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# Evaluating the potentials of a marketable permits system in the field: An application to forest conservation in Shaktikhore, Nepal

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**Abstract**

A new paradigm in natural resource management has moved towards more decentralized mechanisms to reverse the degradation. One of such mechanisms is a marketable permits system (MPS). Although the properties of MPS have been studied and identified to be effective in controlled laboratory experiments, little is known about how MPS works in the real field setup. To fill the gap, this paper seeks to evaluate the effectiveness and potentials of MPS in the real forest conservation by implementing a framed field experiment. Shaktikhore, Nepal has been chosen for the experimental site, since farmers' livelihood there depends on forests and they are able to report their valuation of forestry from economic and environmental points of view. This experiment elicits economic valuation of local farmers for each unit of forestland, derives aggregate demand and supply of the permits, and with a uniform price auction (UPA), MPS field experiments were carried out to see equilibrium prices and efficiencies of the market. The results suggest that MPS is effective with high efficiency of 80% in the real field. For this success, UPA institution is identified to be the key element because (i) farmers with elementary education could understand and follow the rules of trading and (ii) they are induced to reveal their valuations of forestland through bids to buy and offers to sell. To our knowledge, this study is the first that designs and employs UPA institution under trader settings, showing the successful performance of such a MPS scheme in the real field of developing nations. Overall, our research suggests that MPS could be the effective policy option for "real" practice of natural resources management even with less administrative expertise, limited education and fewer resources to implement.

**Key Words:** uniform price auction, marketable permits system, framed field experiment, forest management

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# 1 Introduction

The process of evolution in the society has changed natural resource management from centralized to more decentralized and voluntary systems, and such changes have been sweeping the world (Enters et al. (2000)). At the same time, natural resource management and its related livelihood are still two major affairs that impact on conservation of bio-diversity and welfare distribution (United Nations Environment Programme (2004)). With the current trend of the rapid transition towards market economy, equitable welfare apprehension and ineffectiveness of centralized systems, escalation towards voluntary forest management has given contemplation to premeditate a new mechanism for forest preservation. The mechanism is a marketable permits system (hereafter MPS) advocated by economists.

Economists have long considered the MPS to be potentially effective for the valuation and preservation of environment and natural resources, and also that it could even be a solution under decentralized systems with the price signals of market exchanges (see, e.g., Shogren (2005)). One of the most important advantages economists claim is that it can achieve environmental objectives with the least cost to the society (Field and Field (2006)). Given this positive perspective over MPS, extensive studies have been done for testing theories and examining the proposed market performance (See, e.g., Ledyard and Szakaly-Moore (1994)). However, little is still known about how MPS works in the real field setup such as in the context of developing nations as applied to the natural resource management. Therefore, this research seeks to analyze the effectiveness and potentials of MPS in the field, and to provide an important testbed for the proposed market institution with a framed field experiment.

In the last three decades, most environmental management had adopted command and control systems or environmental tax (subsidy), but due to some critical problems in compliance, inflexibility and informational disadvantages that arise from those policies, Dales (1968) and others such as Hahn (1989) and Carlson and Sholtz (1994) have proposed the concept of MPS also known as "tradable property rights," or "trasferable development rights." MPS is theoretically established to be economically efficient. More specifically, it has an informational advantage for achieving efficient pollution reduction, and to give agents stronger incentives to innovate technologies and management practices under decentralized environments (Kolstad (2003)).

The fundamental rules of the MPS employed in many previous works and this study are summarized as follows: First, a central authority determines a total number of permits distributed to an industry and an initial endowment of permits for each agent. Each unit of permits entitles agents to emit one unit of pollution (to develop one unit of the land). In other words, each agent is not allowed to pollute (to develop) without having permits. Second, agents are allowed to buy and sell their permits through some auction or market mechanism during trading periods. This type of MPS is called "cap and trade," and economic theory predicts that MPS achieves the targeted pollution reduction in the least cost way if the government appropriately organizes the market institution and agents in the market are sufficiently rational. It is also known that the least cost property holds even though a central authority does not have any information on agents' abatement costs for the pollution (or valuation for the land).

Many studies on such "cap and trade" MPS have been carried out especially under a controlled laboratory setting with various environments and treatments to verify the performance. There are two important dimensions of experimental designs in these studies: (i) market institution choice: double auction (DA) or uniform price auction (UPA) for permit trading, and (ii) trader or non-trader settings.[1] With respect to the first dimension, it is concerned with how the price determination mechanism is organized in the permit market. DA mechanism is a real-time trading institution in which agents can submit bids to buy and offers to sell for a unit of permits, and can even accept the best bid and offer made by other agents for that unit in any time during trading periods of several minutes.[2] Therefore, it is known that DA gives more flexibility to agents for trading strategy, while there are more opportunities of speculative

[1]There are several experimental works for marketable permits which employ the market institution other than DA and UPA such as Mestelman et al. (1998) and Franciosi et al. (1993). However, we have identified that the mechanism cannot be applied in the real field of Nepal due to several reasons such as critical differences of the environment and characteristics of subjects there. Thus, the results in our work cannot be directly compared with those.

[2]Davis and Holt (1992) for the details about DA.

trades.

On the other hand, UPA is known to be simpler than DA in the sense that all of the permit trades are made with a uniform price.[3] First, each agent is asked to submit "bids to buy" with which he is willing to purchase an additional permit as well as "offers to sell" with which he is willing to sell each unit of permits he has. After all the agents submit bids to buy and offers to sell, a central authority collects and ranks all of the bids to buy from high to low (that is a demand curve), and all of the offers to sell from low to high (that is a supply curve), and determines the intersection of demand and supply curves. More concretely, the intersection occurs at the last unit in which the bid to buy exceeds the offers to sell, and the uniform price is the average between the two. UPA is also established to achieve high efficiency and also stable price dynamics (Smith et al. (1982); Cason and Plott (1996)).

With respect to the second factor of trader or non-trader setting, it is concerned with whether each agent in a permit market can be both a seller and a buyer during trading periods or he can only be either one. If he can be both, we call the environment "trader setting," otherwise "non-trader setting" (Ledyard and Szakaly-Moore (1994)). Reflecting the application of MPS, a trader setting is known to be closer to the reality. However, a considerable portion of experimental works employ non-trader settings since it simplifies the experimental procedures and reduces the decision complexity of agents.

A majority of previous works have used DA for experimental studies of MPS. In particular, the works by Plott (1983); Cason et al. (2003) and Kilkenny (2000) have used that institution under "non-trader settings." They report that average efficiencies observed in the experiments are around 98% and promises greater flexibility and relief from administrative burdens compared to other schemes, though instability in the permit's prices is observed. These MPS results are consistent with high efficiency achieved under DA with non-trader settings in other DA auction studies such as Williams (1980) and Plott and Gray (1990).

Another group of works such as Ledyard and Szakaly-Moore (1994); Godby (1997); Muller

[3] UPA is also known as a call market and see Davis and Holt (1992) for the further reference.

et al. (2002) and Cason and Gangadharan (2006) have also used DA but under "trader settings." The result in these experiments shows that observed efficiencies exhibit higher variation and be lower on the average, compared to the DA experiments under non-trader settings, and the ranges are between 60% and 98%. Furthermore, these works report that observed prices of permits could be unstable. In summary, DA under trader settings are more likely to generate lower efficiencies and less stable price dynamics than those under non-trader settings. Some economists argue that agents are given more opportunities of speculative trades for permits under trader settings and this may be the reason for the above results (See, e.g., Ledyard and Szakaly-Moore (1994)).

Although DA experiments are established to exhibit high performance with respect to efficiency, Cason and Plott (1996) have conducted an experiment with UPA under non-trader settings as a possible alternative. The work confirms that UPA is very efficient in MPS, and induces true revelation of abatement cost schedules for pollution through observed bids to buy and offers to sell in the experiments. It is also found that price dynamics is stable due to the fact that UPA is relatively simple and does not give opportunities of arbitrage trades to agents in the permit market.

With this literature review, we have identified that most of the works, which examine the performance of MPS, have been done in controlled laboratory experiments with induced value frameworks (See Muller and Mestelman (1998); Cason (2010) for an extensive literature review). Also, there is no systematic field experimental work that analyzes the same issue with an eye to the application of MPS to real environmental or natural resource problems outside laboratories such as in the developing nations. To fill this gap, we seek to evaluate the potentials and effectiveness of MPS in the field as applied to forest conservation in Nepal. For this purpose, we designs and implements a framed field experiment with some novel features in the way that it is feasible in the context of developing nations and understood by the "real" subjects.

For an experimental site, we chose Shaktikhore, Nepal since farmers' livelihood there highly depends on forest and they are in a good position to report their valuation of forestry from both economic and environmental points of view. First, we have conducted a survey through which we elicit valuation of local farmers for each unit of forestland, derives demand and supply for forestland as well as for permits. Second, based on these derived aggregate demand and supply for the permits in the first stage, MPS experiments were conducted with UPA under trader-settings. Experiments provide the observations of efficiencies, price dynamics and revelation of valuation through bids to buy and offers to sell, which enable us to analyze the overall performance of UPA in the real field.

Recall that all subjects in this field experiment are local farmers whose life is highly dependent on forests and their education level is quite elementary. Many of them cannot make even a simple arithmetic calculation such as summation and subtraction, but they can understand which number is larger given two different numbers. Thus, they can compare and make a trade of their forest products through local agricultural markets in daily life. With these facts in mind, we chose UPA rather than DA as a market institution since it is simpler and more intuitive to explain to local farmers for each situation of when they incur the loss or gain more profits from the trades under MPS, compared to the real time trading of DA. Another point to mention in our experimental design is that we chose a trader setting to reflect the reality of MPS applied to natural resource management.

The results suggest that MPS is effective with high efficiency of 80-90% in the real field. For this success, UPA institution is identified to be a key element because (i) farmers with elementary education could understand and follow the rules of trading and (ii) they are induced to reveal their valuations of forestland through bids to buy and offers to sell. To our knowledge, this study is the first that designs and employs UPA institution under trader settings, as well as establishes the successful performance of such a MPS scheme in the real field of developing nations. Overall, our research suggests that MPS could be the effective policy option for "real" practice of natural resources management even with less administrative expertise, limited education and fewer resources to implement.

We organize the rest of the paper as follows: In section 2, we describe overview of community forest in Nepal. In section 3, experimental designs are introduced. In section 4, we report experimental results. Final section offers some discussion and conclusion.

## 2 Overview of community forestry in Nepal

The Federal Democratic Republic of Nepal is a landlocked country in South Asia, with a northern border to the People's Republic of China, and south, east, and west to the Republic of India. Total area of the country is 147181 square kilometers of which the hills and mountains cover 80% . The land use system of the country is divided into three parts, 29% of land is forest, 10.6% is shrub, and 12% is grassland (His Majesty Government (1999)). The total population of the country is approximately 30 million, where 80% of them depend upon subsistence farming (Central Bureau of Statistics (2001)). Forestry sector is very critical in terms of socio-cultural and economic points of view as farm, forest, and livestock are interrelated components of farming systems in Nepal (Gilmour and Fisher (1991) and Mahat et al. (1986)). The forest management system has undergone a structural shift from privatization, nationalization to voluntary participation systems (Gilmour and Fisher (1991)).

The forest management prior to 1957 has been based on indigenous practice by local villagers for protection and utilization to meet daily demand of fuels, fodder, poles, and timber. Private Forest Nationalization Act of 1957 nationalized the entire forestland which excludes people from forest utilization and management to avoid further deforestation (Gilmour et al. (1989)). At the period from 1978 onwards, a local institution known as "Community Forestry User Group" has managed local forests known as "Community Forest." Inequality and inclusion poverty are the major problems for the country in its transient phase along with the wide income disparity, political instability and lack of social reform and imprudent utilization of resources.

Community forestry has been considered as decentralized voluntary forestry management systems where community forestry user group (CFUG, here after) contributes labour to organizing activities of forest protection and management such as meeting, harvesting, silviculture, weeding, thinning, pruning, and guarding. CFUG members from the community jointly practice silvicultural operations as one of the activity for several hours. The ways of the CFUG parctices are known to be highly heterogeneous, and it is reported that on the average, Rs. 165 million worth labour force works for the forestry management in terms of one-person a day (Kanel (2004)).

Community forestry management as a participatory system had been considered a viable solution to forestland preservation, however, problems of information asymmetries, incentive incompatibility, ineffective monitoring and poor maintenance have resulted in suboptimal outcomes (Campbell et al. (2001)). Growing literature has backed this finding along with some empirical studies (See, e.g., Adhikari et al. (2004)). Community forestry management system is inefficient in its process because poor households are deprived of resource appropriation and benefit sharing, consequently this system in Nepal has not necessarily helped poor people, but has often worked to their disadvantage (Graner (1997)).

Livelihood of community is directly dependent upon forest, so proper forestry management system should account for societal equatability and provide subsistence requirement to its local users in the community. Gautam (1987) argue indigenous forest management system to be more equitable and effective in conserving natural integrity, compared to formal management systems of community forestry as it fails to address cost-benefit sharing arrangement in a equitable manner to the society. The consequence of such a failure has led to inefficiency in the formal management system of community forestry and has opened the new door for inception of feasible alternative institutional setup for forest management to enhance the access of poorer households to the community forest.

The MPS, which is also known as "tradable property rights," can be a solution and applied to forestland management, as it gives a right to the people for utilization of forest products without clear cutting timbers. This approach provides equal rights to each individual, and by holding the permit, each individual can make a commercial use of forestland under some controlled regulation. To implement MPS, it requires local farmers to enter into a certain time contract to attain an arranged number of permits for forestland use, where they can carry out agro-forestry farming or simply follow ongoing management practices. In addition, initial permits can be allocated equally without any socio-economic discrimination, consequently it can address the issue of inequitable distribution of the resources as an initial right or opportunity. This applicability of the MPS motivates us to implement the field experiment in Nepalese cases.

The Shaktikhore village development committee is located in Chitwan District at southern part of Nepal where we implemented our field experiments (See figure 1). Chitwan district itself is rich in natural flora, fauna and highly committed towards species diversity. The meaning of name *Chitwan* itself is *Heart of the Forest* in Nepali language. The Shaktikhore village holds a unique blend of diversified indigenous ethnic groups such as "Chepang" with approximately 1000 individual households involved mainly in agriculture and forestry.[4] All of the hill forests in the study site are surrounded by agricultural land and has to fulfill primary demands of forest products for rural households.

Subsistence farming in that region is based on a triangular relationship of farm, cattle and forest (Adhikari et al. (2004)). Forestland is very essential for these people as they yield grass fodder to feed livestock, leaf litter for composting, fuel wood for cooking and heating, timber and poles for house construction. Most of the households daily routine is to do farming and harvesting forest products to fulfill their primary needs. The literacy rate in Shaktikhore village is around 60% (Central Bureau of Statistics (2001)), which means most of them have only elementary level education and many of them cannot read, write and make minor arithmetics like addition, subtraction and multiplication etc.

# 3 Designs of framed field experiments

This section provides an overview on the design of our framed field experiments. Firstly, we explain a study site, a feature of subjects' pool and how we elicited economic valuation (hereafter

[4]The "Chepang" is an indigenous ethnic group that inhabits this village, and they traditionally practice slash-and-burn agriculture, or simple hoe-based horticulture along with mostly hunting and gathering from the forests.

EV) of local farmers for each unit of forestland. Next, we highlight how the information of EVs has been utilized in the MPS with UPA for the forest conservation at Shaktikhore, Nepal. Finally, we explain the procedure and general sequences of experiments focusing on how long each session lasts and how much each participant gets paid.

We set our field experiment at Shaktikhor, village development committee in Chitwan District at southern part of Nepal. As mentioned earlier, this choice is made since farmers' livelihood there depends on forests and they are able to report their valuation of forestry from economic and environmental points of view. The field experiment was conducted at the community hall especially constructed for "Tourism for rural poverty alleviation program" by Chitwan hill guides group. Subjects were randomly chosen from five different villages at Shaktikhore, Nepal. All together 40 subjects participated in the experiment, where subjects are typical farmers and community forestry user group members. We have conducted the four session each of which has employed 10 subjects from different villages and consist of 10 experimental periods. Each session took 3 hours on average. In the first stage, each subject has to go through the survey interview for the elicitation of EVs for each unit of commercial forestland they demand.

To fulfill this objective, we have asked respondents what is the maximum price he or she is willing to pay (WTP) for each unit of forestland realizing the net benefit they can gain if the unit is given as a commercial forest (See the row of "Economic Value (EV)" in table 4). Note that if people obtain a commercial forest, they can utilize the forest to produce forest products including timber and non-timber products following the regulation of Nepalese government. Of course, the regulation prohibits some extreme production activities of commercial forests such as clear cutting. On the other hand, irrespective of the ownership of commercial forest, they have a series of obligations to participate in community forestry management as a member described in the previous section. Thus, economic valuation we asked a respondent in this survey is the net benefit of obtaining a unit of commerical forests considering the fact that the respondent has some obligations for community forest management, too.

For some respondents, economic valuation for a unit of commercial forests may be low, because their life is not dependent on forests and they may be employed in non-farming forms of jobs. For others, economic valuation could be very high, because they have some experitses to generate timber and non-timber products through their forest management practices, and are confident to obtain large net benefit. In summary, through a series of these WTP questions, we have elicited the demand of each individual until their WTPs for commercial forests get zero or negative. For instance, table 4 exhibits a schedule of WTPs elicited from one respondent and this person report zero WTP or negative value for 11th unit of forestland.[5] Recall that the respondents are very knowledgeable and experienced in forestry practices and have been trading forest commodities in their every day life, which satisfies the sufficient conditions for employing a open-ended question format (See, e.g., Cummings et al. (1986) and Mitchell and Carson (1988)). Fortunately, we have found that respondents did not find any difficulty in reporting WTP values throughout the survey and thus the open-ended format appeared to be appropriate.

After the collection of EVs, we can derive the aggregate demand of forestland for each session as shown in figure 2. This figure consists of four subfigures each of which corresponds to the demand in each session. For instance, subfigure 2(c) shows the downward derived demand of commercial forestland for session 3. This is drawn by pooling and ranking the collected EVs in session 3 from high to low where aggregate farmers' demand (or WTPs) become zero at the 64th unit of forestland. Other subfigures 2(a), 2(b) and 2(d) are drawn in the same way and show that their demands are qualitatively similar each other in the sense that their demands are downward in the same degree and becomes zero around 60th unit of forestland.

Next, we have to determine the capped level of commercial forestland provided as permits in the MPS. For this, we referred to the previous studies which suggest that, out of total forestland 3.5 million hectares, around 62% has been already handed to the community for forestland preservation (Regmi (2000)). In this scenario of gradually handing over accessible forestland to the community for preservation, we have determined 30% of total demand to

[5]Note that some respondents report zero WTP for the units of forestland less than 10, such as 8 or 5 units. In such a case, EV cells for those units corresponding to zero WTP are trimmed accordingly.

be allocated to subjects as marketable permits in our field experiments. Given the state of such an affair, the permit endowments are allocated symmetrically to all subject as 30% of their demand so that the capped level has been allotted to preserve 70% of forestland. This is consistent with the ongoing situation of forest management in Nepal as indicated in Regmi (2000). For instance, refer to table 4. This subject has demanded 10 units of forestland and thus he is entitled to have 3 units of permits as initial endowments of 30%. Following this way, the aggregate supply of permits has been derived for each session. For an example of session 3, 22 units has been determined as aggregate supply that is 30% of the total demand of 63 units (see subfigure 2(c)).[6] In other words, we suppose that only 30% of forestland is for commercial use, and the rest of 70% for conservation.

Given the information of EVs for forestland, we can derive the demand and supply for permits in the UPA. As mentioned earlier, we employ UPA under a trader setting. This means that each subject is required to submit bids to buy and offers to sell all at once in a single trading period. More concretely, each subject is asked to submit bids to buy with which he is willing to buy each additional unit of permits as well as offers to sell with which he is willing to sell each unit of permits he possesses. For instance, consider a subject endowed with three permits and facing a EV schedule for each unit of forestland as shown in table 4. In this case, he must submit seven distinct bids to buy each of which corresponds to the potential purchase of permits for 3rd, 4th,..., 10th unit of forestland and three distinct offers to sell each of which corresponds to the potential sale of permits for 1st, 2nd and 3rd units he currently possesses.

If each subject is rational in the sense that he understands the basic rule and how the uniform price is determined, subjects' bids to buy and offers to sell should, in theory, be very close to the EVs (Cason and Plott (1996)). In the experimental instruction written in Nepalese language, we clearly mention that if a bid to buy (an offer to sell) is higher (lower) than the corresponding EV, then it may incur the loss, but we did not repeatedly tell them. Also such

[6]We admit that there might be a better way to determine an initial allocation of permits. However, when each subject reported his EVs, he did not know in advance what types of experiments proceed. Therefore, the way we have done for an initial allocation does not affect the reporting behaviors of the subjects and the results that follow.

irrational behaviors are not prohibited although some previous research does not allow such irrationality. This is motivated by the fact that we seek to clarify whether MPS under trader settings can be effective or not for local farmers in Nepal under the most primitive setting.

Suppose that subjects are sufficiently rational, and they reveal their EVs through submitting bids to buy and offers to sell as predicted by economic theory. We can derive a pair of aggregate demand and supply for permits in each session by ranking bids to buy from highest to lowest and offers to sell from lowest to highest. When the derived demand and supply are plotted together, it yields equilibrium volume of trade and price as an intersection of the two curves. Figure 3 consisting of four subfigures shows a pair of derived demand and supply for permits in each session. Subfigures 3(a), 3(b), 3(c) and 3(d) corresponds to sessions 1, 2, 3 and 4, respectively. These four subfigures show that demand and supply for permits are slightly different with respect to the steepness of the curves, but the qualitative nature of the market appears to be close. In other words, participants are farmers from five different villages and we have randomly selected them. In general, the equilibrium price and volume of trades shown in subfigures are not so different each other.

In a local area of our field, there were neither computers nor internet connection so that everything was manually managed by hiring 10 research assistants for each session. Following the general rule of UPA, each subject does not know anything about EVs of other subjects and volumes of trade that occurred, and the corresponding payoffs of others. Subjects are not allowed to communicate with each other during the period of trading, and were paid real money based on the cumulative payoffs of their decisions over 10 periods. Given the aforementioned environment, each subject was required to determine bids to buy and offers to sell all at once in a single period. After the announcement of the uniform price, they identify whether they become buyers or sellers and their total payoff in that period.

For instance, suppose that a subject have EVs for forestland as shown in table 4 and is endowed with three units of initial permits. In this case, a subject is asked to submit three distinct offers to sell and seven distinct bids to buy. If the uniform price is announced as 18500 as in table 4, this subject will buy two additional permits by paying 18500 for each since his bids to buy for the corresponding units are higher than the price (21000 and 19000 for 4th and 5th). In that trade, he must pay 37000 (= $2 \times 18500$), and becomes to possess five permits, which gives him a gross benefit of 159000 (summation of EVs from 1st and 5th units). His payoff in that period is the difference between the two, that is, 122000 (= $159000 - 37000$). The further details of the rules and the auction mechanism of UPA in the experiments are summarized in Appendex.

As mentioned earlier, many subjects do not have basic math skills for rigorously calculating final payoffs so that the calculation was usually double-checked by research assistants. However, each subject appeared to understand what kind of situations they incured the loss and obtained more benefit from trading. We instructed subjects to trade in the way that they seek to obtain more benefit from trading without thinking too much about the payoff. This way of explanation was selected due to the fact that many subjects do not have math skills, but they have a sense of trading for forest products in a local market.

Typically, our participants are paid local money whose value is almost equal to US \$2 as a show-up fee. At the end of the session, experimental rupees has been converted to real NRs at the rate of 1000 experimental rupees= 1NRs, each subject earned min NRs 500 and max NRs 2000 and average NRs 800 which is equivalent to \$12 approximately. This is high stake for typical farmers in that region because their daily earning as a labor input in forestry is \$4 $\sim$ \$7.

# 4 Experimental results

This section provides the details of the experimental results. The first subsection gives an overview about the demand of forestland by the local farmers at Shaktikhore, Nepal, the derived demand and supply of marketable permits. The second subsection reports overall efficiency gains from the trading. The third subsection shows observed equilibrium price behaviors and the associated volume of trades. The final subsection addresses the trading behavior of individuals regarding "bids to buy" and "offers to sell" strategies.

## 4.1 Elicitation of economic valuation for forestland

The demand and supply of marketable permits in each session are derived, based upon the elicited demand for forestland taken through the survey. Figure 2 consisting of four subfigures shows the aggregate demand for forestland elicited from 10 subjects in each session. Subfigures 2(a), 2(b), 2(c) and 2(d) corresponds to the elicited aggregate demand in sessions 1, 2, 3 and 4, respectively. From comparison of the four subfigures, we can see that they are not so different qualitatively and the total aggregate demand in a session is approximately 60 *Khatta*.[7] Furthermore, the intersection between the supply and demand occurs around NRs 20000 in each session and note that it could be considered an equilibrium price of permits in MPS, which is explained later.

The demand and supply curves are now derived as in figure 3 consisting of four subfigures, each of which exhibits demand and supply for the permits in each session. As mentioned earlier, the demand and supply of permits represent "bids to buy" from high to low and "offers to sell" from low to high, respectively (See subfigures 3(a), 3(b), 3(c) and 3(d)). Initial endowments in sessions 1, 2, 3 and 4 are 24, 20, 22 and 18 permits, respectively, and 6, 9, 12 and 8 trades should occur with the equilibrium prices, or equivalently, uniform prices of NRs 16000, 22500, 20000 and 25000 in sessions 1, 2, 3 and 4, respectively. The information about the market in each session is summarized in Table 2.

Equilibrium prices derived in figure 3 appear to be plausible, reflecting the current income and price level of the villagers at Shaktikhore, Nepal. These derived markets across 4 sessions exhibit an average equilibrium price of around NRs 22,000 per Khatta of forestland, where arable land price is at around NRs 100,000 per Khatta.[8] The crop intensity in Nepal is known to be higher in the mid hills geographic area such as Shaktikhore of our field. For instance, 4

[7]One *"Khatta"* unit in Nepali language is approximately equivalent to $500m^2$ land.

[8]The heterogeneous group of farmers from the five different villages and the community forestry user group determined this equilibrium price (See, again, figure 3), with small variation in the equilibrium price, i.e. a minimum NRs 16,000 and maximum NRs 25,000.

to 5 types of crops are cultivated in that arable land during a year and it can suffices to sustain the life of approximately 3-4 months for a family of 4 to 5 members (See Chhetri (2011)). In such a case, forestry products can only function as complementary goods to the production of crops raised in such arable land. Hence, forestry products are not taken as main products in the life of villagers in that area, just as complements for agriculture or a life itself. This life story is consistent with the fact that the price of forestland is four times less than that of arable land. Thus, we can conclude that demand elicitation by the local farmers at Shaktikhore, Nepal, is very plausible.

## 4.2 Market efficiency, price dynamics and trade volume

### 4.2.1 Efficiency

The theoretical surplus is the maximum possible surplus, i.e., the triangular area between the supply and demand curves to the left of their intersection (See figure 3). The efficiency is measured as a ratio between the surplus obtained from permit trades of the market in a single experimental period to the theoretical surplus. If the maximum surplus extracted from the market in each single trading period is equivalent to the total theoretical surplus, then we say that 100% efficiency gain is achieved, or equivalently permit trading yields a maximum gain from exchanges.

Figure 4, which consists of four subfigures, shows the efficiency gains from the permit trading by subjects over 10 periods in each session. The least efficiency gain is observed in session 4 (See subfigure 4(d) and 30% efficiency in period 4) and the highest efficiency gain is observed in session 3 (See subfigure 4(c) and 100% efficiency in some periods), but in total, the efficiency levels observed over periods have heterogeneous patterns across sessions where the range is between 60% and 90%, regardless to some exception (See figure 4). Pooling all of the observed efficiency gains by taking an efficiency gain per period in each session as one observation, the average efficiency is 80% and the correspoding standard deviation is 20%.

As mentioned earlier, a certain degree of the variation in the observed efficiency gains is confirmed across the sessions (See figure 4). The degree of efficiency gains from trading is known to be sensitive to the structure of demand and supply as well as the characteristics of subject pools. Although derived supply and demand for permits in each session are not so different in a qualitative nature, some hidden heterogeneous factors may contribute to the variation of efficiency gains in our field experiment. In fact, we admit that some small portion of subjects appeared to be confused with the rule of trading at the initial stage in some sessions, especially, session 4. In that session, we have observed that such confusion led to very irrational bidding and offering strategies and contributed to the loss of efficiency gains. However, as periods went, we have also found that the confusion gradually disappeared.

In summary, UPA under trader settings in our experiments has shown sufficiently high efficiency of 80% on the average. In comparison to the prior laboratory experiments with UPA and DA, the statistics and observed efficiency reported above are consistent with the pervious works (Cason and Plott (1996)). For instance, Cason and Plott (1996) report that efficiency gain is 90.9%, using more educated subjects and UPA under non-trader settings. Since our experiment has been conducted in a real field with real subjects under trader settings, the 10% decline of efficiency observed in our experiment can be considered legitimate. Overall, we would say that observed efficiencies are high enough that MPS is effective in the real field.

#### 4.2.2 Market price dynamics

Figure 5, which consists of four subfigures, displays the evolution of the observed prices in the UPA market over periods in each session. In figure 5, a solid line represents a level of theoretical equilibrium prices (TEP, hereafter) and a solid diamond marker represents a observed uniform price per period in each session. Overall, the result suggests that the UPA generates observed equilibrium prices which are not so going far out from TEP or can be considered close to it (see and compare subfigures 5(a), 5(b), 5(c) and 5(d)).

The observed prices are mostly stable (see subfigures 5(a), 5(b) and 5(c)), except in session 4 (See subfigure 5(d)) and most of the observed price ranges between Nrs. 15000 and Nrs. 25000.

The greater deviation between TEP and observed price is visible in session 4. In fact, we realize that in that session, subjects do not follow the best responses of true demand revelation under UPA as argued by Smith and Williams (1982) due to the confusion they had at the initial stages (mentioned earlier), and this may be the main reasons for the huge discrepancy between TEP and observed prices in that session.

### 4.2.3 Trade volume

Table 3 presents average units of permits traded across the sessions along with the theoretical-trade volume. The results show that on the average, 70% of theoretical trade volume has been realized in each period. The average permits traded remained less than the predicted trade volume across sessions (See table 3). This result is quite consistent with the past literature with UPA in the sense that the volume of trade that occurred in the experiments tend to be less than the theoretical volume of trades. This information associated with the actual trade volume indicates that substantial trades have occurred although it is not always identical to the predicted trade volume.

## 4.3 Demand revelation

This subsection reports how subjects reveal their demands for forestland through bids to buy and offers to sell and compare whether there is a qualitative difference between the two in our MPS experiments. This analysis is important in the sense that efficiency gains are more likely to rise when subjects are induced to reveal their true valuation for forestland through the market exchange. Economic theory predicts that UPA tends to induce demand revelation at margin if subject behaves optimally, and should submit their “bids to buy” and “offer to sell” close to the real value of EVs (see, e.g., Cason and Plott (1996)).

In figures 6 and 7, a circle marker represents each observation of bids to buy and offers to sell aggregating the data across sessions, a straight line represents 45 degree line, and a thick line represents the prediction derived from the regression which we will explain later. We observe a persistent tendency to submit "bids to buy" below EVs and "offers to sell" above EVs. We have confirmed that this behavioral pattern applies to many participants, although their bids and offers are positively correlated with the EVs, in general. To confirm this correlation between the behavior of subjects and EVs, we obtain an OLS estimate by running the regression where the observed bid and offers are taken as a dependent variable and the corresponding EV value is an independent variable. Note that if our regression results exhibits something close to 45 degree line, it means that subjects are induced to reveal their true value through bids to buy and offers to sell.

The regression is specified as follows:

$$bid_i = \beta_0 + \beta_1 v_i + \varepsilon \tag{1}$$

$$offer_i = \beta_0 + \beta_1 v_i + \varepsilon \tag{2}$$

where $bid_i$ is a observed bid to buy and $offer_i$ is an offer to sell revealed by subject $i$ during the experiments, $v_i$ is the corresponding EV for the unit of forestland, $\beta_0$ and $\beta_1$ are the parameters and $\varepsilon$ is defined as stochastic error term. Note that if the OLS estimates in the above regressions show the zero intercept and the slope of 1, then subjects are identified to be 100 percent demand revelation.

Then the OLS estimates for each of bids to buy and offers to sell are obtained as follows:

$$bid_i = \underset{(163.11)}{2585.4} + \underset{(0.0074)}{0.5} v_i, \quad R^2 = 0.72, \quad T = 1741,$$

$$offer_i = \underset{(13109.08)}{-122558.9} + \underset{(0.35)}{7.436} v_i, \quad R^2 = 0.34, \quad T = 841.$$

The numbers in the parentheses are standard errors, respectively. The estimation of this model shows both the coefficients of the slope estimates $\beta_1$ are positive and statistically significant, although the magnitudes are very different over bids to buy and offers to sell regressions. With respect to the estimates of intercept, we can clearly see that bids to buy regression has a positive value of the intercept, while offers to sell regression has a negative value of the intercept. Based on these regression results, we can say that demand revelation through bids to buy and offers to sell has not been made perfectly in our experiment, but the bids to buy and offers to sell are positively correlated with the corresponding EVs with statistical significance to a certain extent. Therefore, we say that UPA induces at least partial demand revelation to some extent that efficiency gains becomes around 80% on average.

The reasons for the difference of regression results between bids to buy and offers to sell associated with partial demand revelation can be attributed to several factors. At this point, we conjecture that the endowment effects may be potentially present in our experiment. Note that our experiments have been conducted in the field and asked subjects to think a "real" good of forestland, which is different from the experiment conducted in the literature. Most of the previous works employ a neutral terminology to describe the marketable permits by expressing them as coupons and pollution as production. On the other hand, we have directly used the term of forestry throughout the experiment because our intent is to explore the effectiveness of MPS in the real forest management practices.

In our experimental environment, endowment effects should induce subjects to over-report offers to sell for each permit they initially have much more than the corresponding EVs (See figure 7. Almost all of offers to sell are located above the 45 degree line and the degree of over-reporting is very large). The previous works of Knetsch and Sinden (1987) and Kahneman et al. (1990) have established that if subject are endowed with some real goods, then substantially fewer trades have occured than the theoretically predicted trades in the absence of endowment effects. Such an existence of endowment effects might have reduced the gains from trade in our experiments as well. Fortunately, the results show that efficiency loss from the effects are not so significant, and UPA institution could be considered good enough to apply in the real field even in the presence of endowment effects.

Overall, the market performances observed in our experiment with the UPA institution in a traders setting environment with real subjects are quite consistent with the result of Cason and Plott (1996), although some endowment effects are observed in our cases. It indicates that UPA institution is more likely to be understood to the degree that market performances even under a trader setting in the real field does not significantly fall compared to the results under a non-trader setting in laboratory experiments. Finally, we claim that market allocation of permits through UPA can be efficient and socially desirable, and improves equitable welfare distribution along with preservation of the forestland resources.

# 5 Conclusion

The framed field experiment has been designed to develop MPS under cap and trade schemes for the forestland management at Shaktikhore, Nepal. This attempt has been made to fill the gap that originates from the fact that performance of MPS applied to real resource management in the context of developing nation has not been yet explored. Moreover, this paper has reported effectiveness and potential of MPS through data generated by field experiments with some novel features, representative simulation of economic decisions made by the local farmers for trading marketable permits of forestland utilization. Equilibrium prices per *Khatta* forestland development has been derived trough trades in the field experiments, using the elicited demand and supply relationships of permits for forestland incorporating 40 real subjects.

The experimental result shows that MPS is effective with high efficiency of 80% in the real field. UPA is considered to be a key element for this performance because UPA could perform with simple market information, and farmers with elementary education could understand and follow the rules of trading. Consequently, they are induced to reveal their valuations of forestland through bids to buy and offers to sell, so that overall experimental outcome lies closer to theoretically efficient markets, although endowment effects are observed in "offers to sell" behaviors. In addition, UPA has shown stable price dynamics of the market as substantial trades have occurred in the MPS for forestland development. Furthermore, this result shows a good scope for MPS and it is possible to be the effective policy option for "real" practice of natural resources management with less administrative burden.

Another important point to mention is that through the elicited markets across four sessions of experiments, an average equilibrium price has been estimated as NRs $22,000$ per *Khatta* of forestland. The prime factor that contributes to this price of forestland is a distinctive value among the people and their dependency on forest resources, hence, they can comprehend its cost and benefit based on their daily life experience in forestry. Note that this value is elicited by the local farmers of Shaktikhore, village development committee, Nepal and it is highly plausible considering their present contexts of price levels, living standards and price of commercial land as mentioned earlier.

The MPS itself does not always guarantees the efficient market to emerge by simply asking people to trade marketable permits. This study could be considered an illustration that MPS is a flexible and cost effective market instruments that potentially play the vital role for addressing real world natural resource problems. Here, we admit that inception of marketable permits for forest conservation in rural parts of Nepal itself is an exigent task, however, it has been shown that even local farmers can achieve high efficiency gains under UPA institutions. As an implication of our results, those farmers who have highly valued forestland resources are benefited from the buying of permits and those who have low value will benefit by selling the permits so it solves the issue of social injustice and unfair welfare distribution of the forest resources in a rural household of country like Nepal. Finally, governing body should be very vigilant about a change in the scope and motivation of trading to keep it free from market speculation.

In summary, this paper has used UPA institution under a trader setting in a real field of developing nations, employing local farmers of elementary education, which itself may be considered a pioneering work in a sphere of experimental research. It is our belief that the scope of MPS has been broadened with the implications derived from our experiments for the resource use exclusion such as forestland resources, and the novelties stimulate unique economic application to counter the myth that market-based instrument works for industrialized nations only without exception in developing countries. We are hopeful that our field experiment is considered a benchmark for comparison and the first step towards developing applicable marketable instruments that can analyze policy issues on enduring environmental problems.

# 6 Appendix: The detailed description of field experiments

We did not use any written instruction in introducing our field experiment to subjects, because they are local farmers and most of them are illiterate. Instead, we have repeatedly explained how trades of permits would be determined using a Nepalese local language, and run the trial periods before we strated the “real” experiments. We made sure that every subject understood the rule. In this appendex, we detail the translated version of our verbal explanations made in front of our subjects.

You can earn “experimental money” by trading “permits.” However, subjects including yourself do not know in advance how many periods they will experience until the end of the experiment. Subjects’ earnings in each period are determined as follows:

$$\begin{aligned} \text{Payoff} =& \text{Net benefit (EV, hereafter) from commerical forestland} \\ &+ \text{Sale proceeds from selling permits} \\ &- \text{Amount spent on buying permits.} \end{aligned}$$

## Why permits are required?

Permits are necessary for farmers to utilize forestland as private commerical forests, enjoying forest product and resources harvested from there. However, note that all subjects have to bear some obligations as a member in community forest user group (CFUG), irrespective of the ownership of commercial forests.[9] You can enjoy EVs of the commercial forestland if they own the permits. If anybody wants to have further commercial forestland to develop and utilize, he has to buy additional permits, and those who does not want to utilize forestland, they can sell their permits to others, and receive the payments. Simply, subjects have a chance to trade "permits" in each period.

Everyone starts an experiment with initial "permits," and can adjust their own holdings of "permits" by buying and selling them in a market that will operate. If subject sells the permit, their benefit increases by the sales, and if subject buys some additional permits, their benefit decreases by the amount of payment. In what follows, we explain the rules for buying and selling permits.

## Why a subject might want to buy permits?

Remember, as mentioned above, permits allow subjects to develop or utilize forestland for commercial use as they wish. First, see table 4, and this subject reveals 10 units (1st to 10th) of forestland demand as per his given EV. He currently holds 3 permits, 1st, 2nd and 3rd units for which he can enjoy the corresponding EVs. However, for the remaining 7 units from 4th to 10th units, he cannot enjoy the corresponding EVs, because he does not possess the permits for these units of forestland. In summary, his total commercial forestland demand is 10 units, but he can only receive the summation of EVs ($= 113000 = 30000 + 38000 + 45000$) as a net benefit if he has 3 units of permits. However, if he is allowed to trade the permits, it may be better to buy an additional permit. For instance, the EV of fourth unit is 25000, and if the subject can buy an additional permit with the price less than 25000, this might be a good idea because he obtain an addition unit of the forestland in cheaper value than his EV. More specifically, if the subject buy an additional permit with the price of 21000, he gets surplus of 4000 = (25000 - 21000). In this case, the subject ends up owning 4 units of permits after the trade, and, thus, can develop 4 units of forestland for commercial use. Note that the same logic applies when

[9] Note that even when people have certain units of permits, they are not allowed to do clear cutting or some other extreme activities of forest production by Nepalese government regulation.

subject wants to buy additional permits to increase surplus for each of $5th, 6th, \ldots, 10th$ units of forestland.

## Why might a subject want to sell permits?

Continuing the illustration based on the previous example, suppose that the subject initially holds 3 permits with corresponding EVs as in table 4. The EV of the 3rd unit is 30000, but if he can sell a permit of the 3rd unit with the price more than 30000, this might be a good idea because these sales revenues exceed his EV of this unit. For example, if he sell the permit of the 3rd unit with the price, 35000, which is higher then his EV, he will get a surplus of 5000 $(= 35000 - 30000)$. The same logic applies to the 1st and 2nd units of permits whenever he wants to sell an additional permit.

## Trading rules of permits

The authority requires that, in each period, a subject submits bids to buy at which he is willing to buy each additional unit of permits, and offers to sell at which he is willing to sell each additional unit of permits that he has. Refer to table 4. This subject has 3 permits, then he must submit 3 distinct offers to sell at which he is willing to sell for each unit of permits he holds, and also must submit 7 distinct bids to buy at which he is willing to buy for each additional permit he may obtain. Therefore, the general rule for submitting offers to sell and bids to buy for each subject is written as follows:

$$\begin{aligned}&\text{The number of offers to sell} + \text{the number of bids to buy}\\&\qquad\qquad = \text{total permit demand for commercial forestland.}\end{aligned} \quad (630)$$

After the offers to sell and bids to buy from all participants are collected in the same way explained above, the authority ranks all bids to buy from high to low as a demand curve and offers to sell from low to high as a supply curve for permits. For example, imagine that aggregate demand by 10 participants for forestland in one session is 43 units where 13 units of permits are distributed to subjects. Then the authority will receive 13 distinct offers to sell and 30 distinct bids to buy, and create a ranking for these offers and bids as shown in table 5. Here, units of permits are traded in order as long as the bids to buy exceed or equal the matching offers to sell. In that table, the highest 12 bids to buy and the lowest 12 offers to sell should be accepted as effective trades.

The uniform price, which is paid by all buyers and is received by all sellers, is determined as the average of the bid to buy and offer to sell of the last unit traded. In this example, the last unit traded is 12th unit of permits and therefore, the uniform market price is 20000 = (20000+20000)/2 and all units traded in this market are bought and sold at this price. After the authority announces this uniform price, trades occur and pay-offs are calculated as mentioned earlier.

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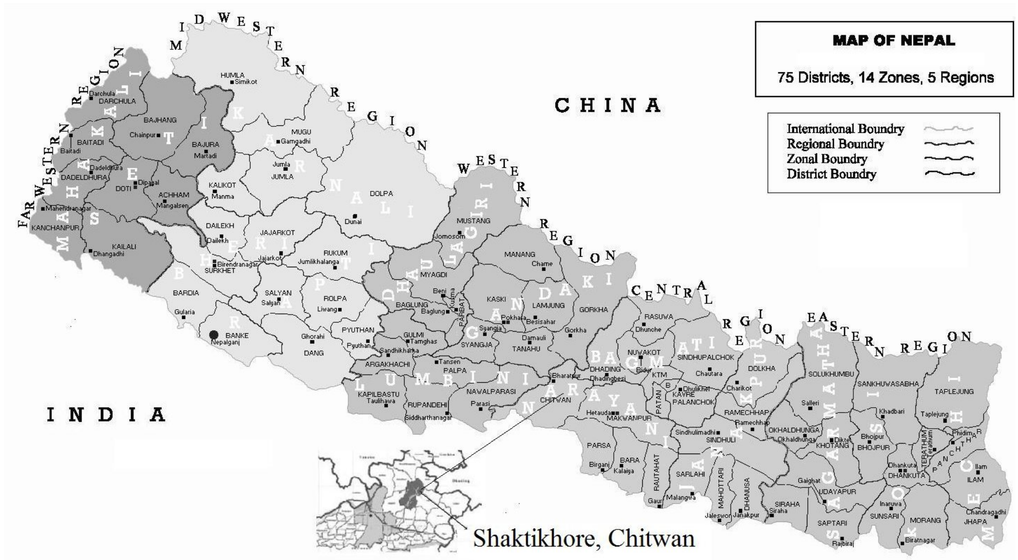
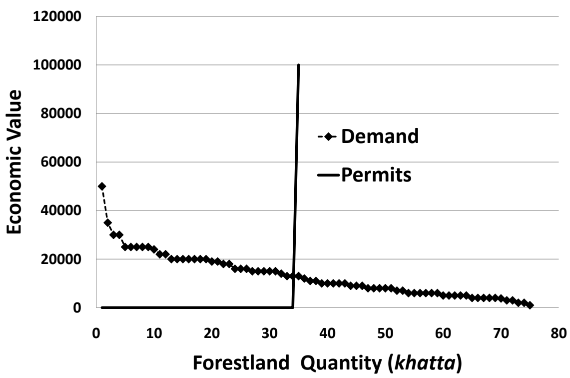
Figure 1: A location of Shaktikhore, Chitwan in Nepal



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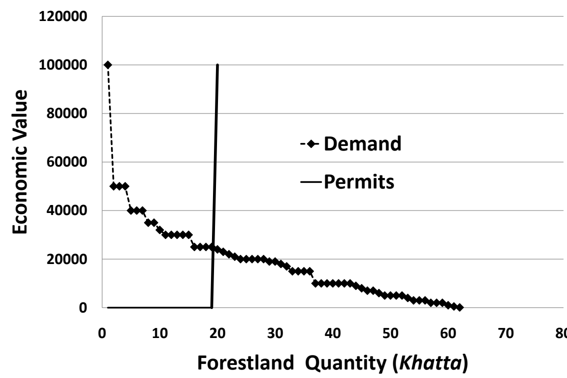


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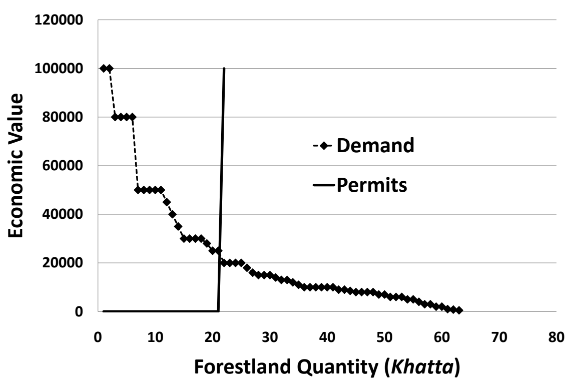


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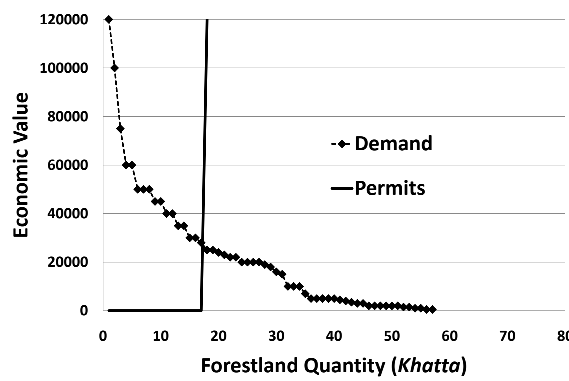
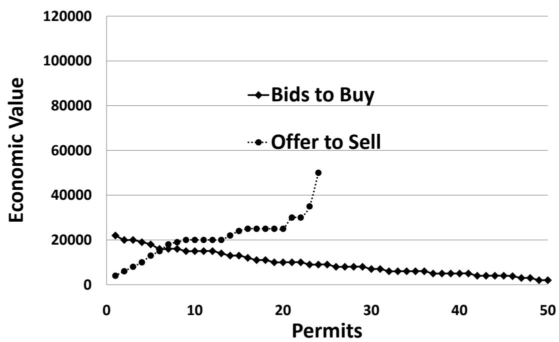



(d) Session 4

Figure 2: Elicited demand for forestland and permits supply across each session

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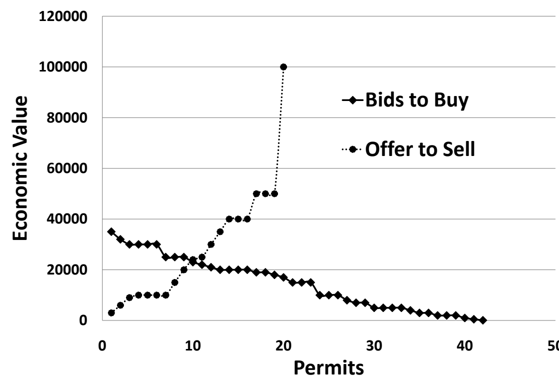


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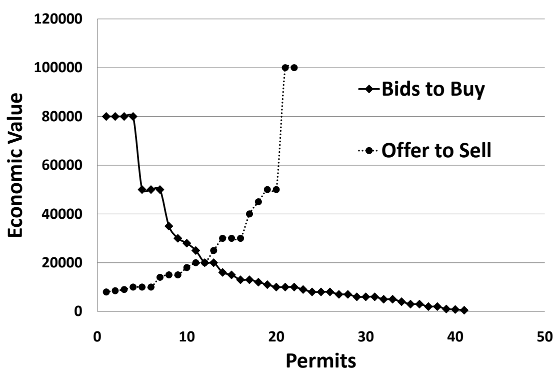


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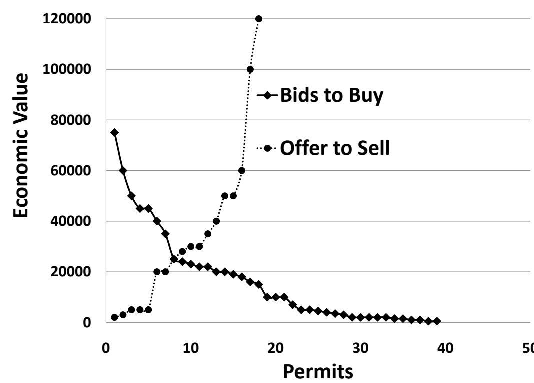
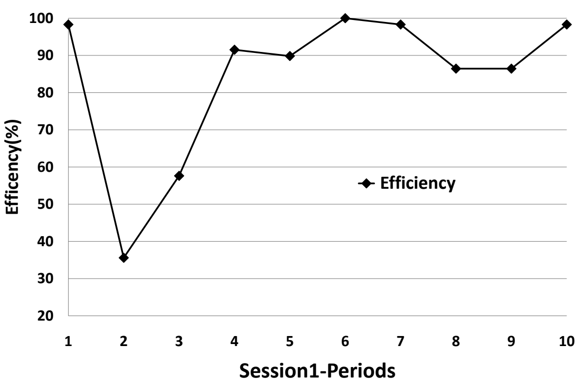



(d) Session 4

Figure 3: Theoretical equilibrium of forestland demand and permits in each session

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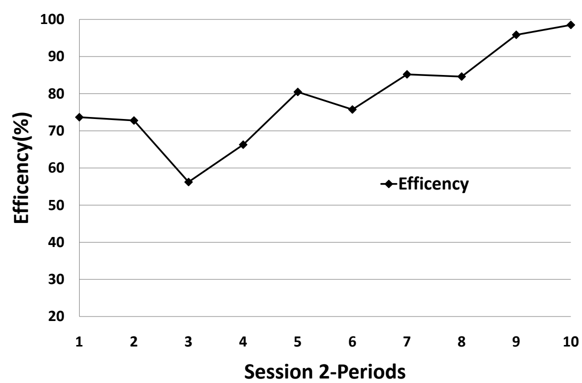


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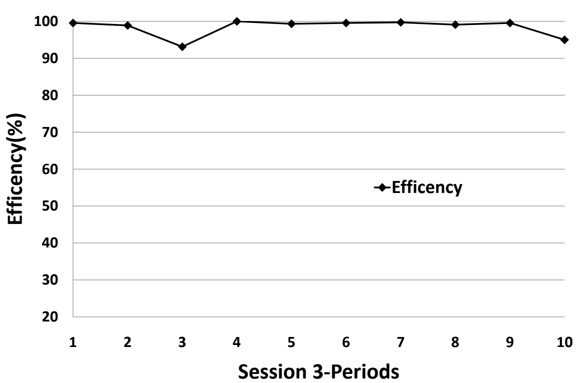


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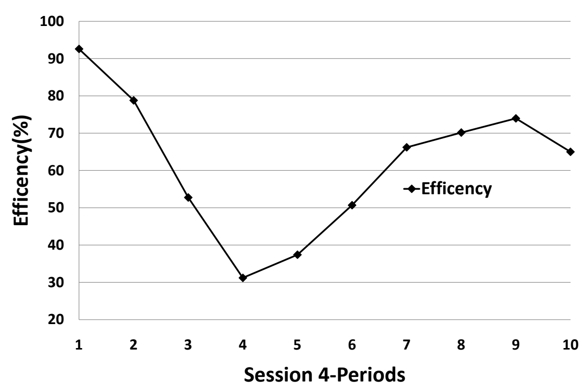
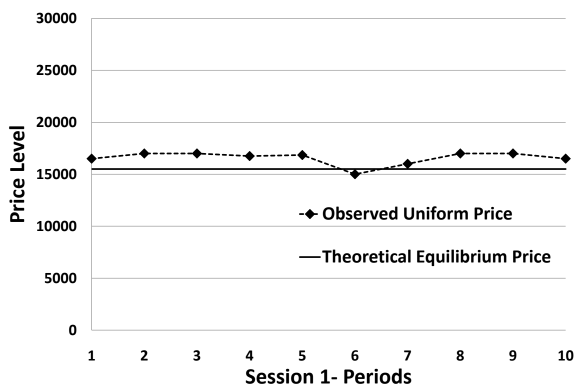



(d) Session 4

Figure 4: Observed efficiency gains over the periods across each session

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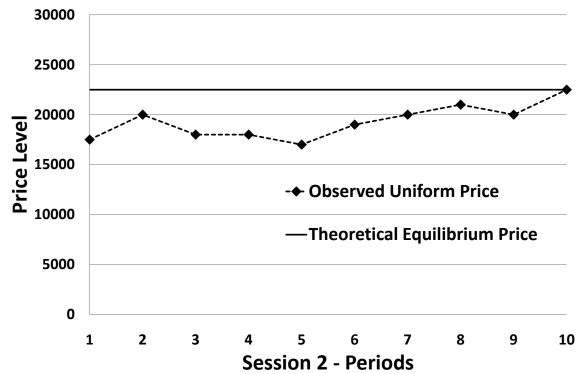


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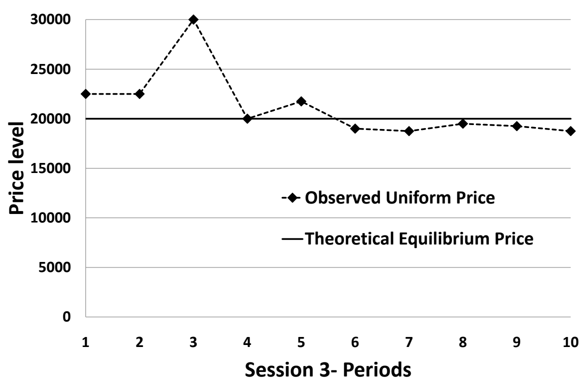


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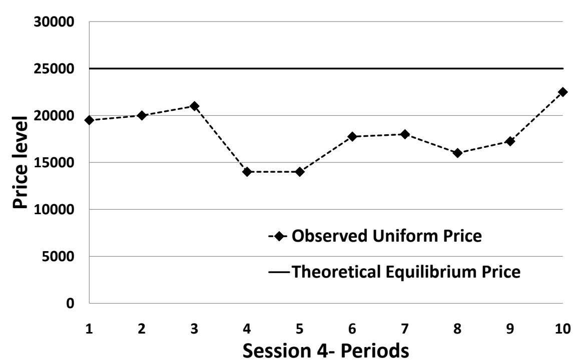


(d) Session 4

Figure 5: Observed prices movement over the periods across each session

Figure 6: Bids to buy

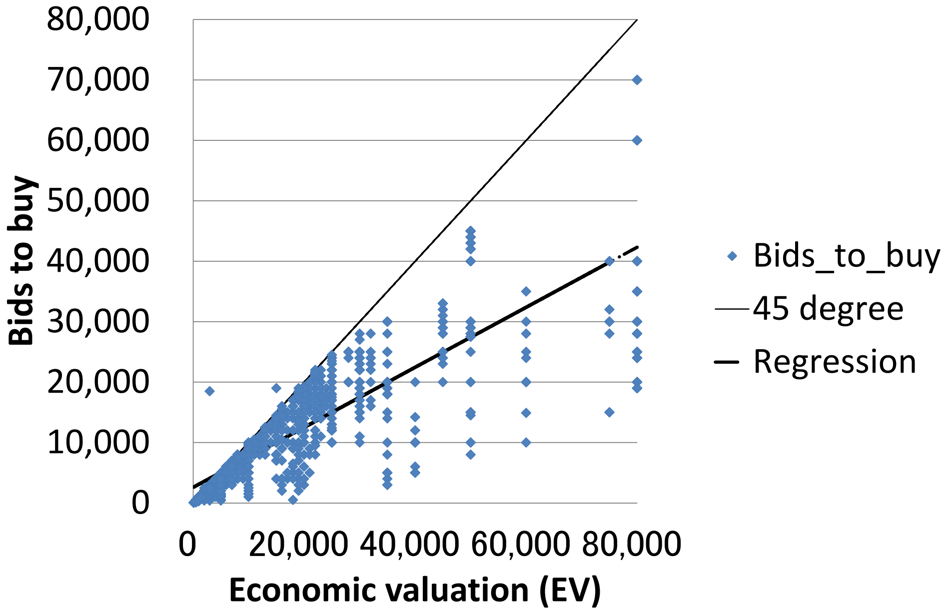


Figure 7: Offers to sell

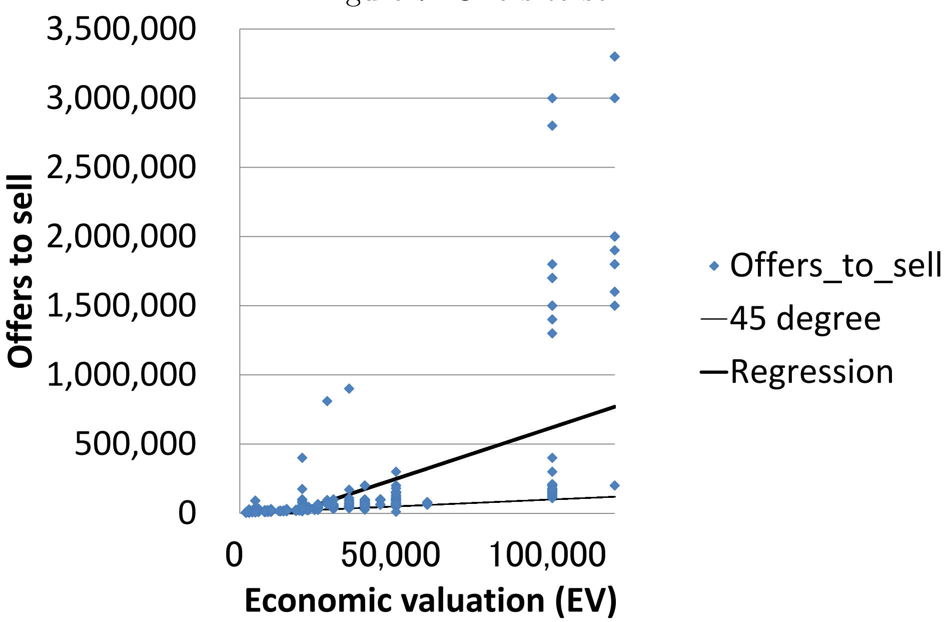

Table 1: Summary of the experimental environment

| | |
|---|---|
| Subjects | Local farmers and members of CFUG* |
| Location | Shaktikhore Village Development Committee |
| Education of subjects | Illiteracy or elementary |
| Session | Four sessions, with 10 periods in each session |
| Institution | Uniform price auction |
| Time per session | 180 to 220 minutes |

*CFUG represents Community Forestry User Group which is explained in the manuscript.

Table 2: Summary of market information

| | Session 1 | Session 2 | Session 3 | Session 4 |
|---|---|---|---|---|
| Total demand for commerical forest | 75 | 62 | 63 | 57 |
| Total permits supply | 24 | 20 | 22 | 18 |
| Efficient equilibrium price | 16000 | 22500 | 20000 | 25000 |
| Efficient trade volume | 6 | 9 | 12 | 8 |

Table 3: The trade volume per sessions

| | Session 1 | Session 2 | Session 3 | Session 4 |
|---|---|---|---|---|
| Predicted efficient trades | 6 | 9 | 12 | 8 |
| Average trades over 10 periods | 4.7 | 6.6 | 9.1 | 4.5 |
| Median | 5 | 6.5 | 9 | 4.5 |
| Mode | 5 | 6 | 9 | 5 |
| Standard deviation | 1.05 | 1.34 | 0.56 | 1.50 |

Table 4: Farmers' elicited economic value of forestland information sheet

| **Round** | **10** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Uniform Price** | **18,500** | | | | | | | | | |
| **Commercial Forest Land (Unit)** | **10th** | **9th** | **8th** | **7th** | **6th** | **5th** | **4th** | **3rd** | **2nd** | **1st** |
| **Economic Value (EV)** | 10000 | 13000 | 15000 | 16000 | 18000 | 21000 | 25000 | 30000 | 38000 | 45000 |
| Offers to Sell | | | | | | | | 55000 | 70000 | 75000 |
| Bids to Buy | 8000 | 10000 | 12000 | 14500 | 16000 | 19000 | 21000 | | | |

| | |
|---|---|
| Payoff = | 122000 |

Table 5: Example of uniform price determination

| units | Bids to buy | offer to sell |
|---|---|---|
| 1 | 80,000 | 8,000 |
| 2 | 80,000 | 8,500 |
| 3 | 80,000 | 9,000 |
| 4 | 80,000 | 10,000 |
| 5 | 50,000 | 10,000 |
| 6 | 50,000 | 10,000 |
| 7 | 50,000 | 14,000 |
| 8 | 35,000 | 15,000 |
| 9 | 30,000 | 15,000 |
| 10 | 28,000 | 18,000 |
| 11 | 25,000 | 20,000 |
| 12 | 20,000 | 20,000 |
| 13 | 20,000 | 25,000 |
| 14 | 16,000 | |
| 15 | 15,000 | |
| 16 | 13,000 | |
| 17 | 13,000 | |
| 18 | 12,000 | |
| 19 | 11,000 | |
| 20 | 10000 | |
| 21 | 10,000 | |
| 22 | 10,000 | |
| 23 | 9000 | |
| 24 | 8,000 | |
| 25 | 8,000 | |
| 26 | 8,000 | |
| 27 | 7,000 | |
| 28 | 7,000 | |
| 29 | 6,000 | |
| 30 | 6,000 | |