Proceedings of the 2nd International Conference on Financial Technology and Business Analysis
DOI: 10.54254/2754-1169/56/20231204

Applicatoin of TTCC Algorithm in House Reallocation Market in China

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Abstract: In recent years, many low-income families have been suffering house allocation problem. The current welfare house allocation mechanism is of low effiency. Despite Chinese government has been working on improving the current mechanism to solve this proplem, there are still many people which try to cheat in the house allocation market. Most of the people could not even truly express their preference through the current mechanism. It is important to find a more suitable mechanism which can help low-income familes reallocate their welfare housing. This article tries to make anaysis about applying Top Trading Cycles and Chians mechansim (TTCC) in the house reallocation market. This mechanism can lead to a more efficient result. Besides, this article expalins why TTCC is better than the current mechanism by studing the feature of the result from TTCC. The results show that TTCC can be used to in house reallocation market with a strcit ranking among low-come familes and there requires a strcit background investigation organization as well.

Keywords: TTCC mechanism, house lottery mechnaism, waitlist option, chain selection rule

1. Introduction

As the urban area in China keeps increasing, more and more families from rural area have moved to the cities and the growth of the population in urban area has caused many problems. The demand of living house is much higher than the actual number of the available ones in China. The price of one commodity house in the central city can sometimes exceed one billion. Consequently, instead of buying house in the urban area, 33.9% of the low-income families choose to live in rental houses [1]. However, the rent is too high that most of those families could not afford it at all.

To solve this problem, Chinese government has built up many new houses since 2015 [2]. Those houses are welfare homes for those low-income families. They can rent those houses at low prices. This plan has brought significant effect to the low-income population living issue. Until now, with the help of welfare housing, 88.4% of the low-income families only pay 300 yuan per month [1]. The rent is far below the market price in central city.

Nevertheless, after the development of those low-income families in these years, the current houses are not suitable for those people anymore for many reasons, like changing in workplaces or the increasing number of family members [3]. The Ministry of Construction in China has announced that Chinese government would not plan to add the number of welfare housing [2]. Consequently, it is important to reallocate the welfare housing and study for a suitable house allocation mechanism.

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Compared with the existing mechanism (which is a house lottery) [4], Top Trading Cycles and Chains (TTCC) mechanism, which is a variant of Top Trading Cycles (TTC) by David Gale can lead to a Pareto efficient, strategy-proof, and individual rational result [5]. The application of this mechanism is based on a strict preference, the house reallocation can satisfy this demand.

This article focuses on making descriptions of the current house allocation mechanism in China (house lottery), and application of TTCC in the house reallocation market with an example.

2. House Lottery Mechanism

The most cities in China chose to apply house lottery mechanism in the first round of house allocation. Every family which is in the lottery mechanism will be allocated a randomly welfare house. Many problems have been caused by using this mechanism. In China, lottery mechanism can be used in many markets such the lottery in the welfare housing allocation market [6], school district housing market [7] and it is also applied as a policy for primary school students entering [8].

Overall, this mechanism ignores the preference of low-income families. The position of the rental housing was too far to their workplace. For some families, the area of the house is too small which lead to a result that many families could not live in it at all. For example, the occupancy rate in XiangLin ShiJi HuaFu, a living community, in Shenzhen was only 40% when it was allocated as a welfare house [2]. Some children in those families were forced to transfer to another school because of the lottery mechanism. Lottery mechanism is of low efficient, and it is hardly to satisfy the demand of mostly low-income families.

3. TTCC Mechanism

Top Trading Cycles and Chains mechanism (TTCC) which was proposed by Roth, Sonmez, and Unver in 2004, was applied in the kidney exchange market. Briefly, TTCC mechanism is the extension of TTC mechanism. The differences between TTCC and TTC are the implement of TTCC is adding a specific chain selection rule and ‘waitlist option’ when applying TTC algorithm.

Housing allocation problem and kidney exchange problem are regarded as two different problems [9]. Every patient in the kidney exchange market would never escape from the mechanism because they only survive with at least one healthy kidney which means every patient would stay in TTCC mechanism until they receive a suitable kidney. However, in the house reallocation problem, these low-income families have the same feature because they are living a non-satisfactory condition and they always want to move to better and more suitable houses. Even the house is a welfare one, those low-income families still need to pay for the rent. Consequently, comparing with escaping from the algorithm, those low-income families prefer to choose to keep their house in trading, stay in the ‘waitlist option’ as they would not reject to have a better life. Further, in the normal house market, there is no role for money trading between the low-income families. The supplier of the welfare housing is Chinese government.

Before starting to explain the application of the TTCC mechanism officially, it is important to introduce ‘waitlist option’ and the chain selection rule firstly which can facilitate the understanding of TTCC mechanism.

3.1. Waitlist Option (W-Chain)

Waitlist option (w-chain) is an ordered chain with a starting house and an ending tenant. The starting house always point to their current owner and the owner can point to their best choice house according to a strict preference list. In TTC mechanism only exist complete cycles because every tenant will escape from the mechanism easily if they find all other houses are unacceptable. However, in the w-chain if there are no acceptable house for the ending tenant. Instead of escaping from the algorithm,

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she will ask waitlist option for help. Compared with the cycle, a pair (h_m, t_m) can be in the part of over one w-chains. A pair can only be part of one cycle because every cycle will be removed from the algorithm immediately when it is formed. Besides, the length of an ordered chain is not always fixed, a w-chain can be added into the tail of another w-chain.

In Example 1, every tenant has been assigned a house which has the same index. A list of the w-chain in Figure 1 has been shown below, with W_1= (h_3, t_3), W_2= (h_2, t_2, h_3, t_3), W_3= (h_1, t_1, h_2, t_2, h_3, t_3), W_4= (h_4, t_4, h_2, $_{t2,}$ h_3, t_3), and W_5= (h_5, t_5, h_3, t_3).

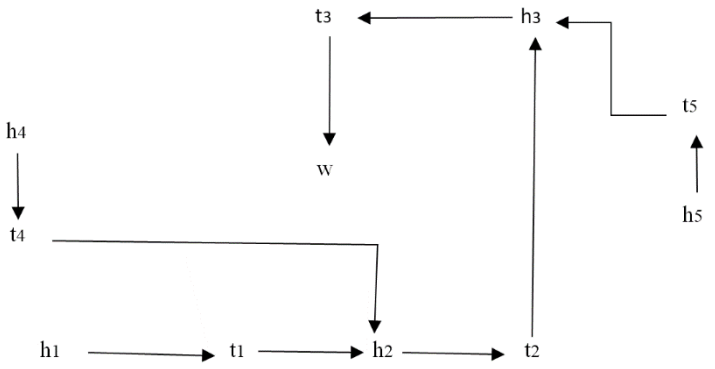

Figure 1: W-chain in Example 1.

3.2. The Chain Selcetion Rule

It is clearly that there are more than one w-chains in Example 1. Each w-chain can intersect with others. How to choose an efficiently w-chain from these figures has been a problem.

The chain selection rule that will be applied in this mechanism is choosing a maximal w-chain. In this way it can benefit the most people at the same time. If there are more than one the longest chain. This mechanism will choose the one with higher priority tenant inside. If the highest priority tenant is in more than one the longest chain. The choose the second longest chain. This step is repeated until complete finding the chain, and every w-chain is the shortest. Those chains can be combined together as the tail of w-chain is flexible, considering preference list. Nevertheless, when this situation still happens after this step, each tenant will point to the waitlist option waiting for the next round of allocation. The selected w-chain will be kept until the last step of the algorithm is completed. All the pair inside of the chain is going to be assigned the house they point because all the houses that the tenant point to are acceptable for them. In the end, only the head of the w-chain point at the waitlist option, and they will own the highest priority in the next round of house reallocation.

3.3. The Application of TTCC Mechanism

Step 1: Firstly, all the remaining houses always point at their paired tenants. Tenants can point at the houses which they preferred.

Step 2:

Step 2-1: Every tenant can point at their most preferred houses, so there are at least one cycle or chain exist [7].

Step 2-2: If there is a cycle formed, then keep it. Whenever a cycle has formed, all the house and tenants are removed in the cycle and every point at their most preferred house again.

Step 2-3: Step 2-1 and 2-2 are repeated until there are no further chains available.

Step 3:

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Step 3-1: If there is no any other house and tenant left anymore, then the algorithm end (everyone has assigned an acceptable welfare house).

Step 3-2: If there are some chains exist at Step 2-1, the algorithm then can apply the chain selection rule to select the most suitable chain.

The chain is going to be removed from all the w-chains for the moment until the last step of the algorithm. The selected chain is not fixed, the head of this chain do not have to point to w when it is selected. Other pairs can be added to the tail of the selected chain.

Step 4: Whenever a chain has been chosen, another cycle is formed in the meantime [10]. Then agents can repeat Step 2 and 3. At the end of this step, there is no any pair remaining. The head of the selected chain should be assigned the waitlist option and the algorithm end.

3.4. A Modelling Example by Using TTCC Mechanism

Before beginning the explanation about the Example 2, the TTCC mechanism must base on a strict preference. Table 1 shows a preference list for all the tenant in this example. Assuming that the tenant with the smallest has the highest priority. From the left to the right side, with the decreasing of the index of tenant, the priority is decreasing as well.

Table 1: The preference list of the tenant.

t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
h_3	h_1	h_1	h_6	h_2	h_1	h_4	h_3
h_2	h_3	h_8	h_5	h_4	h_3	h_2	h_1
h_4	h_8	h_5	h_7	h_8	w	h_1	h_2
h_7			h_3			h_5	h_4
h_5			h_1			h_6	h_3
h_8			h_2				h_5
h_6			h_8				
			w				

Firstly, every tenant can point at their preferred house, and both carry a paired-houses which is used to be traded. The paired house always points at their current owner.

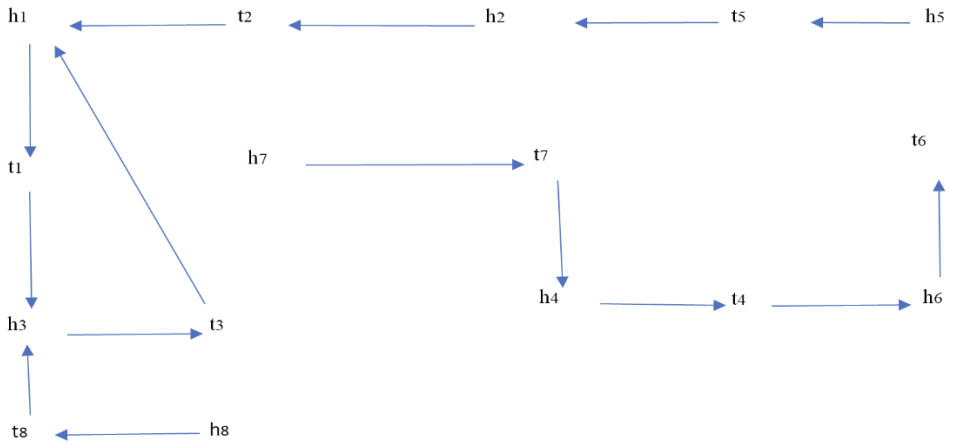

Figure 2: The first round in Example 2.

According to the Figure 2, there is a cycle been formed which is C_1= (h_1, t_1, h_3, t_3). The cycle then should be erased in this figure and t_1 receive h_3, t_3 receive h_1, and then Round 1 ends.

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Then, the process goes to the second round, that every non-removed point at the remaining house which they preferred the most.

According to Figure 3, there is a new cycle which is C_2= (h_2, t_2, h_8, t_8). Then, the same step in round one is repeated, removing the whole cycle and assign h_8 to t_2, h_2 to t_8, then round 2 ends.

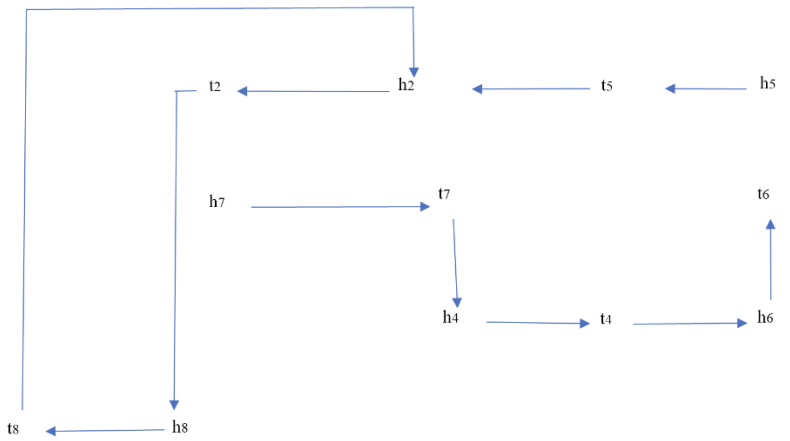

Figure 3: The second round in Example 2.

In the third round, there is no cycle anymore and according to the Figure 4, two chains have been formed. The first one is W_1= (h_5, t_5, h_4, t_4, h_6, t_6) and the second one is W_2= (h_7, t_7, h_4, t_4, h_6, t_6)

Now the algorithm starts the chain selection rule. W_1 and W_2 are both the longest chain in the Figure 4. Compare with t_5 and t_7, t_5 has the smaller index. Consequently, W_1 should be removed from the algorithm for a moment.

The remaining pair (h_7, t_7) can be added into the tail of W_1. According to the Table 2, h_5 is acceptable to t_7 and round 3 end. Now W_1 is the only chain in the whole algorithm.

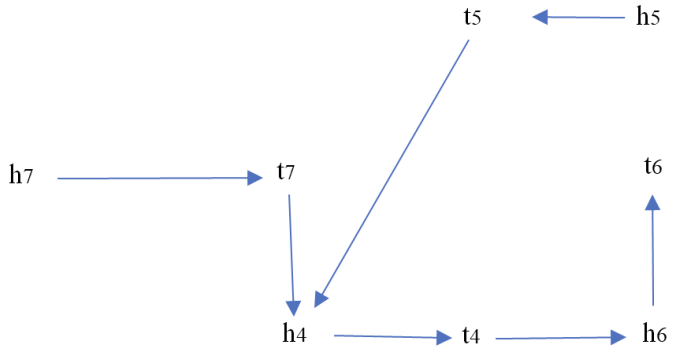

Figure 4: The third round in Example 2.

According to the Figure 5 and Table 2 below, the mechanism can allocate h_6 to t_4, h_4 to t_5, h_5 to t_7 there is no more acceptable house for t_6, then t_6 must point to w and ask the waitlist option for help, which means waiting for the next round of house reallocation and the algorithm ends.

In the application of TTCC in the reallocation of welfare housing market. There first need to be a strictly supervisory institution. Some of the low-income families might not need to change there currently living places like others. Just for moving to a better place. Then they ask for joining the algorithm. Second, for all the tenants who are already in the reallocation plan list. Chinses government need to rank them from high to low. For example, the family with the most membership can be

DOI: 10.54254/2754-1169/56/20231204

assigned the smallest index. Only with this rank list, during the application of TTCC mechanism, the chain selection rule can be carried out.

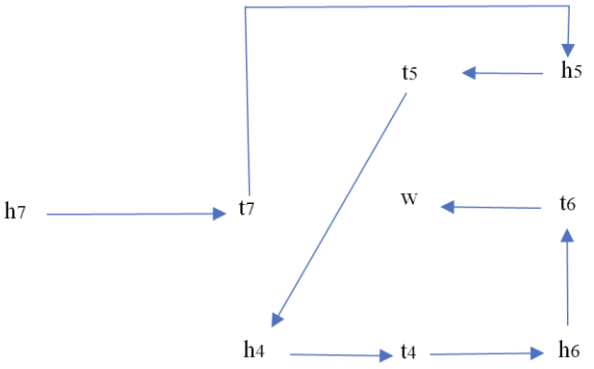

Figure 5: The last round in the Example 2.

Table 2: Matching results in the end.

t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
h_3	h_8	h_1	h_6	h_4	w	h_5	h_2

4. Conclusion

This article first explains briefly about the house lottery mechanism, then making a briefly description about the TTCC mechanism. Compare the differences between these two mechanisms, it is clear to see that TTCC mechanism is much better than another one. Many families which are not poor at all try to save money and receive the best welfare housing by giving money to the government employer. It is difficult to satisfy the demand of most tenants. TTCC mechanism can lead to a result with many advantages. The output of the TTCC mechanism has been proved to be Pareto efficient, strategy-proof, and individual rational. After explaining the reason of applying TTCC mechanism in the house reallocation problem, the paper focus on the detailed of TTCC. The detailed description of TTCC is split into three parts. The first part is the waitlist option in TTCC, which can help those families stay in the mechanism, giving them hope to receive a more suitable housing. The second part is explaining the chain selection rule. There is a specific chain selection rule in this problem, and it is aimed to benefit the most people in the shortest time. With these two parts, it is easier to understand how TTCC works.

There are limitations about using TTCC mechanism. On the one hand, like TTC mechanism, it must need a strict preference when carrying out. On the other hand, people cannot lie in the mechanism at all. Every tenant must stay honest. Chinese government has to examine whether those families are literally living a hard life like they described. In the future, how to rank the priority in the chain selection rule for those tenants can be studied, and there are many standard need to be showed in the future and which kind of low-income people can join this mechanism. It also needs a strict standard.

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