newcomer 2

  The Decision Sheet inside your envelope tells you who you are.

- There are two houses to allocate: house A and house B. House A currently belongs to the Existing Tenant. House B is vacant. **Each house can only be allocated to one participant**. Therefore, one of the participants needs to be left without a house.

- **Your payoff** depends on the house you hold at the end of the experiment and it is given in the following table.

	A	B	Nothing
Existing Tenant	$10	$15	$3
Newcomer 1	$10	$4	$3
Newcomer 2	$10	$15	$3

  Therefore, if you are the Existing Tenant, you will be paid $10 at the end of the experiment if you get house A, $15 if you get house B and $3 if you get nothing. If you are Newcomer 1, you will be paid $10 if you get house A, $4 if you get house B and $3 if you get nothing. If you are Newcomer 2, you will get $10 if you get house A, $15 if you get house B and $3 if you get nothing.

- During the experiment each of you will simultaneously make your decisions by completing the Decision Sheet in your envelope.

- If you are the Existing Tenant, you must first choose between **IN** and **OUT**.
  If you choose **OUT**, you will keep house A.

  If you choose **IN**, you will then need to choose one of the two possible rankings of the houses in order to indicate your preferences.
- If you are Newcomer 1 or Newcomer 2, you need to choose one of the two possible rankings of the houses in order to indicate your preferences.

- After everyone have completed their Decision Sheet, the experimenter will collect all Decision Sheets and start the allocation process by the following House Allocation Method.

House Allocation Method

- **Case 1:** If the Existing Tenant chooses **OUT**, then
  - The Existing Tenant keeps house A.
  - One of the two Newcomers are chosen with a fair coin-toss: that means each Newcomer has an equal chance of winning.
    * The winner of the coin-toss is assigned house B, and
    * the loser of the coin-toss is assigned nothing.
- **Case 2:** If the Existing Tenant announces **IN**, then
  - All three participants are lined in a **queue** with a fair dice-roll: that means each participant has an equal chance of being the first in the queue, being the second in the queue, and being the last in the queue.
  - Participants are assigned the best available house, one at a time, based on the order of the queue. In other words:
    * The first participant in the queue is assigned the best house **based on his/her chosen ranking of the houses**,
    * the second participant in the queue is assigned the remaining house, and
    * the last participant in the queue is assigned nothing.

You will have ten minutes to go over the instructions at your own pace, and make your decisions. Feel free to earn as much cash as you can. Are there any questions?

Instructions - Mechanism Y

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House Allocation Method

- **Case 1:** If the Existing Tenant chooses **OUT**, then
  - The Existing Tenant keeps house A.

  - One of the two Newcomers are chosen with a fair coin-toss: that means each Newcomer has an equal chance of winning.
    * The winner of the coin-toss is assigned house B, and
    * the loser of the coin-toss is assigned nothing.

- **Case 2:** If the Existing Tenant chooses **IN**, then
  - All three participants are lined in a **queue** according to the results of a fair dice-roll: that means each participant has an equal chance of being first in the queue, being second in the queue, and being last in the queue.
  - This queue represents the order the participants will be allocated the best available house **based on their chosen rankings of the houses**, with one important exception: **whenever a Newcomer demands house A, the Existing Tenant will get to go ahead of this Newcomer because the Existing Tenant lives in house A. This way the Existing Tenant is always guaranteed a house.** More specifically,
    * If the Existing Tenant is the first in the queue, then
      · the Existing Tenant is assigned the best house **based on his/her chosen ranking of the houses**;
      · the second participant in the queue is assigned the remaining house; and
      · the third participant is assigned nothing.
    * If one of the newcomers is ordered first in the queue and if he/she has chosen house A as his/her top choices, then
      · the Existing Tenant gets to go ahead of this Newcomer and gets assigned the best house **based on the Existing Tenant's chosen ranking of the houses**;
      · the first participant in the queue is assigned the remaining house; and
      · the third participant is assigned nothing.
    * If one of the newcomers is ordered first in the queue and if he/she has chosen house B as his/her top choices, then
      · the first participant in the queue is assigned house B;
      · the Existing Tenant is assigned house A; and
      · the third participant is assigned nothing.

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Instructions - Mechanism T

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- During the experiment each of you will simultaneously make your decisions by completing the Decision Sheet in your envelope: you need to choose one of the two possible rankings of the houses in order to indicate your preferences.

- After everyone have completed their Decision Sheet, the experimenter will collect all Decision Sheets and start the allocation process by the following House Allocation Method.

House Allocation Method

- All participants are lined in a **queue** according to the results of a fair dice-roll: that means each participant has an equal chance of being first in the queue, being second in the queue, and being last in the queue.
- This queue represents the order the participants will be allocated the best available house **based on their chosen rankings of the houses**, with one important exception: **whenever a Newcomer demands house A, the Existing Tenant will get to go ahead of this Newcomer because the Existing Tenant lives in house A. This way the Existing Tenant is always guaranteed a house.** More specifically,
  - If the Existing Tenant is the first in the queue, then
    * the Existing Tenant is assigned the best house **based on his/her chosen ranking of the houses**;
    * the second participant in the queue is assigned the remaining house; and
    * the third participant is assigned nothing.
  - If one of the newcomers is ordered first in the queue and if he/she has chosen house A as his/her top choices, then
    * the Existing Tenant gets to go ahead of this Newcomer and gets assigned the best house based on the Existing Tenant's chosen ranking of the houses;
    * the first participant in the queue is assigned the remaining house; and
    * the third participant is assigned nothing.
  - If one of the newcomers is ordered first in the queue and if he/she has chosen house B as his/her top choices, then
    * the first participant is assigned house B;
    * the Existing Tenant is assigned house A; and
    * the third participant is assigned nothing.

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