KOCHI UNIVERSITY OF TECHNOLOGY

Social Design Engineering Series *SDES-2015-22*

Evaluating the potential of marketable permits in a framed field experiment: Forest conservation in Nepal

Raja Rajendra Timilsina
Kochi University of Technology

Koji Kotani
Kochi University of Technology
Research Center for Social Design Engineering, Kochi University of Technology

29th September, 2015

School of Economics and Management
Research Center for Social Design Engineering
Kochi University of Technology

Evaluating the potential of marketable permits in a framed field experiment: Forest conservation in Nepal

Raja Rajendra Timilsina* Koji Kotani†

September 29, 2015

Abstract

A marketable permits system (MPS) has been deemed effective in laboratory experiments, however, little is known about how the MPS works in the field. We evaluate the MPS efficiency for forest conservation by framed field experiments in Nepal. Forestland demands are elicited from farmers, with which the experiments are carried out. The novelty lies in instituting a uniform price auction (UPA) under trader settings and in identifying the efficiency in the field of developing nations. The results suggest that farmers with limited education understand UPA rules, reveal their forestland valuations and that the MPS is effective with 80% of efficiency.

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

*Kochi University of Technology (e-mail: 196018s@gs.kochi-tech.ac.jp).

†Professor, School of Economics and Management, Kochi University of Technology, 2-22 Eikokuji-cho, Kochi-shi, Kochi 780-0844, Japan (e-mail: kotani.koji@kochi-tech.ac.jp).

Contents

1 Introduction

Economists have long considered a marketable permits system (MPS) to be potentially effective for preservation of environments and natural resources due to the decentralized nature and the price signals of market exchanges (Shogren, 2005).[1] The most important advantage economists claim for the MPS is that it can achieve environmental objectives with the least cost to the society, i.e., efficiency (Field and Field, 2006). Given this positive view of the MPS, extensive studies have been conducted to test theories and examine the performance (Ledyard and Szakaly-Moore, 1994). However, little is still known about how the MPS achieves the efficiencies in the real-world conditions of the field, especially in the context of managing the natural resources of developing nations. Therefore, this research addresses the efficiency of the MPS and to provide an important test for its proposed institution in a framed field experiment.[2]

Many studies on MPS experiments have been conducted to verify the performance in controlled laboratory settings with various environments and treatments. There are two important dimensions of the experimental designs: (i) the market institution for permit trading, either a double auction (DA) or a uniform price auction (UPA), and (ii) the trader or non-trader settings. The first dimension is concerned with the organization of the price determination mechanism in the permit market. The DA mechanism is a real-time trading institution where agents can submit bids to buy and offers to sell for permits or can accept the best bid and offer made by other agents at any time during trading periods of several minutes.[3] Therefore, the DA gives more flexibility to agents in terms of trading strategy.

In comparison, the UPA is simpler because all of the permit trades are made with a uniform price.[4] First, each agent is asked to submit his or her "bids to buy," representing the price she is willing to pay for each unit of additional permits, as well as "offers to sell," representing the price with which she is willing to sell each unit of permits she has. After all the agents submit bids to

[1]In this paper, the MPS is interchangeably referred to as "tradable property rights" or "transferable development rights."

[2]We categorize our experiment as a "framed field experiment" following Harrison and List (2004) and List (2011).

[3]Refer to Davis and Holt (1992) for the details of the DAs.

[4]A UPA is also known as a call market. See Davis and Holt (1992) for further reference.

buy and offers to sell, a central authority collects and ranks all of the bids to buy from high to low (the demand curve), all of the offers to sell from low to high (the supply curve) and determines the intersection of the demand and supply curves. Specifically, the intersection occurs at the last unit in which the bid to buy exceeds the offer to sell, and the uniform price is the average between the two. The UPA has also been established to achieve high efficiencies and stable price dynamics (Smith et al., 1982, Cason and Plott, 1996).

The second dimension is concerned with whether each agent in a permit market can be both a seller and a buyer or each agent can be only one of these during trading periods. If he (she) can be both, we call the environment a "trader setting," and if he (she) cannot, the environment is a "non-trader setting" (Ledyard and Szakaly-Moore, 1994). Regarding application of the MPS, the trader setting is known to be closer to real-world conditions. However, a considerable portion of experimental works employ non-trader settings as it simplifies the experimental procedures and reduces the decision complexity for agents.

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

Another group of studies, such as Ledyard and Szakaly-Moore (1994), Godby (1997), Muller et al. (2002) and Cason and Gangadharan (2006), also have used the DA but under trader settings. The results of these experiments indicate that the observed efficiencies exhibit higher variations and can be lower on average than the DA experiments under non-trader settings, ranging between 60% and 98%. Furthermore, these works report that the observed prices of permits could be unstable. In summary, the DA under trader settings is more likely to generate lower efficiencies and less stable price dynamics than those under non-trader settings. Some economists argue that agents have more opportunities for speculative trades under trader settings and that this may be the reason for the results (Ledyard and Szakaly-Moore, 1994).

Cason and Plott (1996) have conducted an experiment with the UPA under non-trader settings. The work confirms that the UPA is very efficient in the MPS and induces true revelation of abatement costs for pollution through the bids to buy and offers to sell in the experiments. It is also found that the price dynamics are stable because the UPA is relatively simple and does not offer agents the opportunities of speculative trades in the permit market. In summary, most of the research that has examined the performance of MPS mechanisms has been conducted in controlled laboratory conditions with induced value frameworks, irrespective of market institutions and of trader or non-trader settings (Muller and Mestelman, 1998, Cason, 2010).

Some MPS markets are operated in the real world, especially in developed countries such as the European union emissions trading scheme, and several empirical studies were conducted to estimate their effectiveness (Ellerman and Montero, 1998, Montero, 1999, OECD, 2000, Newell et al., 2005, Ellerman and Montero, 2007, Ellerman et al., 2010, Hahn and Stavins, 2011). However, these empirical studies have not addressed or cannot identify how the market has achieved overall efficiency, i.e., market surplus achieved under the MPS through permit trading. This is due to the fact that each agent or firm in the market never reveals his private information of abatement costs to others, otherwise there is no way for authorities to know the abatement costs. Therefore, there has been no MPS research to explicitly report and compare the efficiency and applicability in the field with those in laboratories.[5] Furthermore, no previous works evaluate the applicability of the MPS in the field of developing countries where depletion of natural resources such as forests is a more serious concern (FAO Forest Department, 2010, 2015).

Given this paucity, our research question becomes "how does the MPS perform and achieve the overall efficiency in the field of developing nations?" To answer this question, we conduct a framed field experiment of the MPS based on local farmers' valuation for forests and evaluate the overall efficiency and performance of the MPS as applied to forest conservation in the field of Nepal. Note

[5]Levitt and List (2007) claim that the comparison between fields and laboratory experiments is important for bridging the gap.

that the setup of our field experiment is in contrast to the laboratory setting with induced value frameworks. More specifically, we have designed a novel setup of framed field experiments that is feasible in developing nations and can be understood by the "real" subjects. We chose Shaktikhore in Nepal as a site because the livelihoods of farmers highly depend on the forest and the farmers can naturally report their valuations of forestry. First, we conducted a survey through which we elicited valuations of local farmers for each unit of forestland, i.e., deriving the demand and supply for forestland as well as for permits.[6] Second, MPS experiments were conducted with the UPA under trader settings based on the aggregate demand and supply derived in the first stage. These experiments allow for observations of efficiencies, price dynamics and revelation of valuations through bids to buy and offers to sell and enable us to analyze the overall performance of the UPA in the real field.

Subjects in this field experiment were local forest users and farmers who have elementary education. Many of them cannot make some arithmetic calculations, such as a series of summations and subtractions, but they can understand which number is larger when given two different numbers. Thus, they can compare and trade their forest products in their daily life. With these facts in mind, we chose the UPA as a market institution because it is simpler and more intuitive for local farmers regarding how they incur the loss or to reap the benefit from the permit trades, compared to the real-time trading of the DA. We chose a trader setting for our experimental design to reflect the real-life condition of the MPS when applied to natural resource management. Due to the aforementioned arguments, an additional novelty in this research lies in designing a field experiment with real subjects of a developing country in comparison with a standard laboratory experiment of WEIRD subjects as claimed in Henrich et al. (2010).[7]

The results suggest that the MPS is effective with high efficiency of 80% in the field. In this success, the institution of the UPA is identified as a key element because (i) farmers with

[6]The permits are entitlements for the owners to utilize a single unit of forestland for commercial purposes in a legal way. More detailed explanation for the definition of permits will be given in later sections.

[7]Henrich et al. (2010) claim that although behavioral scientists publish many research papers of human behavior with samples of population from western, educated, industrialized, rich and democratic (WEIRD) societies as a "standard" approach, such WEIRD sample is something we should not consider as "standard." They argue the necessity of implementing behavioral experiments with less-standard samples.

elementary educations could understand and follow the rules of trading and (ii) they are induced to reveal their valuations of forestland through their bids to buy and offers to sell. To our knowledge, this study is the first to design and employ a UPA institution under trader settings as well as to establish successful MPS performance in the real-life conditions of developing nations. Overall, the MPS could be an effective policy option for natural resources management, even for those with less administrative expertise, limited educations and fewer resources to implement.

2 Overview of community forestry in Nepal

Nepal is a landlocked country in South Asia that shares its northern border with the People's Republic of China and its borders to the south, east, and west with the Republic of India. The total area of the country is $147181 km^2$, 80% of which is covered by hills and mountains and the land use of the country is divided as follows: forests (29%), shrubs (10.6%), grassland (12%), cultivated land (30%). The rest is categorized as others such rocky mountain (18%) (FAO Forest Department, 2010, 2015). The total population of the country is approximately 30 million, 80% of which depend upon subsistence farming (Central Bureau of Statistics, 2011). The forestry sector is very critical from socio-cultural and economic points of view as farms, forests and livestock are interrelated components of Nepal's farming systems (Gilmour and Fisher, 1991, Mahat et al., 1986). The forest management system has undergone a structural shift away from privatization and nationalization toward voluntary participation systems (Gilmour and Fisher, 1991).

Prior to 1957, the forest management had been based on the indigenous practices of local villagers who utilized the forest to meet their daily demands of fuel, fodder, poles, and timber. The Private Forest Nationalization Act of 1957 nationalized the entire forestland which prevented people from utilizing forests to avoid deforestation (Gilmour et al., 1989). Since 1978, a local institution "Community Forestry User Group" (hereafter, CFUG) has managed the local forests as "community forest." Inequality and poverty are the major problems in this transitional phase, along with political instability, absence of social reforms and imprudent utilization of resources

(Gilmour et al., 1989).

Community forestry is a voluntary forestry management system in which the CFUG members contribute labor to organizing some collective activities of forest protection and management, such as meeting, harvesting, weeding, thinning, pruning and guarding. In return, they are allowed to harvest non-timber products. Harvesting non-timber products is highly labor-intensive. Poor households do not usually possess land and cattle (Adhikari et al., 2004). Thus, firewood is the only non-timber product they are motivated to harvest. Unfortunately, however, it is reported that such poor households cannot sufficiently allocate their own labor for harvesting firewood because they are swamped with daily agricultural labor works and do not have enough money to hire additional external labor (Adhikari et al., 2007).

Relatively high-income or middle-income households within the CFUG usually possess land and cattle so that they are motivated to harvest a variety of non-timber products such as leaf litter, fodder and thatching materials (Adhikari et al., 2007). Since they are not struggling with their daily life compared to poor households, they can allocate their own time to harvest such non-timber products or can even hire additional external labor. Therefore, poor households do not utilize the opportunities of CFUG, while middle-income or high-income households utilize them more efficiently (Adhikari et al., 2004, 2007).

In summary, community forestry management as a participatory system had been considered a viable solution to forestland preservation. However, it have resulted in undesirable outcomes for poor households due to the aforementioned problems. Previous literature has supported this finding, and the community forestry management system is claimed to be inefficient in its process because poor households are deprived of the appropriation of resources and the benefits of sharing (e.g., Campbell et al., 2001, Adhikari et al., 2004, 2007). Consequently, this system has not necessarily helped poor people in Nepal, but has often worked to their disadvantage (Graner, 1997, Adhikari et al., 2007). Gautam (1987) argues that the indigenous forest management is more equitable and effective in conserving nature's integrity than community forestry because the latter fails to achieve an equitable cost-benefit sharing arrangement for society. The consequences of such a failure have led to inefficiencies and have opened the door to the inceptions of feasible and alternative institutional setups for new forest management to enhance the access of poorer households to the forest.

The MPS could be a solution when applied to forestland management, as it gives a right to the people to utilize forest products without clear-cutting timbers. This approach can provide equal rights to all individuals, and by holding the permits, each individual can commercially utilize forestland under some controlled regulations. To implement the MPS, local farmers are required to enter into a time contract to attain an arranged number of permits for forestland use, in which they can carry out agro-forestry farming. Initial permits can be allocated equally without socio-economic discrimination and, thus, the MPS can address inequitable distributions of resources through the allocation of initial rights.

The Shaktikhore village development committee is located in Chitwan district of the southern part of Nepal, where we implemented our field experiments (See figure 1). Chitwan district is rich in natural flora and fauna and is highly committed to species diversity. The word *Chitwan* itself means *Heart of the Forest* in the Nepali language. The Shaktikhore village comprises a unique blend of diversified indigenous ethnic groups, such as "Chepang," who reside in approximately 1000 households that are involved in agriculture and forestry.[8] All of the hill forests at the study site are surrounded by agricultural lands and have to fulfill the primary demands of rural households.

[Figure 1 about here.]

Subsistence farming in that region is based on a triangular relationship among the farms, the cattle and the forests (Adhikari et al., 2004). Forestland is essential for these people as it yields grass fodder for feeding livestock, leaf litter for composting, fuelwood for cooking and heating, timber and poles for constructing houses. Most of the households' daily routines are based on farming and harvesting of forest products to fulfill their primary needs. The literacy rate in Shaktikhore village is approximately 65%, implying that most of the population has only an elementary-level

[8]The "Chepang" is an indigenous ethnic group that inhabits Shaktikhore. They traditionally practice slash-and-burn agriculture or simple hoe-based horticulture, along with hunting and gathering in the forests.

education (Central Bureau of Statistics, 2011). In fact, many subjects could only perform simple calculation. However, they have a sense of valuing forestland and trading forest products based on their daily experiences.

3 Design of the framed field experiments

This section provides an overview for the design of our framed field experiments. First, we describe a study site, a feature of the subjects' pool and how we elicited the economic valuations (hereafter, EVs) of local farmers for each unit of forestland. We next highlight how the information about EVs was utilized in the MPS with the UPA for the conservation of forests in Shaktikhore, Nepal. Finally, we explain the procedure and the general sequence of experiments.

The field experiment was conducted at the community hall, which was especially constructed for the "Tourism for Rural Poverty Alleviation Program" by the Chitwan hill guides group. Subjects were randomly chosen from five different villages in Shaktikhore, Nepal. A total of 40 subjects participated in the experiment.[9] They were farmers and CFUG members. We conducted four sessions, each of which involved 10 subjects from different villages and consisted of 10 experimental periods. Each session lasted 3 hours on average. The summary of our experimental design is given in table 1. In the first stage, each subject had to go through a survey interview for the elicitation of EVs for each unit of commercial forestland he (she) demands.

[Table 1 about here.]

[Table 2 about here.]

To fulfill this objective, we have asked each respondent about the maximum price he (she) is willing to pay (WTP) for each unit of forestland, realizing the net benefit he (she) could gain if

[9]Given the time & money constraints and geographic settings for our field experiments, this is the maximum number of subjects we could collect. For instance, we randomly picked forest users from different villages to avoid a situation where subjects in a session know each other. It takes more than 5-7 hours to go from one village to another village on foot where roads are not paved. Likewise, one subject needed to come to the city hall for our field experiments by walking of 5 hours on average.

the given unit is of commercial forest (See the row "Economic Value (EV)" in table 2).[10] Note that if a person obtains a commercial forest unit, he (she) can utilize the forest to harvest timber and non-timber products for commercial purposes following the regulations of Nepalese government. Nevertheless, irrespective of the ownership of commercial forests, the respondents have an obligation to participate in community forestry management as described in the previous section.[11] Thus, the economic valuations we asked from respondents in this survey represent the net benefit of obtaining a unit of land as commercial forests.

For some respondents, the economic valuations for a unit of commercial forests could be low, because they may possess non-farming jobs or do not have enough resources to fully utilize forests. For others, the economic valuations could be high, because they have some expertise in generating forest products with their management practices and expect to have the large net benefits. In summary, through a series of these WTP questions, we elicited the demand of each individual or household until his or her WTPs for commercial forests arrived at zero or a negative value. For instance, table 2 exhibits a schedule of WTPs elicited from one respondent, with the reporting of a zero WTP or negative value arriving at the 11th unit of forestland.[12] The respondents are very knowledgeable, experienced in forestry practices and have been trading forest commodities in their everyday life. This satisfies the sufficient conditions for employing an open-ended question format (See, e.g., Cummings et al., 1986, Mitchell and Carson, 1988). Fortunately, we have found that respondents did not have any difficulties in reporting WTP values in the survey.

[Figure 2 about here.]

After the collection of EVs, we derived the aggregate demand of forestland for each session

[10]Every subject in this framed field experiment possesses hands-on experiences in practicing forest management, because people's life in these areas is highly dependent upon forests. When we elicited the WTP per unit of commercial forest, we asked subjects to answer the WTP focusing only on the net "economic" value (EV) they can gain. This question was easily answered by the subjects in our survey.

[11]We acknowledge that monitoring and enforcement for obligations or regulations in managing community forestry are crucial issues for MPS, and there exist several works that focus on this issue (Murphy and Stranlund, 2006, 2007, 2008). However, note that monitoring and enforcement are out of our scope in this paper. This is because our field experiment becomes too complex for subjects if we try to include that aspect in the experimental design.

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

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

We subsequently determined the capped level of commercial forestland provided by the permits in the MPS. For this calculation, we referred to previous studies suggesting that about 62% of a total forestland of 3.5 million hectares has been handed to the CFUG for preservation where only non-timber products can be harvested mainly for non-commercial purposes, and it is expected to be preserved up to 70% (Regmi, 2000). In this scenario of gradually transferring accessible forestland to the community for preservation, we assume that 70% of forestland is conserved under current CFUG schemes, while the rest of 30% is managed and utilized by the MPS. To mimic this scenario, 30% of the total demand was allocated to subjects as marketable permits in the field experiments. Given the conditions, the initial permit endowments were randomly allocated to all subjects such that the total capped level was allotted to preserve 70% of forestland. Table 2 shows that the subject has demanded 10 units of forestland and is entitled to have 3 permits. In this way, the aggregate supply of permits was derived for each session. For example, in session 3, 22 units were determined as the aggregate supply, which is 30% of the total demand of 63 units (See figure 2(c)).[13]

Utilizing the information from the EVs of forestland, we can derive the demand and supply of permits in the UPA. As mentioned earlier, we employ the UPA under trader settings. This means that each subject is required to submit his or her bids to buy and offers to sell all at once in a single trading period. Specifically, each subject is asked to submit his or her bids to buy, representing how much he (she) is willing to pay for each additional unit of permits, as well as his or her offers

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

to sell, representing the price with which he is willing to sell for each unit of permits he (she) possesses. For instance, consider a subject who is endowed with 3 permits and who faces an EV schedule in table 2. In this case, he must submit 7 distinct bids to buy, each of which corresponds to the potential purchase of the permits for the 4th, 5th, . . ., 10th units of forestland, and 3 distinct offers to sell, each of which corresponds to the potential sale of the permits for the 1st, 2nd and 3rd units he (she) currently possesses.

If subjects are rational, the subjects' bids to buy and offers to sell should theoretically be very close to the EVs (Cason and Plott, 1996). In the experimental instructions by the Nepali language, we clearly stated that if a bid to buy (an offer to sell) is higher (lower) than the corresponding EV, then it may incur a loss. However, we did not repeatedly tell them so. Additionally, such irrational behaviors are permitted, although some previous research does prohibit such irrationality. This decision is motivated by the fact that we sought to clarify whether the MPS under trader settings could be efficient for farmers under the most primitive setting in Nepal.

[Figure 3 about here.]

Suppose that subjects are sufficiently rational and that they reveal their EVs through bids to buy and offers to sell as predicted by economic theory. We can derive the aggregate demand and supply for permits in each session by ranking the bids to buy from high to low and the offers to sell from low to high. When the derived demand and supply are plotted together, it yields an equilibrium volume of trade and an equilibrium price as the intersection of the two curves. Figure 3, which consists of four subfigures, shows the derived demand and supply for permits in each session. Figures 3(a) to 3(d) correspond to sessions 1, 2, 3 and 4, respectively. These four figures show that the demand and supply for permits are slightly different across sessions, but the qualitative nature of the markets appears to be close.

While there were neither computers nor internet connections in the field, everything was managed manually by hiring research assistants for each session. Following the general rule of the UPA, each subject does not know about the EVs of other subjects, and the volumes of trade that occurred, and the corresponding payoffs of others. Subjects were 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 conditions, each subject was required to determine his or her bids to buy and offers to sell at the same time in a single period. After the announcement of the uniform price, they identified whether they would become buyers or sellers and their payoffs for that period.

Suppose that a subject has the EVs for forestland as shown in table 2 and is endowed with 3 units of initial permits. In this case, a subject is asked to submit 3 distinct offers to sell and 7 distinct bids to buy. If the uniform price is announced as 18500, this subject buys two additional permits by paying 18500 for each, because his bids to buy for the corresponding units are higher than the price (21000 and 19000 for the 4th and 5th, respectively). In that trade, he must pay 37000 ($= 2 \times 18500$) and will come into possession of five permits, which gives him a gross benefit of 159000 (the 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 of the auction mechanism of the UPA employed in this study are summarized in the appendix.

Many subjects do not have good math skills. Therefore, the calculations of the payoffs were double-checked by research assistants. However, each subject appeared to understand the types of situations in which he (she) incurred losses or obtained more benefits from trading. We instructed subjects to trade in a way that they seek to obtain more benefits from trading. This explanation was selected because many subjects have only limited educations but do have a sense of trading for forest products in a local market. Typically, our participants were paid the equivalent of almost US $\$2$ in the local currency as a show-up fee. At the end of the session, experimental rupees were converted to real NPR at the rate of 1000 experimental rupees $=$ NPR 1, with each subject earning a minimum of NPR 500 and a maximum of NPR 2000 for an average of NPR 800 which is equivalent to approximately $\$12$. This is a high stake for typical farmers in that region, as their daily earnings range from $\$4$ to $\$7$.

4 Experimental results

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

4.1 Elicitation of economic valuation for forestland

The demand and supply of marketable permits in each session are derived, based upon the demand for forestland elicited by the survey. Figure 2, consisting of four subfigures, shows the aggregate demand for forestland elicited from 10 subjects in each session. Figures 2(a) to 2(d) correspond to the aggregate demands in sessions 1, 2, 3 and 4, respectively. From a comparison of the four figures, we can see that they are not so different qualitatively and that the total aggregate demand in a session is approximately 60 *Khatta*.[14] Furthermore, the intersection of the supply and demand occurs around NPR 20000 in each session. Note that this value could be considered an equilibrium price of permits in the MPS.

The derived demand and supply curves are in figure 3, which consists of four subfigures, each exhibiting the demand and supply for the permits in each session. As mentioned earlier, the demand and supply for permits, respectively, represent the "bids to buy," as arranged from highest to lowest and the "offers to sell," as arranged from lowest to highest, assuming that the subjects are rational (See figures 3(a) to 3(d)). When subjects are rational, they should submit their bids to buy and offers to sell that are close to their own EVs. Therefore, we should be able to observe the similar demand and supply for permits in the experimental results as derived in figure 3 for each session.

The initial endowments of sessions 1, 2, 3 and 4 are 24, 20, 22 and 18 permits, respectively. The

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

trades of 6, 9, 12 and 8 should occur with the equilibrium prices, or equivalently, the uniform prices of NPR 16000, NPR 22500, NPR 20000 and NPR 25000 in sessions 1, 2, 3 and 4, respectively. Accordingly, the market surplus is identified as the area surrounded by the derived demand and supply on the domain between 0 and the equilibrium price. The information about the market in each session is summarized in table 3. Note again that subjects' actual bids to buy and offers to sell would deviate from the EVs derived in figure 3 if they do not understand the rule of the MPS with the UPA or if they are irrational. In this case, losses of market surplus (or efficiency losses) would be realized.

[Table 3 about here.]

The equilibrium prices derived in figure 3 appear to be plausible, reflecting the current incomes and the price levels of the villagers in Shaktikhore, Nepal. These derived markets exhibit across 4 sessions an average equilibrium price of around NPR 22000 per Khatta of forestland, where arable land price is approximately NPR 100000 per Khatta.[15] The crop intensity in Nepal is known to be higher in the mid-hills geographic areas such as Shaktikhore, our field site. For instance, 4 to 5 types of crops are cultivated in the arable land of Shaktikhore over a year and it can sustain the lives of a family of 4 to 5 members for approximately 3-4 months (See Chhetri, 2011). In such cases, forest products can function only as complementary goods to the crops produced in such arable land. Hence, forestry products are not considered the main products for the lives of villagers, rather the complements to agriculture or a living itself. This observation is consistent with the fact that the price of forestland is a quarter of the arable land price. Thus, the elicited demand from the local farmers at Shaktikhore, Nepal, is very plausible.

[15]The heterogeneous group of farmers from the five different villages and the community forestry user group determined this equilibrium price with a small variation of the equilibrium price: a minimum of NPR 16000 and a maximum of NPR 25000 (See figure 3).

4.2 Market efficiency, price dynamics and trade volume

4.2.1 Efficiency

The maximum possible surplus (hereafter, theoretical surplus) is the triangular area between the supply and demand curves to the left of their intersection (See figure 3). The efficiencies were measured as a ratio between the surplus obtained from a single experimental period's market and the theoretical surplus. If the surplus that was obtained from the market in a single trading period is equivalent to the theoretical surplus, then 100% efficiency gain is considered to be achieved, or equivalently, if the permit trading in a single experimental period yields the maximum surplus from exchanges.

Figure 4, which consists of four subfigures, shows the efficiency gains from permit trading by subjects across 10 periods in each session. The least efficiency gain is observed in session 4 (See figure 4(d) and the 30% efficiency of period 4) and the highest efficiency gain is observed in session 3 (See figure 4(c) and the 100% efficiency in some periods). However, in total, the efficiency levels observed during the periods have heterogeneous patterns across sessions that range between 60% and 90%, regardless of exceptions (See figure 4). By pooling all of the observed efficiency gains over the 10 periods in each session, the average efficiency is calculated to be 80%, with a corresponding standard deviation 20%.

[Figure 4 about here.]

As mentioned earlier, a certain degree of variation in the efficiency gains is observed across the sessions (See figure 4). The degree of the efficiency gains from trading is known to be sensitive to the structure of demand and supply as well as to the characteristics of subject pools. Although the derived supply and demand for permits in each session are not so different qualitatively, some hidden heterogeneous factors may have contributed to the variation of efficiency gains in our field experiment. In fact, we admit that a small portion of subjects appeared to be confused with the rule of trading at the initial stage in some sessions, especially, during session 4. In that session, we observed that such confusion led to very irrational bidding and offering strategies and contributed to the loss of efficiency gains.[16] However, as additional periods passed, we also have found that such confusion gradually disappeared in most cases of sessions 1, 2 and 3.

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

4.2.2 Market prices and trade volume

Figure 5, which consists of four subfigures, depicts the evolution of the observed prices in the UPA market over the periods of each session. In figure 5, a solid line represents the level of theoretical equilibrium prices (hereafter, TEP) and a solid diamond marker represents the observed uniform price per period for each session. Overall, the results suggest that the UPA generated observed equilibrium prices that are not so far from the TEP and can be considered close to it except for session 4 (see and compare figures 5(a) to 5(d)).

[Figure 5 about here.]

The observed prices are stable (see figures 5(a) to 5(d)). Most of the observed prices range between NPR 15000 and NPR 25000. The greatest deviation between the TEP and the observed price is visible in session 4. As mentioned earlier, we realize that in that session, some subjects did not follow the usual trading or consistent strategies under the UPA as argued by Smith and Williams (1982), Cason and Plott (1996) because of the confusion they had at the initial stages,

[16] In session 4, we could not observe that efficiencies rise over periods. This is due to the fact that a few subjects seem not to have consistent strategies for bids to buy and offers to sell throughout that session.

and this may be the main reason for the large discrepancy between the TEP and the observed prices of that session.

Table 4 presents the average units of permits traded across the sessions and the theoretical trade volume. The results show that an average of 70% of the theoretical trade volume was realized. The average number of permits traded remained less than the predicted trade volume across the sessions (See table 4). This result is quite consistent with past literature on the UPA in the sense that the volume of trades that occurs in experiments tends to be less than the theoretical volume of trades. This information regarding the actual trade volume indicates that substantial trades have occurred although they are not always identical to the predicted trade volume. This result could be argued in relation to endowment effects, which will be detailed later.

[Table 4 about here.]

4.3 Demand revelation

This subsection reports how the subjects revealed their demands for forestland through bids to buy and offers to sell and considers whether there is a qualitative difference between the two in our MPS experiments. This analysis is important because efficiency gains are more likely to rise when subjects are induced to reveal their true valuations for forestland through market exchange. Economic theory predicts that a UPA will tend to induce demand revelation at a margin if a subject behaves optimally, which means that he (she) should submit his or her "bids to buy" and "offer to sell" near the EVs (See Cason and Plott, 1996).

In figures 6 and 7, a circle mark represents each observed bid to buy and offer to sell, the straight line represents a 45 degree slope, and a thick line represents the median regression line estimated with the data which will be explained later. In these figures, we can observe that bidding and offering behaviors are positively correlated with the EVs, and a persistent tendency to submit "bids to buy" below the EVs and "offers to sell" above the EVs. This means that many circle marks exist below the 45 degree line for bids to buy and above it for offers to sell (See figures 6 and 7). We can also confirm that this behavioral pattern applies to many participants by looking at each individual data. To clarify the positive correlation between the actual behaviors of subjects and their EVs, we obtain an slope estimate by running the median regression, in which the observed bids and offers are taken as dependent variables and the corresponding EV values are the independent variable. Note that if this regression is close to the 45 degree line, it means that the subjects are induced to reveal their true values through their bids to buy and offers to sell.

[Figure 6 about here.]

[Figure 7 about here.]

The regression is specified as follows:

$$\mathit{bid}_i = \beta_0 + \beta_1 v_i + \varepsilon \tag{1}$$

$$\mathit{offer}_i = \beta_0 + \beta_1 v_i + \varepsilon \tag{2}$$

where bid_i is an observed bid to buy, and offer_i is an offer to sell as revealed by subject i during the experiments, v_i is the corresponding EV for the unit of forestland, β_0 and β_1 are the parameters and ε is defined as the stochastic error term. Note that if the estimates in the above median regressions produce a zero intercept and a slope of 1, then the subjects are considered to have 100% demand revelation.

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

$$\widehat{\mathit{bid}}_i = \underset{(90.99)}{666.67} + \underset{(0.0042)}{0.67}\, v_i, \quad \text{Pseduo } R^2 = 0.57, \quad T = 1740,$$

$$\widehat{\mathit{offer}}_i = \underset{(753{,}89)}{-753.89} + \underset{(0.020)}{1.53}\, v_i, \quad \text{Pseduo } R^2 = 0.23, \quad T = 840.$$

The numbers in the parentheses are the respective standard errors. The estimation from this model shows that both of the slope estimates β_1 are positive and statistically significant, although the magnitudes are different from the regressions for bids to buy and offers to sell. With respect to the estimates of the intercepts, we can clearly see that the bids to buy regression has a positive intercept value, while the offers to sell regression has a negative intercept value. Based on these regression results, it seems that the demand revelation through bids to buy and offers to sell has not been perfectly rendered in our experiment, but the bids to buy and offers to sell are positively correlated with the corresponding EVs to a certain extent of statistical significance. Therefore, we say that a UPA induces at least a partial demand revelation to such an extent that efficiency gains become approximately 80% on average.

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

In our experimental environment, endowment effects can induce the subjects to over-report their offers to sell for each permit in relation to 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 subjects are endowed with real goods, then substantially fewer trades have occured in comparison to the trades theoretically predicted in the absence of endowment effects. The endowment effects might have reduced the gains from trade in our experiments. Fortunately, the results demonstrate that efficiency losses from the effects are not so significant, and that our UPA institution could be considered efficient in the field even in the presence of endowment effects.

Overall, the market performances observed in our experiment, with the UPA institution under trader settings with real subjects, are quite consistent with the result of Cason and Plott (1996), although some endowment effects were observed in our cases. These data indicate that the UPA institution's market performances, even under trader settings in the field, do not significantly fall shorter than the results under non-trader settings in laboratory experiments. Finally, we claim that the market allocation of permits through the UPA can be efficient and socially desirable with an appropriate scheme of the initial allocation and can improve equitable welfare distribution along with the preservation of forestland resources.

4.4 Discussion

Our results can potentially provide some implication not only to forest conservation in Nepal but also to other cases. Currently, the implementation of the REDD+ program has been reviewed in Nepal and in many other parts of the countries to stop worldwide rapid deforestation (Sukhdev et al., 2012, FAO Forest Department, 2015). This program is an effort to create a financial value for the carbon stored in forests, offering incentives for people in developing countries to reduce emissions from forestland and to invest in low-carbon paths to sustainable development. The REDD+ goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

The MPS induces forest users who are innovative and productive to buy and hold more forestland and the REDD+ program is considered an additional source of benefits for such productive forest users. However, this does not mean that less productive forest users suffer. The existence of the REDD+ program together with the MPS shall strongly motivate forest users to be more productive, implying that overall efficiency gain achieved under the MPS can be larger based on our experimental results. In such a situation, less productive users should be able to sell the land with higher prices and gain more benefit as well, leading to more overall efficiency. In this sense, the REDD+ program can reinforce the effectiveness of the MPS for forest management. Therefore, evaluating the potential efficiencies of the MPS for forest management through field experiments in other parts of the world shall be more important and our results could be considered a benchmark for the future research.

By analogy, the MPS of our field experiments could be related to other land use issues such as potential conflicts between development and conservation of farmland, preserving country-side amenity, protection of natural environment and so on. Due to heavy pressures from urban sprawl and rise in agricultural demand, many countries face potential depletion of wilderness and natural environment. For example, USA, European countries, say, Germany, Switzerland, and Netherland, Asian countries, Indonesia and Philippines as well as South American countries, Brazil and Costa Rica, face the similar type of problems. Starting in the 1970s, the transferable development rights (hereafter, TDR, or equally the MPS) have been implemented to address the land use problems in more than one hundred locations of USA, while most countries have not adopted the TDR yet (Renard, 2007, Pruetz and Standridge, 2009, Corkindaie, 2013). To the best of our knowledge, the TDR efficiencies have not been addressed empirically in the field, and such evaluation is going to be important for further application of TDRs. Our research implies that the efficiencies of TDR applied to many types of land use in these countries can be evaluated through field experiments, and it is likely that high efficiencies in TDR field experiments are observed.

5 Conclusion

This framed field experiment was designed to develop the MPS under cap and trade schemes for the management of forestland at Shaktikhore, Nepal. This attempt was made to fill the gap in the literature in that the performance of the MPS applied to real resource management in the context of a developing nation has not been yet explored. Therefore, this paper has reported the efficiencies and potentials of the MPS by the field experiments with some novel features: (i) implementation of the UPA under trader settings in the field and (ii) representative simulation of economic decisions made by the local farmers with elicited demand for forestland. Equilibrium prices per *Khatta* forestland development were derived through the observed trades in field experiments, using the elicited demand and supply relationships of permits involving 40 subjects.

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

Another important point to mention is that through the markets elicited across the four sessions of experimentation, an average equilibrium price was estimated at NPR 22000 per *Khatta* of forestland. The prime factors that contribute to this price of forestland are distinctive valuations among the people and their dependency on forest resources; hence, they can comprehend its costs and benefits based on their daily life experiences in forest. Again, recall that these values are elicited from the local farmers of the Shaktikhore village development committee, Nepal, and it is highly plausible considering their present conditions for price levels, living standards and commercial land prices, as mentioned earlier.

The MPS itself does not always guarantee an efficient market to emerge through simply asking people to trade marketable permits. This study could be considered an illustration of how the MPS is a flexible and cost-effective market instrument that could potentially play a vital role in addressing real world natural resource problems. Here, we admit that the inception of marketable permits for forest conservation in rural parts of Nepal is a very difficult task in reality. However, our field experiments have shown that even local farmers can achieve high efficiency gains under UPA institutions, which may be considered an important first step toward realistic application of the MPS to natural resource conservation. As an implication of our results, the farmers who highly value forestland resources will benefit from buying permits and those who put a low value will benefit by selling the permits. Hence, the issues of social injustice and the unfair welfare distribution of forest resources to rural households of a country like Nepal can be solved. Finally, a governing body should be very vigilant about changes in the scope and motivations of trading to keep trades free from market speculation.

For the future research, there are several possible research topics emanating from this work. It appears that endowment effects play important roles in our field experiments. However, we did not vary the distributions of permits as a control and thus could not identify how initial endowments of permits to subjects affect the overall performance. We conjecture that endowment effects play more significant roles in the field than in the laboratory. Another possible direction of the future research is evaluation of efficiencies in transferable development rights (TDRs) for preservation of wilderness and so on as mentioned in discussion section. There are several places where TDRs have been implemented, however, the TDR efficiencies have never been evaluated in the field experiments. This shall be an important research for further applications of the TDRs.

In summary, this paper has employed the UPA institution under trader settings in the real-life conditions of a developing nation, involving local farmers with elementary educations, which itself could be considered a pioneering work in the sphere of experimental research. It is our belief that the scope of the MPS has been broadened with the implications of our experiments regarding the resource-use exclusion of forestland resources, and our research counters the myth that market-based instruments work only for industrialized nations. In fact, the MPS would work well in developing countries. We hope that our field experiment is considered an important step toward applying the MPS to various resource problems in both developed and developing nations.

6 Bibliography

Adhikari, B., Di Falco, S., and Lovett, J. C. (2004). Household characteristics and forest dependency: Evidence from common property forest management in Nepal. *Ecological economics*, 48:245–257.

Adhikari, B., Williams, F., and Lovett, J. C. (2007). Local benefit from community forests in the middle hills of Nepal. *Forest policy and economics*, 9:464–478.

Campbell, B., Mandondo, A., Nemarundwe, N., Sithole, B., Jong, W. D., Luckert, M., and Matose, F. (2001). Challenges to proponents of common property recource systems: Despairing voices from the social forests of Zimbabwe. *World development*, 29:589–600.

Cason, T. N. (2010). What can laboratory experiments teach us about emissions permit market design? *Agricultural and resource economics review*, 39:151–161.

Cason, T. N. and Gangadharan, L. (2006). Emissions variability in tradable permit markets with imperfect enforcement and banking. *Journal of economic behavior and organization*, 61:199–216.

Cason, T. N., Gangadharan, L., and Duke, C. (2003). Market power in tradable emission markets: A laboatory testbed for emission trading in Port Phillip Bay, Victoria. *Journal of environmental economics and management*, 46:469–491.

Cason, T. N. and Plott, C. R. (1996). EPA's new emission trading mechanism: A laboratory evaluation. *Journal of environmental economics and management*, 30:133–160.

Central Bureau of Statistics (2011). *Population Census*. Nepal.

Chhetri, N. B. (2011). Climate sensitive measure of agricultural intensity: Case of Nepal. *Applied geography*, 31:808–819.

Corkindaie, J. (2013). Using transferable development rights for land use planning purposes. *Environmental law and management*, 25:223–232.

Cummings, R. G., Brookshire, D. S., Gerking, S. D., and Schuzle, W. D. (1986). Measuring the elasticity of substituion of wages for municipal infrastructure: A comparison of the survey and wage hedonic approaches. *Journal of environmental economics and management*, 3:269–276.

Davis, D. D. and Holt, C. A. (1992). *Experimental economics*. Princeton university press.

Ellerman, A., Convery, F. J., and de Perthuis, C. (2010). *Pricing carbon: The European union emissions trading scheme*. Cambridge university press.

Ellerman, A. and Montero, J. (1998). The declining trend in sulfur dioxide emissions: Implications for allowance prices. *Journal of environmental economics and management*, 36:26–45.

Ellerman, A. and Montero, J. (2007). The efficiency and robustness of allowance banking in the U.S. acid rain program. *Energy journal*, 28:47–72.

FAO Forest Department (2010). Global forest resource assessment 2010. Technical report, Food and Agriculture Organization of the United Nation.

FAO Forest Department (2015). Global forest resource assessment 2015. Technical report, Food and Agriculture Organization of the United Nation.

Field, B. C. and Field, M. K. (2006). *Environmental economics*. McGraw-Hill/Irwin.

Gautam, K. H. (1987). Legal authority of forest user group. *Banko Janakari*, 1:1–4.

Gilmour, D. A. and Fisher, R. J. (1991). *Villagers, forests, and foresters: The philosophy, process, and practice of community forestry in Nepal*. Sahayogi press.

Gilmour, D. A., King, G. C., and Hobley, M. (1989). Management of forests for local use in the hills of Nepal changing forest management paradigms. *Journal of world forest resource management*, 4:93–110.

Godby, R. (1997). Emission trading with shares and coupons when control over discharges is uncertain. *Journal of environmental economics and management*, 32:359–381.

Graner, E. (1997). *The political ecology of community forestry in Nepal*. Saarbrucken: Verlag fur Entwickungspolitik.

Hahn, R. W. and Stavins, R. N. (2011). The effect of allowance allocations on cap-and-trade system performance. *Journal of law and economics*, 54:267–294.

Harrison, G. W. and List, J. A. (2004). Field experiments. *Journal of economic literature*, 42:1009–1055.

Henrich, J., Heine, S. J., and Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and brain sciences*, 33:61–135.

Kahneman, D., Knetsch, J. L., and Thaler, R. H. (1990). Experimental tests of the endowment effect and the Coase theorem. *Journal of political economy*, 98:1325–1348.

Kilkenny, M. (2000). A classroom experiment about tradable permits. *Review of agricultural economics*, 22:586–606.

Knetsch, J. L. and Sinden, J. (1987). The persistence of valuation disparities. *Quarterly journal of economics*, 102:691–696.

Ledyard, J. O. and Szakaly-Moore, K. (1994). Designing organizations for trading pollution rights. *Journal of economic behavior and organization*, 25:167–196.

Levitt, S. D. and List, J. A. (2007). What do laboratory experiments measuring social preferences reveal about the real world? *Journal of economic perspectives*, 21:153–174.

List, J. A. (2011). Why economists should conduct field experiments and 14 tips for pulling one off. *Journal of economic perspectives*, 25:3–15.

Mahat, T., Griffin, D. M., and Shepherd, K. R. (1986). Human impacts on some forests of the middle hills of Neal: Forestry in the context of the traditional resources of the state. *Mountain research and development*, 6:223–232.

Mitchell, R. C. and Carson, R. T. (1988). *Using surveys to value public goods: The contingent valuation method*. RFF Press.

Montero, J. (1999). Voluntary compliance with market-based environmental policy: Evidence from the U.S. acid rain program. *Journal of political economy*, 107:998–1033.

Muller, R. and Mestelman, S. (1998). What have we learned from emissions trading experiments? *Managerial and decision economics*, 19:225–238.

Muller, R., Mestelman, S., Spraggon, J., and Godby, R. (2002). Can double auctions control monopoly and monopsony power in emissions trading markets? *Journal of environmental economics and management*, 44:70–92.

Murphy, J. J. and Stranlund, J. K. (2006). Direct and market effects of enforcing emissions trading programs: An experimental analysis. *Journal of economic behavior and organization*, 61:217–233.

Murphy, J. J. and Stranlund, J. K. (2007). A laboratory investigation of compliance behavior under tradable emissions rights: Implications for targeted enforcement. *Journal of environmental economics and management*, 53:196–212.

Murphy, J. J. and Stranlund, J. K. (2008). An investigation of voluntary discovery and disclosure of environmental violations using laboatory experiments. In *Environmental economics, Experimental methods*. Routledge.

Newell, R. G., Sanchirico, J. N., and Kerr, S. (2005). Fishing quota markets. *Journal of environmental economics and management*, 49:437–462.

OECD (2000). *Implementing domestic tradable permits for environmental protection*. OECD publishing.

Plott, C. R. (1983). Externalities and correctives policies in experimental markets. *Economic journal*, 93:106–127.

Plott, C. R. and Gray, P. (1990). The multiple unit double auction. *Journal of economic behavior and organization*, 13:245–258.

Pruetz, R. and Standridge, N. (2009). What makes transfer of development rights work? *Journal of the American planning association*, 75:78–87.

Regmi, R. R. (2000). Forest people's participation and conflicts in nepal. Occasional Papers in Sociology and Anthropology. Volume 6.

Renard, V. (2007). Property rights and the transfer of development rights: Questions of efficiency and equity. *Town planning review*, 78:41–60.

Shogren, J. F. (2005). Experimental methods and valuation. In Maler, K. and Vincent, J. R., editors, *Valuing Environmental Changes*, volume 2 of *Handbook of Environmental Economics*, pages 969–1027. Elsevier.

Smith, V. and Williams, A. (1982). The effects of rent asymmetries in experimental auction markets. *Journal of economic behavior and organization*, 3:99–116.

Smith, V., Williams, A., Bratton, W. K., and Vannoni, M. (1982). Competitive market institutions: Double auctions vs. sealed bid-offerauctions. *American economic review*, 72:58–77.

Sukhdev, P., Prabhu, R., Kumar, P., Bassl, A., Patwa-Shah, W., Enters, T., Labbate, G., and Greenwalt, J. (2012). REDD+ and a green economy: Opportunities for a mutually supportive relationship. Technical report, UN-REDD programme.

Williams, A. W. (1980). Computerized double-auction markets: Some initial experimental results. *Journal of business*, 53:235–258.

7 Appendix: Detailed description of the field experiment

We mainly rely on oral explanation to introduce our field experiment to the subjects because they are local farmers and many of them are illiterate. Therefore, we repeatedly explained how the trades of permits would be determined using the Nepali local language of the first author, and ran trial periods before we started the "real round" experiments. We made sure that every subject understood the rules. In this appendix, we detail translated versions of our oral explanation made to our subjects.

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

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

Why are permits required?

The permits are necessary for farmers to utilize the forestland as private commercial forests, enjoying the forest product and resources harvested from there. However, note that all subjects have to bear some obligations as a member of a community forest user group (CFUG), irrespective of their ownership of commercial forests.[17] You can enjoy the EVs of the commercial forestland the you own in permits. If anybody wants to have additional commercial forestland to develop and utilize, he has to buy additional permits, and those who does not want to utilize forestland can sell their permits to others and receive the payments. Simply, subjects have a chance to trade "permits" in each period.

Everyone starts the experiment with his or her initial "permits," and can adjust his or her own holdings of "permits" by buying and selling them in the market that will operate. If subjects sell their permits, their benefit increases by the amount of sale. If subjects buy additional permits, their benefit decreases by the amount of payment. In what follows, we explain the rules for buying and selling permits.

Why might a subject want to buy permits?

Remember, as mentioned earlier, that permits allow subjects to develop or utilize forestland for commercial use as they wish. First, see table 2, in which a subject reveals the EVs for 10 units (1st to 10th) of forestland as his or her demand. He (she) currently holds 3 permits, the 1st, 2nd and 3rd units of which he can enjoy the corresponding EVs. However, for the remaining 7 units from the 4th to 10th units, he (she) cannot enjoy the corresponding EVs, because he does not possess the permits for these units of forestland. In summary, his or her total commercial forestland demand is 10 units, but he (she) can only receive the sum of EVs for the 1st, 2nd and 3rd units of commercial forestland ($= 113000 = 30000 + 38000 + 45000$) as a net benefit when he (she) has 3 units of

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

permits. However, if he (she) is allowed to trade the permits, it may be better to buy an additional permit. For instance, the EV of the 4th unit is 25000, and if the subject can buy an additional permit with a price less than 25000, this might be a good idea because he (she) obtains an additional unit of forestland at a cheaper value than the EV. More specifically, if the subject buys an additional permit at the price of 21000, he gets a surplus of $4000 = 25000 - 21000$. In this case, the subject ends up owning 4 units of permits after the trade, and can thus develop 4 units of forestland for commercial use. Note that the same logic applies when the subject wants to buy additional permits to increase the surplus for each of the $5th, 6th, \dots, 10th$ units of forestland.

Why might a subject want to sell permits?

Continuing the previous example, suppose that a subject initially holds 3 permits with corresponding EVs, as in table 2. The EV of the 3rd unit is 30000, but if he (she) can sell a permit of the 3rd unit with a price more than 30000, this might be a good idea because these sales revenues exceed his EV of this unit. For example, if he (she) sells the permit of the 3rd unit with the price, 35000, which is higher than 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, representing the price he (she) is willing to pay to purchase each additional unit of permits, and offers to sell, representing the price with which he (she) is willing to sell each additional unit of permits that he (she) holds. Table 2 illustrates that as this subject has 3 permits, he (she) must submit 3 distinct offers to sell, representing the price with which he is willing to sell each unit of permits he (she) holds, and also must submit 7 distinct bids to buy, representing the price he is willing to pay to purchase 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:

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

After the offers to sell and bids to buy from all participants are collected in the way explained above, the authority ranks all the bids to buy from highest to lowest as a demand curve and all the offers to sell from lowest to highest as a supply curve for permits. For example, imagine that the aggregate demand of 10 participants for forestland in one session is 43 units, in which 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 of 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.

[Table 5 about here.]

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 the offer to sell of the last unit traded. In this example, the last unit traded is the 12th unit of permits. 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 described earlier.

List of Figures

Figure 1: The location of Shaktikhore, Chitwan in Nepal

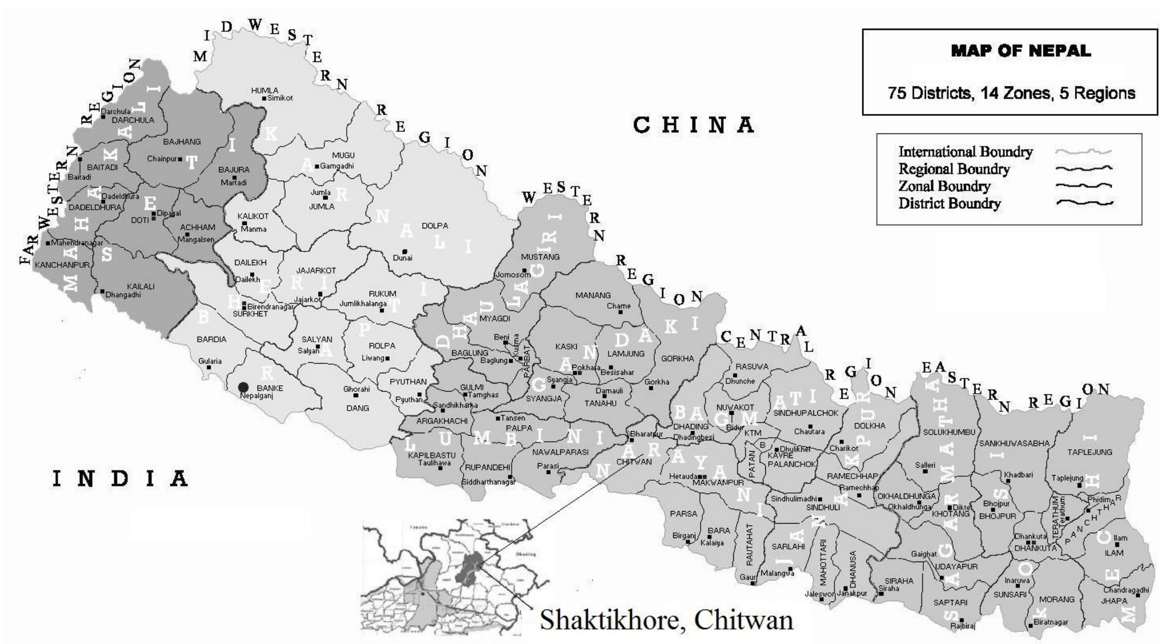


Figure 2: Elicited demands for forestland and the supply of permits across each session

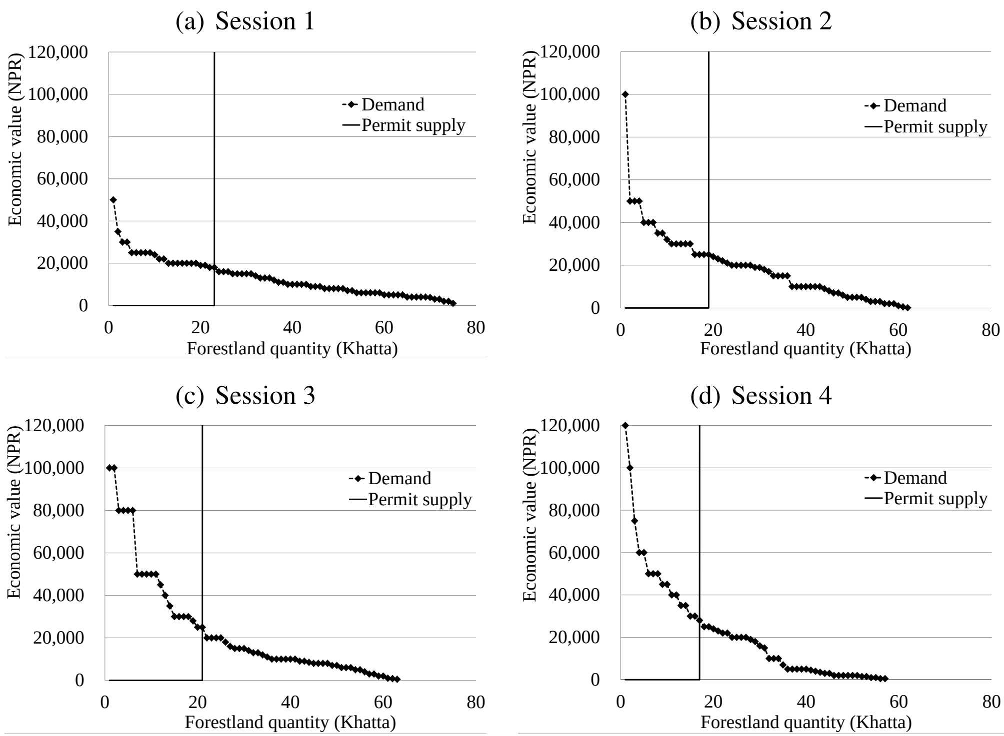


Figure 3: Theoretical equilibrium of permit demand and supply in each session

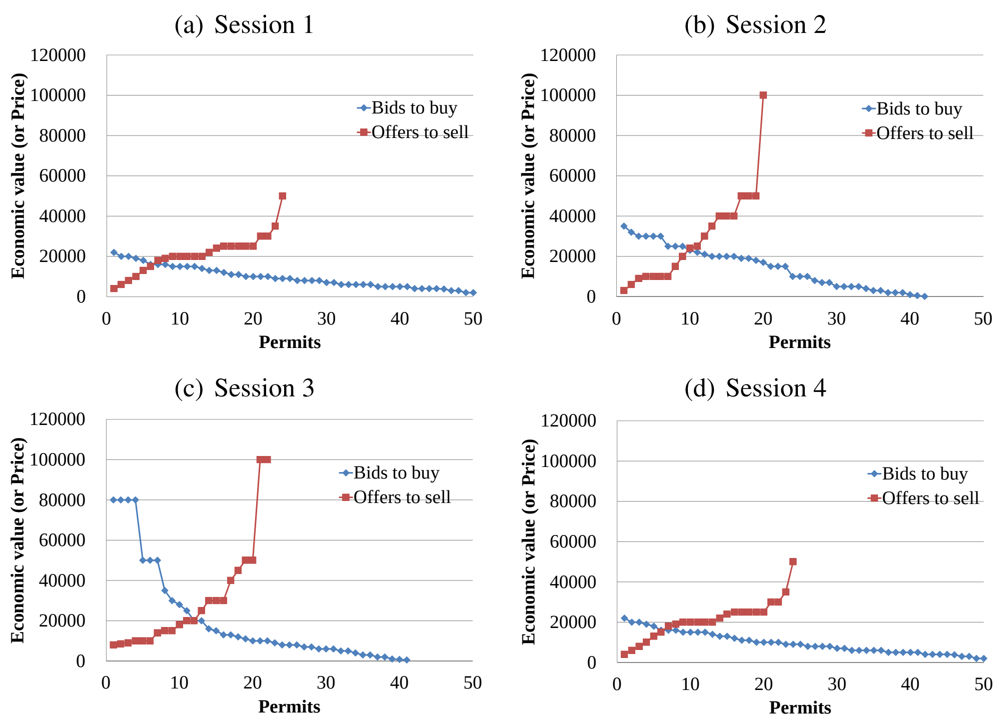


Figure 4: Observed efficiency gains over the periods across each session

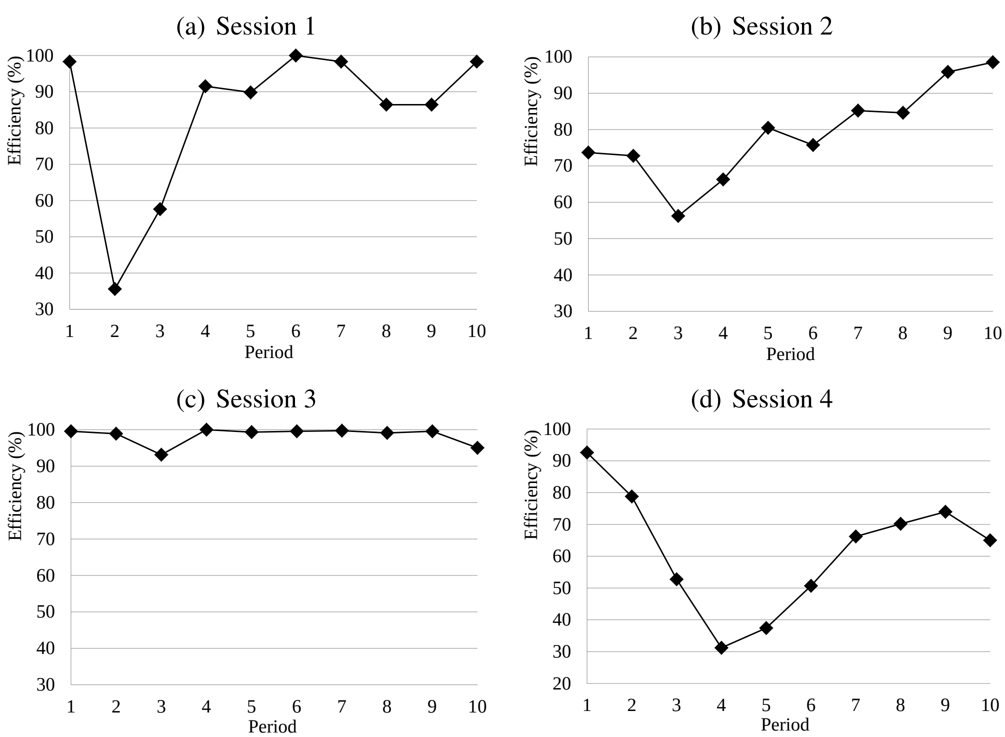


Figure 5: Observed movement of prices over the periods across each session

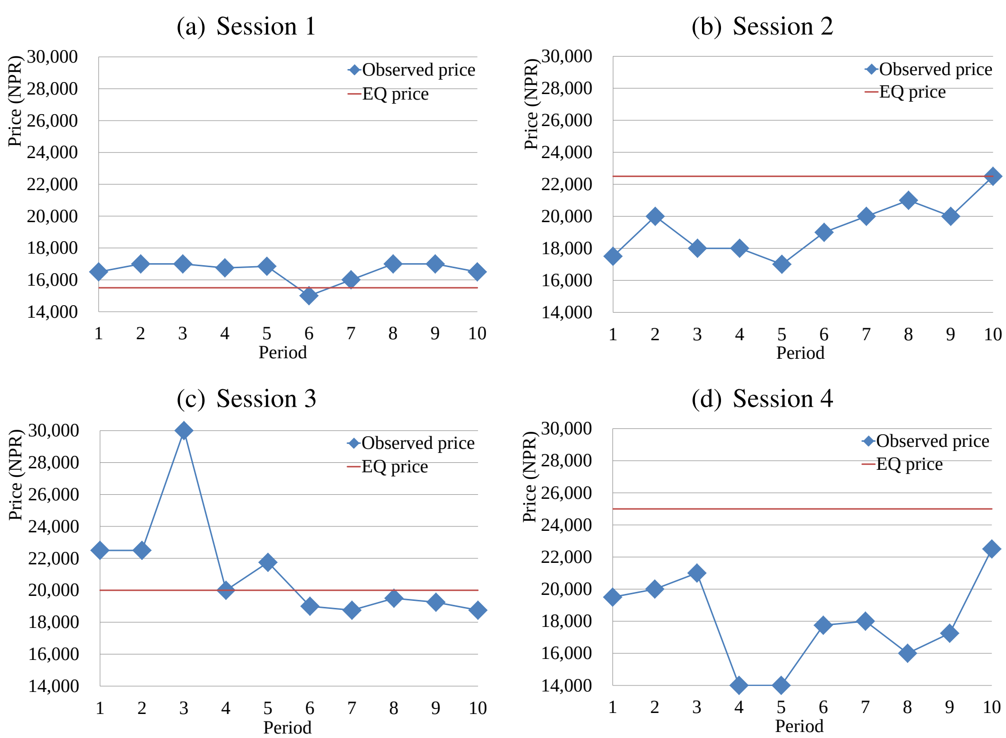


Figure 6: Bids to buy

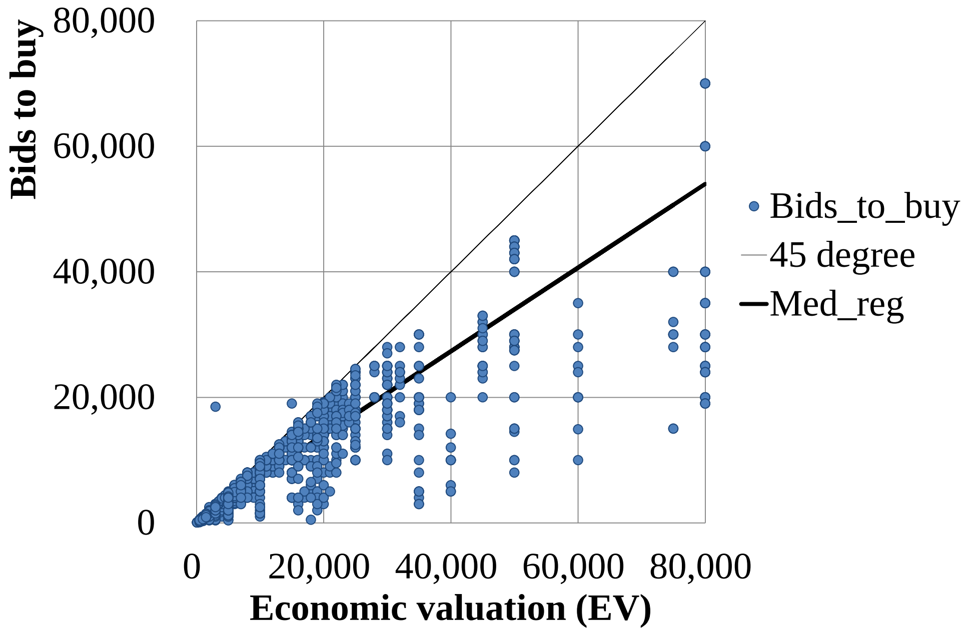
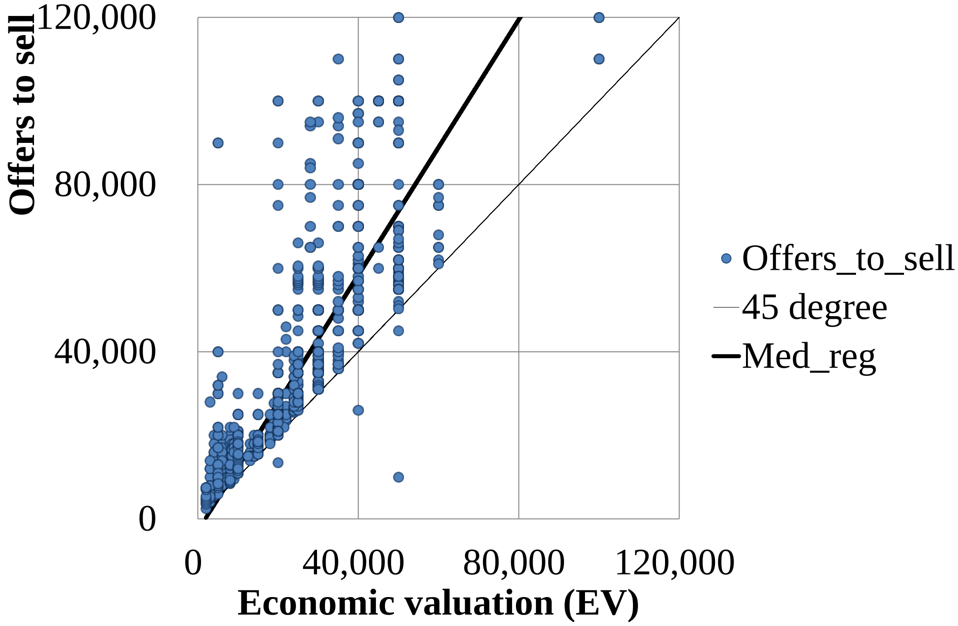


Figure 7: Offers to sell



List of Tables

Factors	Experimental designs
Subjects	Local farmers and members of CFUG
Location	Shaktihore village development committee
Education level of subjects	Illiterate or elementary level
Session and experimental periods	4 session, each consists of 10 periods
Market institution	Uniform price auction
Time per session	Approximately 180 minutes

Table 1: Summary of experimental design

Table 2: A farmer's elicited economic valuation in the forestland information sheet

Round	10									
Uniform price (NPR)	18500									
Commercial forest land (unit)	10th	9th	8th	7th	6th	5th	4th	3rd	2nd	1st
Economic value (NPR)	10000	13000	15000	16000	18000	21000	25000	30000	38000	45000
Offer to sell (NPR)	-	-	-	-	-	-	-	55000	70000	75000
Bid to buy (NPR)	8000	10000	12000	14500	16000	19000	21000	-	-	-
Payoff (NPR)	122000									

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

Table 3: Summary of market information per session

Session	1	2	3	4
Efficient trade volume	6	9	12	8
Average trade volume	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	1.5

Table 4: Observed trade volume per session

Table 5: Example of a uniform price determination

Permit	Bid to buy (NPR)	Offer to sell (NPR)
1st	80000	8000
2nd	80000	8500
3rd	80000	9000
4th	80000	10000
5th	50000	10000
6th	50000	10000
7th	50000	14000
8th	35000	15000
9th	30000	15000
10th	28000	18000
11th	25000	20000
12th	20000	20000
13th	20000	25000
14th	16000	-
15th	15000	-
16th	13000	-
17th	13000	-
18th	12000	-
19th	11000	-
20th	10000	-
21st	10000	-
22nd	10000	-
23rd	9000	-
24th	8000	-
25th	8000	-
26th	8000	-
27th	7000	-
28th	7000	-
29th	6000	-
30th	6000	-