The B.E. Journal of Economic Analysis & Policy

Topics

Volume 7, *Issue* 1 2007 *Article* 7

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Recommended Citation
Tomomi Tanaka (2007) "Resource Allocation with Spatial Externalities: Experiments on Land Consolidation," *The B.E. Journal of Economic Analysis & Policy*: Vol. 7: Iss. 1 (Topics), Article 7.
Available at: http://www.bepress.com/bejeap/vol7/iss1/art7

Resource Allocation with Spatial Externalities: Experiments on Land Consolidation*

Tomomi Tanaka

Abstract

This paper compares the performance of a two-sided combinatorial call market, direct negotiation, and double auction for consolidating fragmented land. Experimental results suggest direct negotiation produces higher efficiencies than other mechanisms. The combinatorial call market tends to alleviate the exposure problem, and performs well when 1) swapping is easily agreeable, and 2) the number of subjects and commodities are increased and the initial endowments are unchallenging. The two-sided combinatorial call market, however, suffers from the holdout problem when the number of subjects and commodities is small.

KEYWORDS: mechanism design, two-sided combinatorial auction, holdout

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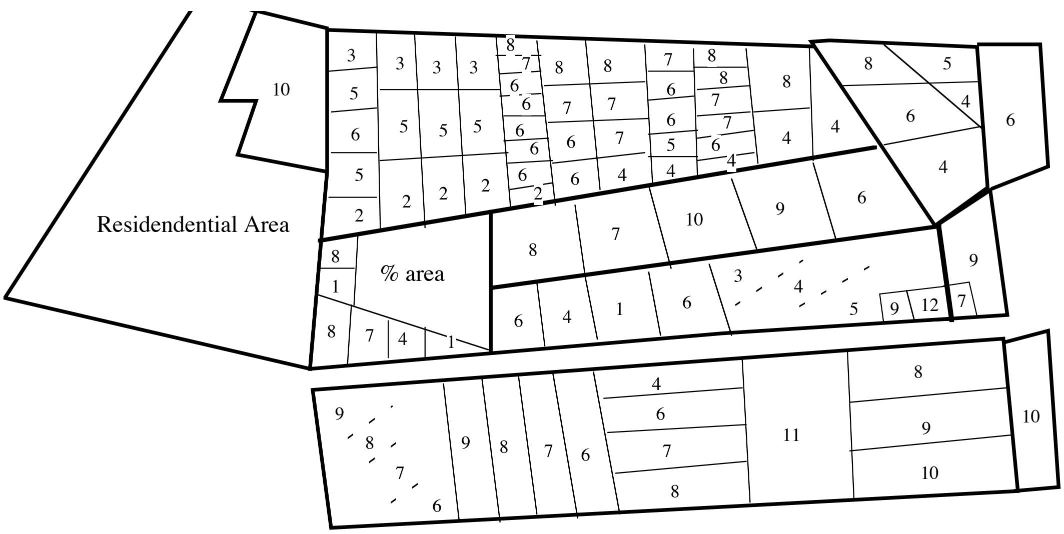
1 Introduction

This study examines alternative mechanisms for consolidating fragmented land. In many former communist countries, farmland was allocated through administrative procedures in an effort to introduce private ownership in the 1990s (Deininger, 2002; Lerman et al., 2002). In Tien Xa 3 Village in Vietnam, farmland was classified into twelve grades as shown in Figure 1. Numerous plots of different land grades and locations were allocated to each household in hopes of achieving equality. As a result, households received as many as 20 plots, although the total land area averaged less than 0.3 hectare. Land fragmentation, i.e., non-contiguous landholdings, can cause significant levels of production loss due to high supervision costs and increased time requirement. Wan and Cheng (2001) estimate China's grain output could rise by 15.3 percent if fragmentation were eliminated.

Figure 1 Grades of Farmlands in Tien Xa 3 Village
(1=Highest Grade, 12=Lowest Grade)



Land fragmentation is not unique to transition economies. It's considered to be one of the most serious obstacles to agricultural growth in many countries (Heston and Kumar, 1983; Jabarin and Epplin, 1994; Monke et al., 1992; Parikh and Shah, 1994; Simons, 1985). Deininger (2003) points out how land fragmentation is one of the major sources of high transaction costs in land markets. Assembling contiguous land parcels and creating a plot large enough to be a viable cultivation size requires a farmer to negotiate with numerous small landowners.

Several Western European countries have undertaken land consolidation projects (Vitikainen, 2004). However, the participation is often involuntary, and land appraisal involves lengthy and complicated procedures. Vitikainen (2004) articulates the need to develop more cost-effective, simpler and faster procedures for land consolidation.

Can we expect land markets to solve fragmentation? Sabates-Wheeler (2002) reports that the World Bank is encouraging market-assisted land reform and looking to land markets to solve problems of land fragmentation in Albania. Under the market-assisted land reform, the government provides grants to farmers so they can negotiate with each other and redistribute land assets through market transactions (Deininger, 1999). Deininger (2002) asserts that supportive institutions are needed for land markets to function efficiently, and such institutions do not emerge by themselves.

The above empirical evidence indicates a need to design an allocation mechanism to facilitate land consolidation. By conducting laboratory experiments, this study compares the performance of several market institutions that may facilitate efficient redistributions of fragmented land parcels. We consider the following setting: 1) Each individual's preference over land parcels is private information, 2) Individuals initially hold land parcels dispersed in multiple locations, 3) There is a cost associated with holding dispersed land. The cost increases with the distance between parcels. Similar to the market-assisted land reform, we provide monetary endowments to experimental subjects so they can exchange their assets without facing budget constraints.

Experiments have some advantages in testing the performance of market mechanisms (Plott, 1999; Plott, 1994). In experiments, we can create design features that do not exist in naturally-occurring markets, and compare the performance of different market mechanisms. We conduct experiments in simplified market environments but attempt to maintain the features inherent to land consolidation problems.

Land allocation is important because of its role in economic growth. It's also a canonical example of resource allocation with complementarities, which is similar to other important economic environments. One example is the telecommunication spectrum allocation problem, in which owners desire to assemble geographically adjacent licenses (Ausubel et al., 1997; Cramton, 1998; Milgrom, 2000). Or suppose "geography" is not literal physical location, but represents any perceptual dimension in which nearby objects are more valuable when owned jointly. The analysis here might also apply to industrial domains like products which are grouped together in an attribute space. Another potential application is social domains like fraternities, college dorms, and neighborhoods where people prefer to congregate with others like themselves.

There are a number of experimental studies on the performance of market mechanisms when there are synergies across commodities. Ledyard, Porter and Rangel (1997) and Bykowsky, Cull and Ledyard (2000) demonstrate how combinatorial mechanisms dominate both simultaneous and sequential non-combinatorial auctions when there are synergies among commodities. Banks, Olson, Porter, Rassenti and Smith (2003) and Porter, Rassenti, Roopnarine and Smith (2003) compare the performance of the simultaneous auction used by the FCC and a combinatorial auction. They conclude that when licenses are complements, the combinatorial auction outperforms the simultaneous auction.

The present study differs from the earlier research in two ways. First, previous studies often assume superadditive valuations in which competitive equilibrium prices do not exist, then study the exposure problem, i.e., exposure to losses from failing to aggregate licenses. Poor performance of a mechanism may be due to the non-existence of competitive equilibrium, or due to the exposure problem. This study shows how risk exposure problems may still arise even with subadditive valuations. In our study, competitive equilibrium prices exist but subjects still face exposure problems. This allows us to separate the exposure problem from the problem associated with non-existence of competitive equilibrium.

Second, the existing studies investigate one-sided markets. Our study examines two-sided markets in which individuals initially own resources to be reallocated. In two-sided markets, we expect to face different strategic behavior problems from those discussed in the one-sided market studies (Milgrom, 1998, 2000). When an individual attempts to consolidate his holdings, he may face holdouts by the owners of neighboring parcels. This characteristic is shared by other resource allocation problems of location-specific resources, including reallocation negotiation of spectrum licenses. Cramton, Kwerel and Williams (1998) model the reallocation negotiations in spectrum licenses, and point out potential holdout problems but no study has studied holdout problems empirically.

We compare the performance of three alternative mechanisms; direct negotiation, a double auction and a combinatorial market. The negotiation procedure is similar to the market-assisted land reform (Deininger, 1999). Under the market-assisted land reform, the government provides grants to farmers so they can negotiate with landowners and purchase land plots. There is a key difference between the negotiation procedure in our experiment and the market-assisted reform. Under the negotiation procedure in our experiment, subjects deal with all potential trading partners simultaneously whereas in the market-assisted reform, farmers have to search for potential trading partners and negotiate with them bilaterally. Double auction tend to generate efficient outcomes more quickly and consistently compared with other market institutions when competitive equilibrium exists (Davis and Holt, 1993). Under the parameters used in the experiment, competitive equilibrium prices exist. Theoretically speaking, we thus expect efficient outcomes to emerge as a result of competition in double auction. We also test a combinatorial market because the studies on one-sided markets suggest combinatorial mechanisms perform better than other mechanisms when there are synergies among commodities.

An important question is which institution actually yields more efficient outcomes when markets are two-sided and there exist competitive equilibrium prices. Do combinatorial mechanisms still outperform simple (non-combinatorial) mechanisms even when markets are two-sided? Do double auctions perform better than other mechanisms as long as there exist competitive equilibrium prices? How does "holdout" affect market performance?

The paper is organized as follows: Section 2 describes the market environments. In Section 3, we discuss the mechanisms tested. Section 4 describes experimental procedures. Section 5 reports the results and Section 6 contains a summary of conclusions.

2 Market Environment

Suppose there are multiple locations, and there are multiple parcels in each location. Also assume agents have stand-alone value for each parcel, and let us denote agent i's stand-alone value on the k-th parcel l_k by $v_i(l_k)$. We will explicitly model the cost of fragmentation. Assume there are two kinds of costs associated with fragmentation. First, there is a cost associated with holding non-contiguous parcels within a location, which we call Gap Cost 1 in the experiments. Gap Cost 1 increases with the size of "gap" between parcels within a location. Second, there is a cost associated with having parcels in multiple locations, which we call Gap Cost 2. Gap Cost 2 increases with the distance an agent needs to travel between the most distant locations in his holdings. Gap Costs equal zero if an agent holds contiguous land parcels in only one location. Appendix describes the precise structure of Gap Costs used in the experiment.

Agent i's value function over a set of parcels, X, can be expressed as follow:

$$v_i(X) = \sum_{l_k \in X} v_i(l_k) - [\text{Total Gap Cost 1}] - [\text{Gap Cost 2}]$$

The value of a set of parcels to agent i is the summation of stand-alone values of individual parcels comprising the set X, minus total Gap Costs. Note the valuation function of the agents is subadditive.[1] Under the parameters used in this study, there exist competitive equilibrium prices that support efficient allocations. However, to realize the efficient allocations, some individuals may have to pay more than their stand-alone values for some parcels. An agent may face potential exposure to losses if he fails to aggregate adjoining parcels. This is commonly known as the “exposure problem” in the spectrum auction studies.

We conducted four series of experiments, which we labeled Series1 through Series 4. In Series 1 and 3 of our experiments, agents do not pay more than their stand-alone values for any of the parcels under competitive equilibrium prices. In Series 2 and 4, by contrast, agents will have to pay more than their stand-alone values for some parcels under competitive equilibrium prices. Thus, we expect exposure problems to be more severe in Series 2 and 4 compared with Series 1 and 3.

In Series 1 and 2, we conducted experiments with 3 subjects and 6 parcels. In Series 3 and 4, we increase the numbers of subjects and parcels to 8 and 16 respectively, to investigate the robustness of the performance to scaling up. In addition, we use three sets of initial endowments to examine if initial allocations matter.

Series 1

In Series 1, there are three agents, numbered 1, 2, and 3, and two locations, A and B. In each location there are three parcels. There are a total of six parcels in the economy. Each subject has stand-alone values for each parcel as shown in Table 1. Note these valuations are private information. The value of any combination of commodities is the sum of the valuations of the individual commodities minus Gap Costs. Gap Cost 1 is associated with holding non-contiguous parcels within one location, i.e., A1 and A3, or B1 and B2. Gap Cost 2 is associated with having parcels across two locations. For the simplicity of experiments, we use the same amount of costs, 1000 francs[2], for both Gap Costs 1 and 2. Appendix describes the structure of Gap Costs. It is a simplified setting and the choice of values and gap costs has no empirical foundation. However, we believe it still captures the essence of problems caused by land fragmentation, i.e., production loss due to increased time requirement for management and production activities.

The efficient allocation assigns all parcels in Location A to Subject Number 3, and all parcels in Location B to Subject Number 1. There exist a range of competitive equilibrium prices that support the efficient allocation. Table 1

[1] A value function $v_i(X)$ is subadditive if for all $X,Y \subseteq L$ and $X \cap Y \neq \emptyset$, $v_i(X) + v_i(Y) \geq v_i(X+Y)$

[2] Francs are the currency used in the experiments.

summarizes the lowest and highest equilibrium prices that can be undertaken for each commodity. Equilibrium prices are interdependent across locations. For each parcel, the stand-alone value of the agent who should obtain it in the efficient allocation is below the upper limit of the competitive equilibrium price. Thus, agents do not have to pay more than their stand-alone values for individual parcels in the process of realizing efficient aggregation if trades occur within the range of competitive prices. However subjects may try to extract gains from trade by holding out critical inner parcels (A2 and B2).

Table 1 Stand-Alone Values and Competitive Equilibrium Prices in Series 1

	A1	A2	A3	B1	B2	B3
Agent ID	Stand-Alone Values					
#1	1200	1100	900	**900**	**800**	**700**
#2	1300	1200	1100	800	700	600
#3	**1500**	**1400**	**1300**	600	500	400
	Equilibrium Prices					
Lowest	1300	1200	1100	800	700	600
Highest	1500	1600	1300	900	900	700

Note 1: **Bold** indicates the efficient allocation.
Note 2: Gap Cost 1 = 1000, Gap Cost 2 = 1000
Note 3: Equilibrium prices are interdependent.
When prices of A2 and B2 are above 1400 and 800 respectively, following constraints apply:

$$1300 \le P_{A1} \le 1500, 1400 \le P_{A2} \le 2900 - P_{A1}, 1100 \le P_{A3} \le 2700 - P_{A2}$$

$$800 \le P_{B1} \le 900, 800 \le P_{B2} \le 1700 - P_{B1}, 600 \le P_{B3} \le 1500 - P_{B2}$$

At the beginning of each period, each subject was given a portfolio of 2 parcels and a certain amount of francs as working capital. We use three sets of initial endowments, namely, the Easy Initial Endowment, the Moderate Initial Endowment, and the Hard Initial Endowment. The three initial endowments differ in terms of necessary number of trades it requires to realize efficient allocations, and also differ in whether the subjects with the second highest values hold critical inner parcels or not.

Table 2 indicates who owns which commodities in each set of the initial endowments. The Easy Initial Endowment is a relatively unchallenging set of initial endowments compared to the next two sets of endowments for two reasons. First, two out of six parcels are efficiently allocated in the initial endowment. Second, A2 and B2, the central parcels in Location A and B, are owned by Subject Number 1 and 3, who value these parcels the least among all subjects, respectively. Like the Easy Endowment, two out of six parcels are efficiently allocated in the Moderate Initial Endowment. This set of initial endowments may be harder than the Easy Endowment because Subject Number 2 initially holds the critical inner parcels, A2 and B2, even though he holds no parcels in the efficient allocation. Subject 2 may try to hold these inner parcels to extract as much gains from trade as possible. Under the Hard Initial Endowment, all six parcels need to be traded to achieve efficiency.

Table 2 Initial Endowments

	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	Autarky Value
Series 1																	
Easy	**#3**	#1	#2		**#1**	#3	#2										2700
Moderate	#1	#2	**#3**		#3	#2	**#1**										2700
Hard	#1	#2	#1		#3	#2	#3										2000
Efficient Allocation	**#3**	**#3**	**#3**		**#1**	**#1**	**#1**										6600
Series 2																	
Easy	**#3**	#2	#1		#3	#2	**#1**										2800
Moderate	**#3**	#1	#2		**#1**	#3	#2										2800
Hard	#1	#2	#1		#3	#2	#3										1600
Efficient Allocation	**#3**	**#3**	**#3**		**#1**	**#1**	**#1**										6600
Series 3																	
Easy	#4	#5	#3	**#2**	#6	#8	#7	#1	#3	#7	**#6**	#4	#5	#1	#2	**#8**	5900
Moderate	#4	#8	#1	#3	#2	#6	#5	#7	#1	#3	#5	#8	#7	#6	#2	#4	5120
Hard	#7	#4	#3	#1	#6	#8	#2	#5	#3	#4	#1	#8	#2	#6	#7	#5	5720
Efficient Allocation	**#2**	**#2**	**#2**	**#2**	**#4**	**#4**	**#4**	**#4**	**#6**	**#6**	**#6**	**#6**	**#8**	**#8**	**#8**	**#8**	13800
Series 4																	
Easy	**#2**	#3	#7	#4	**#4**	#5	#3	#8	**#6**	#2	#1	#7	**#8**	#5	#6	#1	5150
Moderate	#1	#3	#8	#6	#3	#6	#1	#8	#5	#7	#2	#4	#7	#4	#5	#2	4550
Hard	#6	#1	#8	#3	#1	#3	#6	#8	#7	#5	#2	#4	#2	#7	#4	#5	5000
Efficient Allocation	**#2**	**#2**	**#2**	**#2**	**#4**	**#4**	**#4**	**#4**	**#6**	**#6**	**#6**	**#6**	**#8**	**#8**	**#8**	**#8**	12000

Note 1: # indicates Subject Identification Number.
Note 2: **Bold** indicates the efficient allocations.
Note 3: In Series 3, underline indicates the inner parcel is held by the subject with the second highest stand-alone value. In Series 4, underline indicates the inner parcel is held by the subject with the highest stand-alone value.

Series 2 to Series 4

Tables 3, 4, and 5 illustrate stand-alone values and equilibrium prices for Series 2, 3 and 4, respectively. Series 2 is similar to Series 1 except for the exposure problem. To realize the efficient allocation, agents will have to pay more than their stand-alone values for inner parcels under competitive equilibrium prices. The lower limits of equilibrium prices of A2 and B2 is 500, which is above 300, the stand-alone values of Subject Number 3 and Subject Number 1 for these parcels, respectively. An agent may face potential exposure to losses if he pays a price higher than his stand-alone value for an inner parcel, and fails to aggregate adjoining parcels. Notice the structure of valuations is complementary between Subject Number 1 and Subject Number 3 in Series 2. It may make it easier for them to agree on swapping parcels if such trade is allowed.

In Series 3 and 4, we investigate the robustness of the performance of mechanisms when the number of agents and parcels increase. We achieve this by increasing the number of agents to eight and the number of parcels to sixteen. The eight subjects are numbered 1 to 8, and the four locations, A, B, C and D. In each location there are four parcels. In Series 3, the stand-alone value for the agent who should obtain it when efficiently allocated is below the lower limit of the competitive equilibrium price, while in Series 4 equilibrium prices for inner parcels are above the stand-alone values of the agents who should obtain them under the efficient allocation, creating the exposure problem.

Table 2 shows initial endowments for all series. Under the Moderate Initial Endowment in Series 1 and 2, and the Hard Initial Endowment in all series, all parcels need to be traded to realize the efficient allocations. Under the Hard Initial Endowment in Series 3, three inner parcels (A2, C1 and D3) are held by the subjects with the second highest values. Under the Hard Initial Endowment in Series 4, four inner parcels (A2, B2, C2 and D2) are held by the subjects with the highest values, making it hard to achieve the efficient allocation.

Table 3 Stand-Alone Values and Competitive Equilibrium Prices in Series 2

	A1	A2	A3	B1	B2	B3
Agent ID			Stand-Alone Values			
#1	900	900	900	**1500**	**300**	**1500**
#2	500	500	500	500	500	500
#3	**1500**	**300**	**1500**	900	900	900
			Equilibrium Prices			
Lowest	500	500	500	500	500	500
Highest	1300	1300	1300	1300	1300	1300

Note 1: **Bold** indicates the efficient allocation.

Note 2: Gap Cost 1 = 1000, Gap Cost 2 = 1000

Note 3: Equilibrium prices are interdependent. Following constraints apply:

$P_{A1}+P_{A2}+P_{A3}\le P_{B1}+2400,\ P_{A1}+P_{A2}+P_{A3}\le P_{B2}+2400,\ P_{A1}+P_{A2}+P_{A3}\le P_{B3}+2400,$

$P_{B1}+P_{B2}+P_{B3}\le P_{A1}+2400,\ P_{B1}+P_{B2}+P_{B3}\le P_{A2}+2400,\ P_{B1}+P_{B2}+P_{B3}\le P_{A3}+2400$

$P_{A1}+P_{A2}+P_{A3}\le P_{B1}+P_{B2}+1500,\ P_{A1}+P_{A2}+P_{A3}\le P_{B2}+P_{B3}+1500,$

$P_{B1}+P_{B2}+P_{B3}\le P_{A1}+P_{A2}+1500,\ P_{B1}+P_{B2}+P_{B3}\le P_{A2}+P_{A3}+1500$

Table 4 Stand-Alone Values and Competitive Equilibrium Prices in Series 3

	1	2	3	4	1	2	3	4
ID	Stand-Alone Values							
#1	500	500	400	400	400	400	400	400
#2	**1200**	**1100**	**1000**	**900**	500	450	400	400
#3	400	400	400	400	800	800	600	600
#4	1000	900	800	700	**1000**	**900**	**800**	**700**
#5	400	400	400	400	700	700	500	500
#6	900	800	700	600	700	600	500	400
#7	500	500	400	400	500	500	450	450
#8	600	600	400	400	500	500	450	450
	Equilibrium Prices							
Lowest	500	500	400	400	800	800	600	600
Highest	1200	1300	1200	900	1000	1100	900	700

	C1	C2	C3	C4	D1	D2	D3	D4
ID	Stand-Alone Values							
#1	600	600	500	500	400	400	400	400
#2	800	750	700	650	400	400	400	400
#3	800	800	700	700	400	400	400	400
#4	1000	900	800	700	400	400	400	400
#5	500	500	500	500	400	400	400	400
#6	**1200**	**1100**	**1000**	**900**	400	400	400	400
#7	600	600	400	400	420	420	420	420
#8	800	800	800	800	**500**	**500**	**500**	**500**
	Equilibrium Prices							
Lowest	800	800	700	700	420	420	420	420
Highest	1200	1300	1200	900	500	580	580	500

Note 1: **Bold** indicates the efficient allocation.
Note 2: Gap Cost 1 = 200, Gap Cost 2 = 200

Table 5 Stand-Alone Values and Competitive Equilibrium Prices in Series 4

	A1	A2	A3	A4	B1	B2	B3	B4
ID				Stand-Alone Values				
#1	250	750	750	250	300	600	600	300
#2	**1000**	**600**	**600**	**1000**	800	200	200	800
#3	200	700	700	200	250	650	650	250
#4	650	100	100	650	**900**	**500**	**500**	**900**
#5	200	700	700	200	300	600	600	300
#6	900	200	200	900	850	200	200	850
#7	200	700	700	200	300	600	600	300
#8	950	200	200	950	850	100	100	850
				Equilibrium Prices				
Lowest	250	750	750	250	300	650	650	300
Highest	700	1000	1000	700	600	900	900	600

	C1	C2	C3	C4	D1	D2	D3	D4
ID				Stand-Alone Values				
#1	200	700	700	200	150	450	450	150
#2	1100	300	300	1100	800	100	100	800
#3	300	700	700	300	100	480	480	100
#4	1000	200	200	1000	700	250	250	700
#5	250	750	750	250	300	400	400	300
#6	**1200**	**600**	**600**	**1200**	700	100	100	700
#7	250	700	700	250	100	500	500	100
#8	1100	100	100	1100	**800**	**400**	**400**	**800**
				Equilibrium Prices				
Lowest	300	750	750	300	300	500	500	300
Highest	900	1000	1000	900	600	800	800	600

Note 1:**Bold** indicates the efficient allocation.
Note 2: Gap Cost 1 = 400, Gap Cost 2 = 400

3 Mechanisms Tested

We study the performance of three exchange mechanisms: an oral double auction mechanism, direct negotiations (committee), and the combined-value call market. The Hungarian government conducted oral one-sided auction when they privatized land (Swain, 1994). Burger reports that the auctions brought about land fragmentation, hampering agricultural growth (Burger, 2001). The negotiation procedure is similar to the market-assisted land reform conducted in several developing countries (Deininger, 1999).

The key difference between the negotiation procedure in our experiment and the market-assisted reform is in the market-assisted reform, farmers have to search for potential trading partners and negotiate with them bilaterally, whereas under the negotiation procedure in our experiment, subjects deal with all potential trading partners simultaneously. The combined-value call market is known to outperform simultaneous auction when the market is one-sided and there are synergies across commodities. We investigate 1) whether the combined-value call market outperforms simple auction mechanisms even when markets are two-sided, 2) if the double auction does better than other mechanisms as long as there exist competitive equilibrium prices, and 3) face-to-face communication under direct negotiations improves efficiency of trade.

Oral Double Auction (DA)

An oral double auction comprises parallel, unconnected markets, i.e., a market is created for each commodity, and is open simultaneously. During a trading period, agents make verbal bids to buy a certain commodity at a specified price, or make offers to sell a commodity for a specified price. A unit is traded when a buyer accepts an existing offer or when a seller accepts an existing bid. Cancellation of bids and asks and resale are all allowed. The double auction has been shown to generate efficient outcome in a wide variety of settings (Plott and Smith, 1978).

In the double auction scheme, subjects can trade only one unit in each transaction, and contingent trades are not allowed. This is a critical difference between oral double auctions and other two mechanisms tested. When each transaction takes place, subjects do not know what terms of trade will be available afterwards. This forces subjects to face complex decision making problems such as when and how much to bid or ask, and whether or not to accept the bids or asks offered by others.

Direct Negotiation (Committee)

Under the direct negotiation, all subjects sit at one table and directly negotiate with one another. Subjects can purchase, sell, and exchange individual commodities or package of commodities with any other subjects. They can freely discuss the terms of trade among themselves, bilaterally or multilaterally. They are also allowed to design their own trading rules if they wish. However, they are not allowed to directly reveal their valuations to others. Each period lasts for at most 12 minutes. One advantage of direct negotiations (as well as the Combined Value Call Market, CVCM, discussed in the next section) over double auctions is that package trades including swapping[3] is possible.

[3] Swapping implies exchange of parcels without side payments.

Let us suppose exchange always occurs between pairs of agents, and in each trade, agents exchange as many parcels as they want. Provided pairs of agents achieve pair-wise efficiency[4] every time they meet, the minimum number of trades required to realize the efficient allocations is 3 for Series 1 and 2 under all initial endowments. Even though the minimum number of trades required to realize efficient allocations is the same in Series 1 and 2, the complementary structure of the individuals' valuations may make it easier for subjects to conduct bilateral trades via swapping in Series 2.

Valley et al. (2002) illustrate how face-to-face communication enhance efficiency in a sealed-bid mechanism. Parkhurst et at. (2002) show that pre-play communication and random pairings highly resolve fragmentation of land for habitat in a laboratory experiment. As the number of both tradable objects and agents increases, however, it may become harder for an agent to find a trading partner with compatible needs. Under the Easy Environment in Series 3, it takes the minimum of ten trades to achieve efficient allocations, even if each trade is pair-wise efficient. In Series 4, there does not exist a sequence of pair-wise efficient trades that lead to the efficient allocation.

The Combined Value Call Market (CVCM)

A combined value call market (CVCM) is a computerized auction mechanism that collects bids from agents and selects an allocation that maximizes trading surplus. The major advantage of CVCM over double auctions is that CVCM allows package bidding. CVCM is expected to mitigate the coordination problems of direct negotiations. An automated system maximizes total surplus by matching buy and sell orders submitted by all subjects. CVCM has several important features. It's continuous in the sense that subjects can submit bids anytime during a trading round. The system provides immediate feedback of bids submitted by others and provisional prices, i.e., the prices subjects need to offer if they want to win the items. Porter, Rassenti, Roopnarine and Smith (2003) assert that auction systems which provide simultaneous feedback and allow bidders to revise their bids produce higher efficiency. The system is also iterative in the sense that a trading period consists of several rounds, and after each round, holdings of commodities are updated. The iterative procedure allows round-by-round update of allocations. Porter, Rassenti, Poopnarine and Smith (2003) reports that in complex economic environments, iterative auctions produce better results than the auction mechanism without iterative features.

The CVCM works as follows: There are several trading periods. Each period consists of 3 rounds in Series 1 and 2, and 4 rounds in Series 3 and 4.

[4] An attainable allocation is pairwise efficient if it is impossible for any two agents to improve their utilities by trading each other.

During a trading round, Subjects can submit bids to buy and/or sell an individual parcel or a combination of parcels. For example, Subject Number 1 could place an order to buy Commodity A1 for 1200 francs, buy A3 for 1000 francs, and sell B3 for 500 francs. This bid will allow him to obtain A1 and A3 in return for B3 and pay at most 1700 francs (=1200+1000-500). During a round, subjects can see all the bids placed by other players and all the bids they have placed. The above bid submitted by Subject Number 1 will appear as "Offer B3 and 1700 for A1 and A3" on the screen. The Subject identification is not shown on the computer screen. Based on the bids submitted by subjects, the computer calculates a set of provisional prices, i.e., the prices subjects need to offer if they want to win the items. The information is updated approximately every 10 seconds. Thus, agents can adjust bids in response to new bids from other subjects and well as provisional prices.

At the end of a round, all standing bids will be transacted, and the consequent holdings will be the initial portfolio for the following round. After the last round, the final endowments of the period are determined. We employ fixed ending time, and the remaining time is shown on the computer screen in each round. The first round in the first period lasts 7 minutes. The length of rounds is then gradually shortened. From the third period until the last periods, each round is 2 minutes.[5] Whether the number of rounds per period chosen above is appropriate is open to discussion. Bossaerts, Fine and Ledyard (2002) report that in their thin financial market experiments using the same combined-value call market mechanism, reducing the number of rounds forces trading to occur earlier in a period. Roth and Ockenfels (2002) show how in one-sided auctions, fixed ending time induces bidders to delay their bids. The same argument may apply to CVCM since the number of rounds is predetermined, and the hard closing (fixed-ending time) is used in CVCM. The strategic reason for late bidding could be to conceal their willingness to pay as well as observing bids submitted by other subjects.

One may argue that providing subjects with full information on orders placed by other bidders could potentially prevent the economy from realizing efficient allocations. Arifovic and Ledyard (2003) demonstrate that in call markets, equilibrium prices and volume are achieved faster when traders receive information only about the trading price, but not bids and offers by others. Porter, Rassenti, Roopnarine and Smith (2003) also control strategic behavior in their one-sided combinatorial auctions by feeding back only the information on item prices. They argue that bidders do not need to know who is bidding, how many are bidding, and on which items or packages they are bidding. We will take into account the above strategic problems when analyzing experimental results.

[5] The number of periods varies from 5 in Series 3 to 9 in Series 1 and 2. See Table 6.

4 Experimental Procedures

A total of 34 sessions, 26 sessions at the California Institute of Technology (CIT) and 8 sessions at the University of Hawaii (UH), were conducted. The general structure of the experiments is shown in Table 6. For each series, two or three sessions of the combined value call markets, oral double auctions, and direct negotiations were carried out at CIT. Having observed the superior performance of direct negotiations at CIT, we conducted eight sessions of the direct negotiations, two for each series, at UH. The purpose was to check the robustness of the high performance of direct negotiations with subjects who have not been exposed to many economic experiments and various types of trading institutions as may CIT subjects have.

At CIT, subjects were undergraduate students who had previous experience participating in a number of economics experiments of various types. Some subjects participated in more than one session, but were not allowed to participate in two of the same series. The combined value call markets were computerized experiments, and were conducted at the Caltech Social Science Experimental Laboratory. The oral double auctions and direct negotiations were conducted in non-computerized classroom settings where the experimenter could use black boards. At the University of Hawaii, subjects were undergraduate students who either had never participated in economics experiments, or had only participated in other, unrelated experiments in oral double auction.

Each experiment consisted of several periods. In Series 1 and 2, the three sets of initial endowments were repeated three times in an Easy-Moderate-Hard cycle, i.e., the Easy Endowment was used in Periods 1, 4 and 7, the Moderate Endowment was used in Periods 2, 5 and 8, the Hard Endowments were used in Periods 3, 6 and 9. In Series 3 and 4, the three sets of initial endowments were repeated two times, i.e., the Easy Endowment was used in Periods 1 and 4, the Moderate Endowment was used in Periods 2 and 5, the Hard Endowments were used in periods 3 and 6.

Table 6 List of Experiments

Exp. ID	Series	Mechanism	Location	Subjects	Periods	Conversion Rate	Average Earning ($)
CVCM 1-(1)	1	CVCM	CIT	3	6	0.001	33.3
CVCM 1-(2)	1	CVCM	CIT	3	9	0.0014	33.0
CVCM 1-(3)	1	CVCM	CIT	3	9	0.0014	31.0
DA 1-(1)	1	DA	CIT	3	6	0.001	35.0
DA 1-(2)	1	DA	CIT	3	9	0.0014	33.0
DA 1-(3)	1	DA	CIT	3	9	0.0014	35.0
Com 1-(CIT1)	1	Committee	CIT	3	9	0.0014	35.0
Com 1-(CIT2)	1	Committee	CIT	3	9	0.0014	35.0
Com 1-(UH1)	1	Committee	UH	3	9	0.0014	25.5
Com 1-(UH2)	1	Committee	UH	3	9	0.0014	25.0
CVCM 2-(1)	2	CVCM	CIT	3	9	0.0013	35.7
CVCM 2-(2)	2	CVCM	CIT	3	8	0.0013	33.7
DA 2-(1)	2	DA	CIT	3	9	0.0013	30.1
DA 2-(2)	2	DA	CIT	3	9	0.0013	34.6
Com 2-(CIT1)	2	Committee	CIT	3	9	0.0013	34.3
Com 2-(CIT2)	2	Committee	CIT	3	9	0.0013	36.0
Com 2-(UH1)	2	Committee	UH	3	9	0.0012	24.7
Com 2-(UH2)	2	Committee	UH	3	9	0.0012	26.0
CVCM 3-(1)	3	CVCM	CIT	8	5	0.0017	30.8
CVCM 3-(2)	3	CVCM	CIT	8	5	0.0017	32.5
DA 3-(1)	3	DA	CIT	8	6	0.0017	24.0
DA 3-(2)	3	DA	CIT	8	6	0.0017	25.3
Com 3-(CIT1)	3	Committee	CIT	8	6	0.0017	33.6
Com 3-(CIT2)	3	Committee	CIT	8	6	0.0017	33.9
Com 3-(UH1)	3	Committee	UH	8	6	0.0012	25.5
Com 3-(UH2)	3	Committee	UH	8	6	0.0012	24.0
CVCM 4-(1)	4	CVCM	CIT	8	6	0.0024	31.9
CVCM 4-(2)	4	CVCM	CIT	8	6	0.0024	31.9
DA 4-(1)	4	DA	CIT	8	6	0.0024	34.4
DA 4-(2)	4	DA	CIT	8	6	0.0024	30.1
Com 4-(CIT1)	4	Committee	CIT	8	6	0.0024	32.0
Com 4-(CIT2)	4	Committee	CIT	8	6	0.0024	33.6

Com 4-(UH1)	4	Committee	UH	8	6	0.0015	24.9
Com 4-(UH2)	4	Committee	UH	8	6	0.0015	24.0

5 Results

We will consider efficiency gain as the key measure of performance. The efficiency gain is measured as the realized increase in total values as a percentage of the maximum possible increase. We do not use the usual measure of efficiency because the efficiency levels of initial endowments differ across treatments.

Table 7 shows the mean efficiency gain by mechanism and initial endowment for each series. It also contains the results of Man-Whitney rank sum tests of the differences in efficiency gain. In most initial endowments in Series 3 and 4, the efficiency gain is highest under the direct negotiations at CIT. On the other hand, the efficiency gain under the direct negotiations at UH is the lowest in most conditions. This implies face-to-face negotiations produce higher efficiency than the other mechanisms when the number of commodities and subjects is increased, but subjects need to be trained to realize efficiency gains.[6] The double auction achieves high efficiency gain under the Easy Endowments in Series 1 and 2, but do not perform well when initial endowments are more difficult and the number of subjects and commodities are increased.

Efficiency gain is higher in CVCM experiments relative to other mechanisms in the Hard Environment in Series 2. Recall the valuations in Series 2 have complementary structures. Figure 2 shows the fractions of units traded by packages and single units. Over 80 per cent of parcels were traded as parts of package trades in CVCM in Series 2. Most of the package trades were made between Players 1 and 3 with no side payment, i.e., swapping. In fact, CVCM performs relatively well under all initial endowments in Series 2 and 4. This suggests CVCM alleviates the exposure problem. CVCM also outperforms other mechanisms in the Easy Environment in Series 3. This indicates that CVCM performs well when the number of subjects and commodities is increased but the initial endowment is easy. However, the efficiency gain significantly diminishes in the Moderate and Hard Environments. The number of rounds may not have been sufficient to allow a large volume of trade.

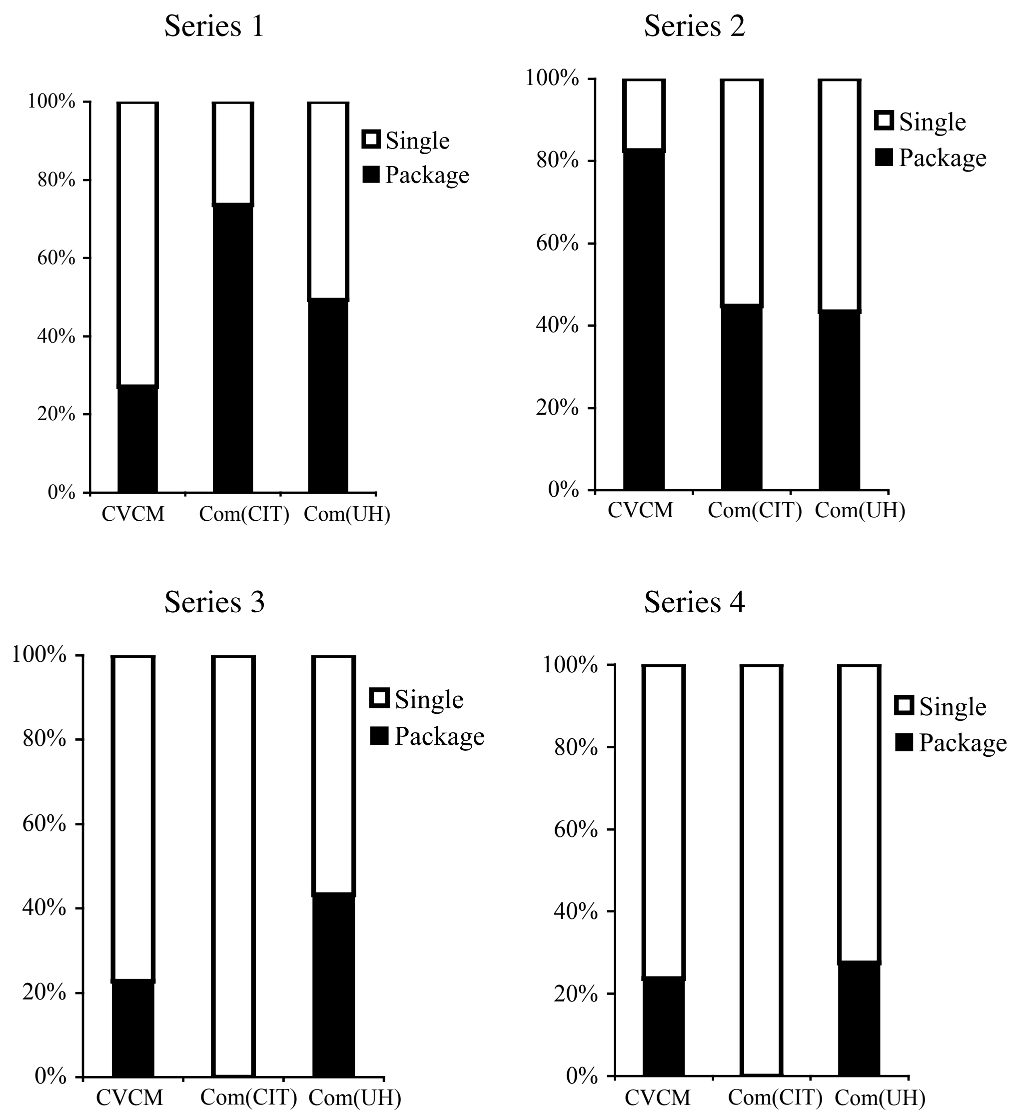
[6] The difference in performance may have resulted from the difference in the characteristics of students in two schools. CIT is a small school and students are accustomed to problem solving. UH is a state school with a large diversity of students.

Table 7 Mean Efficiency Gain by Initial Endowment, Series and Mechanism

Series	Initial Endowment	CVCM	DA	Com (CIT)	Com (UH)
1	Easy	.87	.98 [VV]	.95	.93
	Moderate	.87	.92	.99 [VV, D, HH]	.82
	Hard	.73	.82 [H]	.98 [VVV, HHH]	.64
2	Easy	.89	.96	.89	.89
	Moderate	.94	.87	.89	.81
	Hard	1.00 [DDD, CC, HHH]	.76	.85 [D, H]	.76
3	Easy	.99 [DD, HH]	.83	.93	.84
	Moderate	.82	.89	.95 [VV, D, H]	.69
	Hard	.67	.84 [V]	.97 [V, D]	.79
4	Easy	.84	.79	.85	.80
	Moderate	.72	.63	.80 [DD, HH]	.66
	Hard	.78 [HH]	.74	.85 [HH]	.74

Note:
[VVV,VV,V] indicate the mean efficiency gain of that treatment is higher than the mean efficiency gain of CVCM at the 1, 5 and 10 % significant levels, respectively.
[DDD,DD,D] indicate the mean efficiency gain of that treatment is higher than the mean efficiency gain of DA at the 1, 5 and 10 % significant levels, respectively.
[CCC,CC,C] indicate the mean efficiency gain of that treatment is higher than the mean efficiency gain of Com (CIT) at the 1, 5 and 10 % significant levels, respectively.
[HHH,HH,H] indicate the mean efficiency gain of that treatment is higher than the mean efficiency gain of Com (UH) at the 1, 5 and 10 % significant levels, respectively.

Figure 2 Proportion of units traded by packages and single units



The question is why is CVCM so unsuccessful in Series 1? Figures 3, 4, 5 and 6 present the relations between efficiency gain and the timing of trades in Series 1, 2, 3 and 4, respectively. As shown in Figure 3, the efficiency gain falls in Series 1 when subjects exercise "holdouts", i.e., they wait until later rounds to start trading. For example, in CVCM 1-(1) and 1-(2) the efficiency gain is low especially when subjects wait until the third round to trade. This makes it difficult for them to complete the necessary transactions to achieve the efficient allocation. In Series 2, subjects also have a tendency to hesitate to trade in early periods, but become keen to trade in later periods. It seems that Players 1 and 3 established the swapping routine by then. On the other hand, a certain number of parcels are traded in every period in Series 3 and 4, indicating subjects do not exercise holdouts when the number of subjects and commodities are increased.

Since we did not vary the number of rounds, we cannot offer any conclusion on the effects of the number of rounds on trading behavior. However, it seems that when markets are very thin, with only three subjects and six commodities to trade, subjects are hesitant to trade in early rounds. One possible explanation might be the subject's reluctance to reveal their willingness to pay for individual objects. One may argue that providing subjects with full information on orders placed by other bidders may prevent the economy from realizing efficient allocations, as Arifovic and Ledyard (2003) demonstrated for call markets. There may be both advantages and disadvantages to limit the information on orders. In Series 2 of our experiments, subjects quickly realize the complementary structure of valuations by observing each other's orders. If the information on orders submitted by others is limited, it may not have been possible to discover the complementary structure. Our experimental results in Series 2 demonstrate how providing information on orders of other subjects may better facilitate swapping.

Let us now consider why the direct negotiations at CIT outperform other mechanisms. Do they take better advantages of package trades? As shown in Figure 2, over 70 per cent of trades in the direct negotiations at CIT are package trades in Series 1, and its efficiency gain is significantly higher than other mechanisms. On the other hand, the direct negotiations at CIT did not make any package trades in Series 3 and 4. They conducted sequential double auctions, instead. As discussed in Section 3, it becomes harder for a subject to find a trading partner with compatible needs as the number of both tradable objects and agents increase. In case of Series 4, there does not exist a sequence of pair-wise efficient trades that lead to the efficient allocation. The direct negotiations at CIT handle this difficulty by organizing sequential double auctions.

To examine the impact of package trades on efficiency gain, we conducted fixed-effect model regressions for CVCM and the direct negotiations. The data from Series 1 and 2, and Series 3 and 4 was pooled together for each mechanism, respectively. Since we conducted only two or three experiments for each treatment, we need to account for group effects. For this reason, we use the fixed-effect approach. A dependent variable is the efficiency gain by period, and independent variables are the number of units traded as packages ("Package"), the cross effects of Series 2 (Series 4) with "Package", dummy variables for Series 2 (Series 4) and for each initial endowment in each Series, and a variable called "Learning". The learning variable is defined as the i-th period divided by the total number of periods for each period i in the experiment. If the coefficient of the learning variable is positive and significant, the efficiency gain improves in later periods. For CVCM, we also include the number of units traded in the first round of each period as an independent variable. Its positive coefficient indicates more active trades in the first round improve efficiency.

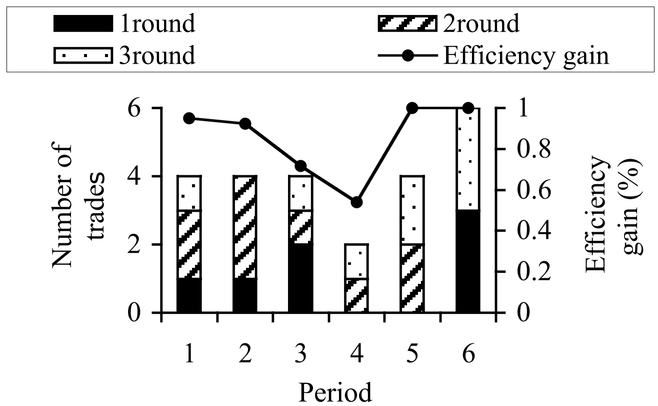
Table 8 contains the regression results.[7] Notice the dummy variables for initial endowments are all insignificant in all series in the direct negotiations at CIT. This suggests the performance of direct negotiations is robust across different endowments at CIT. The table confirms package trading has positive effects on efficiency gain in Series 1 and 2 under CVCM and the direct negotiations at CIT, as well as in Series 3 and 4 in the direct negotiations at UH. The cross effects of Series 2 and Package is positive and significant for the direct negotiations at CIT. This implies package trading was particularly important in Series 2. In the negotiation procedures at CIT, the coefficient of package trades is not reported for Series 3 and 4 since no experimental group conducted package trades.

The coefficient of the number of trades in round 1 is significant for Series 1 and 2 of CVCM, supporting our preceding argument that holdout has negative effects on the performance of CVCM when the number of subjects and commodities is small. The learning variable is significant and positive for the direct negotiation procedures at both CIT and UH in Series 3 and 4. This suggests when the number of commodities increase, it takes some periods to aggregate information and coordinate trades.

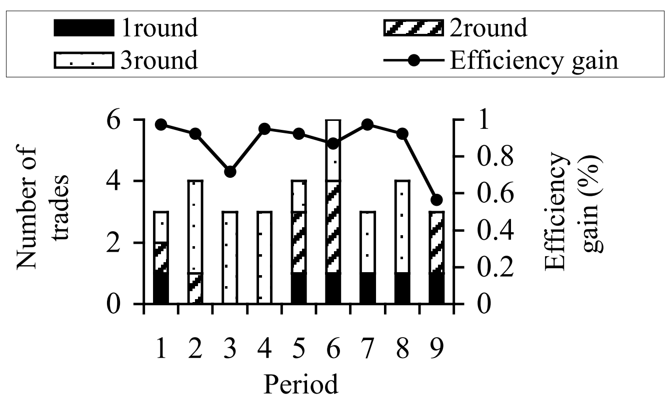
[7] The regression results are comparable when we use efficiency or absolute size of the realized surplus as dependent variables instead of efficiency gain.

Figure 3 Efficiency and number of trade by round in CVCM, Series 1

CVCM 1-(1)



CVCM 1-(2)



CVCM 1-(3)

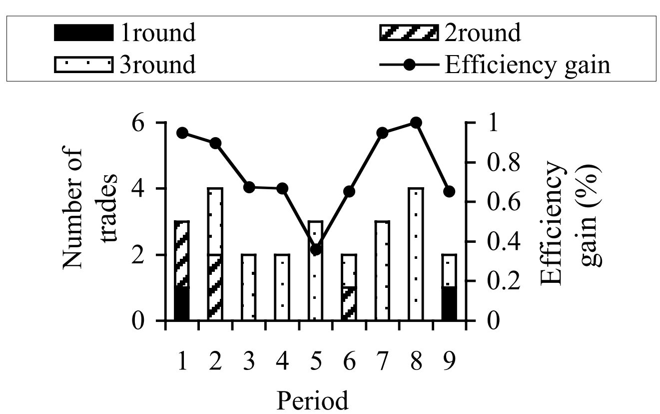
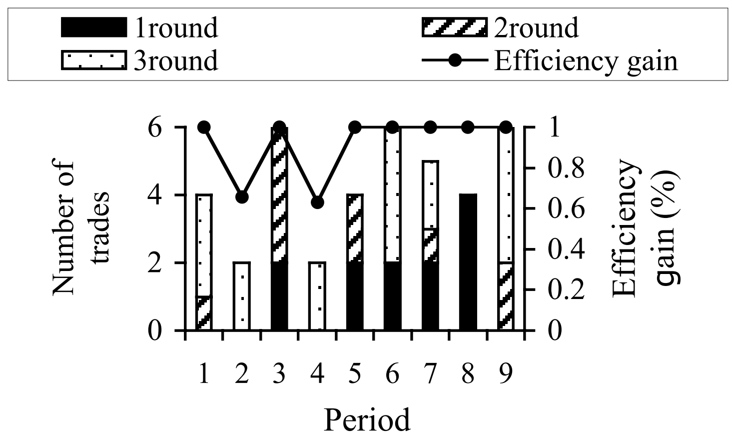


Figure 4 Efficiency and number of trade by round in CVCM, Series 2

CVCM 2-(1)



CVCM 2-(2)

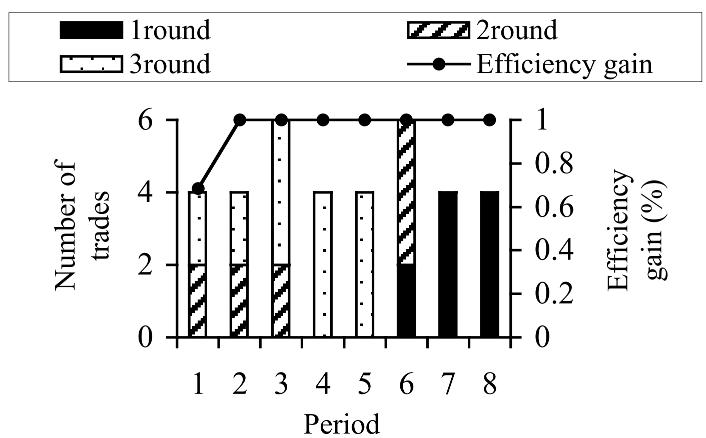
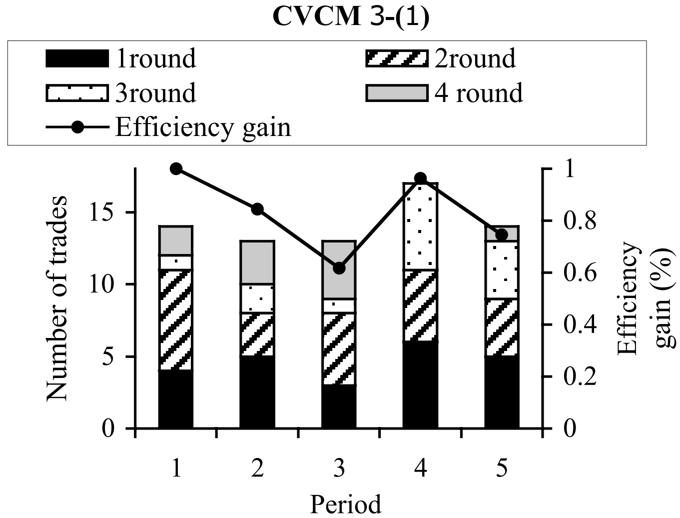


Figure 5 Efficiency and number of trade by round in CVCM, Series 3



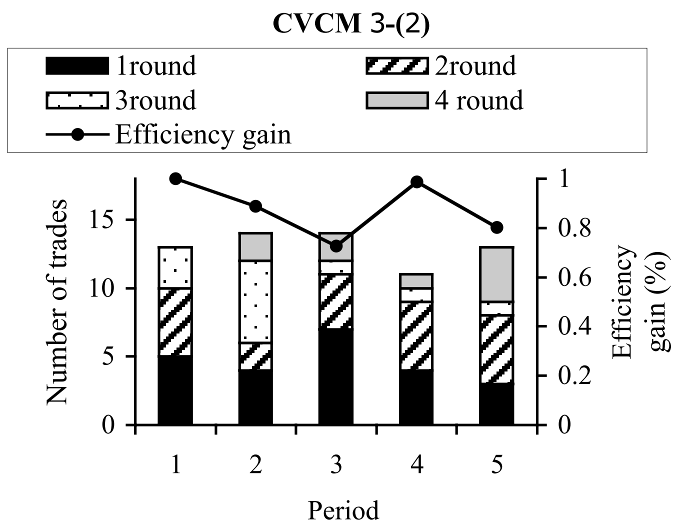
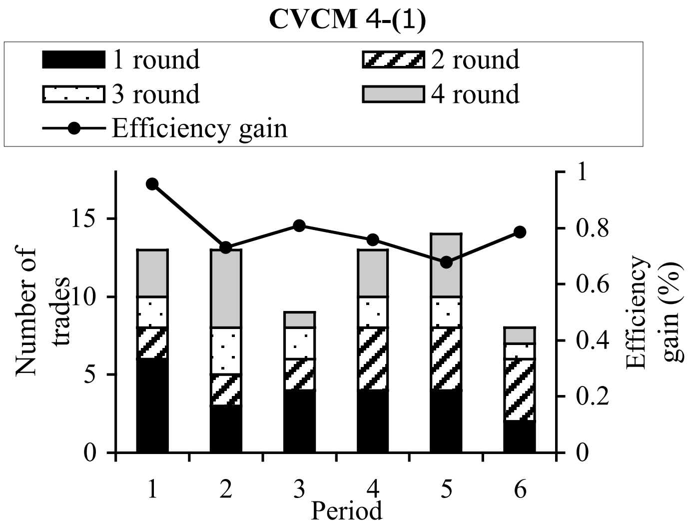


Figure 6 Efficiency and number of trade by round in CVCM, Series 4



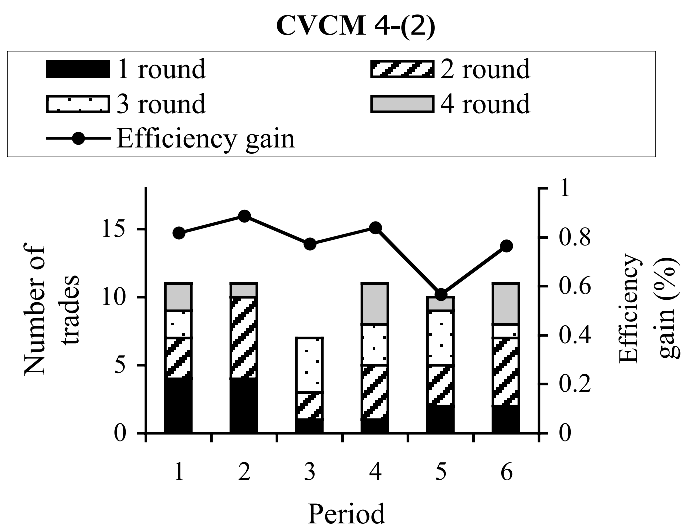


Table 8 Fixed-effect model estimates of efficiency gains for CVCM and direct negotiations

Variables	CVCM	Com (CIT)	Com (UH)
Series 1 and 2			
# of trades in round 1	0.05***		
Package	0.04***	0.01**	0.00
Package*Series2	0.02	0.03**	-0.01
D(Series 1 Moderate)	0.01	0.03	-0.10
D(Series 1 Hard)	-0.18***	-0.01	-0.29***
D(Series 2)	-0.16*	-0.10*	-0.03
D(Series 2 Moderate)	0.02	-0.02	-0.08
D(Series 2 Hard)	-0.18**	-0.07	-0.13
Learning	-0.11	-0.01	0.01
Constant	0.87***	0.94***	0.92***
R^2	0.49	0.35	0.35
Series 3 and 4			
# of trades in round 1	0.02*		
Package	0.00		0.03***
Package*Series4	0.01		-0.02
D(Series 3 Moderate)	-0.13***	0.00	-0.09
D(Series 3 Hard)	-0.31***	0.01	-0.13*
D(Series 4)	-0.08	-0.08	0.12
D(Series 4 Moderate)	-0.09	-0.06	-0.17*
D(Series 4 Hard)	0.01	-0.02	-0.10
Learning	-0.12**	0.08*	0.21***
Constant	0.95***	0.90***	0.54***
R^2	0.84	0.60	0.58

Note: * Significant at the 10% level. ** Significant at the 5% level.
*** Significant at the 1% level.

6 Conclusions

Direct negotiations produce higher efficiency than the other two mechanisms. The two-sided combinatorial call markets (CVCM) do not always yield high efficiency, but seems to alleviate the exposure problem. CVCM performs particularly well when swapping is easy, such as in Series 2. This might be because swapping makes subjects willing to reveal their incentives to trade. When a subject places a package bid under CVCM, his bidding/asking prices for individual items do not appear on the screen. Limiting the information on orders by other subjects may prevent them from finding compatible needs of other subjects in CVCM. CVCM also performs better than other mechanisms when the number of subjects and commodities are increased, but initial endowments and valuations are unchallenging.

We have identified a strategic behavior problem auction studies may face when they extend their research to two-sided markets. When the market is one-sided, the combinatorial markets are known to perform better than other mechanisms. We have shown in two-sided combinatorial markets subject attempts to strategically holdout commodities when the number of subjects and commodities is small. This phenomenon was not observed when the markets are one-sided and subjects are not given initial endowments of commodities.

Resource allocation problems are not subject-matter neutral, and the land allocation problems should be considered within specific social and political contexts. In addition to land exchanges, land consolidation projects often incorporate the improvement of irrigation and transport systems. Our research abstract out these aspects. Also, in our experiment, we have a small number of subjects and commodities compared with the real world land redistribution problems. For these reasons, our experimental results cannot be directly applied to the real world land redistribution problems where there are hundreds of farmers and land parcels involved.

Nevertheless, this study yields a couple of policy implications for designing land consolidation mechanisms. Our experimental results show direct negotiation procedures perform better than other mechanisms when subjects are trained. When subjects are not trained, they do not easily realize high efficiency. Individuals need sufficient experience in a variety of trading institutions to discover the way to efficiently reallocate resources. The direct negotiations resemble the market assisted land reforms, which have been implemented in several developing countries (Deininger, 1999). Under the market-assisted land reforms, the government provides grants to farmers so they can purchase land plots. The key difference between the negotiation procedure in our experiment and the market-assisted reform is under the negotiation procedure, subjects deal with all potential trading partners simultaneously whereas in the market-assisted reform, farmers have to search for potential trading partners and negotiate with them bilaterally. We expect the market-assisted reform to involve higher transaction costs. Our experimental results indicate the government may need to play an active role in coordinating land transactions.

CVCM is expected to mitigate the coordination problems of direct negotiations by shifting computational burdens from agent to computers. A number of studies have demonstrated how one-sided combinatorial auctions outperform double auctions, simultaneous and sequential one-sided auctions under complex environments. When we extend the study to two-sided exchange markets, subjects exercise holdouts when the number of subjects and commodities is small. However, when swapping is easy or when the number of subjects and commodities increase, they stop holding out. This indicates that CVCM may perform better than other mechanisms when we increase the number of subjects and commodities. Unlike our experiments with a small group of participants, land reforms often involve a number of farmers and parcels. CVCM may be a superior mechanism when a large number of participants and land parcels are involved in the redistribution scheme.

Our experimental setting left out the role of credit markets and the provision of public good (such as road and irrigation systems) in land consolidation projects. Potential extensions of this study are 1) to introduce credit markets and the use of land as collateral and investigate the interaction between credit and land markets, and 2) to investigate how the provision of public good eases the tension among traders.

Appendix

This appendix describes the structure of Gap Costs used in the experiment. In Series 1 and 2, there are three agents, numbered 1, 2, and 3, and two locations, A and B. In each location there are three parcels. There are a total of six parcels in the economy; A1, A2, A3, B1, B2 and B3 as shown below.

A1	A2	A3

B1	B2	B3

The value of a bundle of parcels is the sum of the stand-alone values (see Tables 1 and 3) minus Gap Costs 1 and 2. If a subject has A1 and A3 (B1 and B3) but not A2 (B2) at the end of the period, he will have to bear 1000 francs of Gap

Cost 1. If he has parcels in both Locations A and B, then he will have to bear additional 1000 francs of Gap Cost 2.

In Series 3 and 4, there are eight agents, and four locations. The eight subjects are numbered 1 to 8, and the four locations, A, B, C and D. In each location there are four parcels. Thus there are a total of sixteen parcels in the economy; A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3, C4, D1, D2, D3 and D4. Following is the geographical representation of locations of above parcels.

A1	A2	A3	A4

B1	B2	B3	B4

C1	C2	C3	C4

D1	D2	D3	D4

Gap Cost 1 and Gap Cost 2 are both 200 francs in Series 3. A subject is penalized 200 francs for each "gap" in each location. For example if he holds A1 and A3 but not A2, he will be penalized 200 francs. If he holds A1 and A4, but not A2 and A3, he will be penalized 400 francs.

Gap Cost 2 increases with the distance an agent needs to travel between the most distant locations in his holdings. If a subject holds parcels in Locations A and B but not in C or D, then Gap Cost 2 is 200 francs. If a subject holds parcels in Locations A and C but not in D, then Gap Cost 2 is 400 francs. It does not matter whether he holds parcels in Location B because Gap Cost 2 correlates with the distance an agent needs to travel between the most distant locations. If a subject has parcels in both Locations A and D, then Gap Cost 2 increases to 600 francs. In Series 4, the structure of the gap costs is the same as Series 3, but is twice as large (400 francs). We double Gap Costs to make exposure problems more severe.

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