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Xuehong Wang^a, Jeff Bennett^a, Jintao Xu^b & Haipeng Zhang^b

^a Crawford School of Economics and Government, Australian National University, Canberra, ACT, 0200, Australia

^b College of Environmental Science and Engineering, Peking University, Beijing, 100871, P. R. China

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An auction scheme for land use change in Sichuan Province, China

Xuehong Wang^{a*}, Jeff Bennett^a, Jintao Xu^b and Haipeng Zhang^b

^a*Crawford School of Economics and Government, Australian National University, Canberra ACT 0200, Australia;* ^b*College of Environmental Science and Engineering, Peking University, Beijing 100871, P. R. China*

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This paper presents the application of an auction scheme for the allocation of funds for environmentally improving land use change (LUC) amongst farm households in Sichuan Province, China. Competing bids were ranked using their benefit to cost ratios. Results show that the auction approach can be both practically feasible and efficient in the Chinese context. The auction approach was 15% more cost-effective than the status quo fixed payment afforestation programme. The auction approach was also more closely targeted to achieve environmental improvements. Potential improvements to the auction process would be achieved through increased heterogeneity across bids and lower transaction costs from taking bids from aggregations of farmers.

Keywords: auction; land use change; China

1. Introduction

Worldwide, payments made by governments to stimulate land use change (LUC) are often primarily determined by political considerations, rather than any economic evaluation of the benefits and costs involved. This is true of the ecological restoration programmes in China, including the Conversion of Cropland to Forest and Grassland Program (CCFGP), the Forest Ecosystem Compensation Program (FECGP) and the Natural Forest Protection Program (NFPP). Previous studies have found that subsidies provided under the CCFGP are inefficient in achieving LUC (Xu *et al.* 2003, Uchida *et al.* 2005, Bennett *et al.* 2008). Under the CCFGP, payments are made on the basis of a broad assessment of the opportunity costs of land with only two levels of payments across the country to differentiate crop productivity in the North and South. This ignores heterogeneity in the net benefits generated by each LUC.

Bennett *et al.* (2008) found that the fixed-rate payments have various impacts on farm households. While the payments were important in changing land use patterns in some counties, they were less significant in precipitating change in other counties where farm households were better off with the LUC even without the CCFGP payments. Payments under the Programme did not reflect the heterogeneity evident across farm households partly because the government did not have adequate information on the individual costs of implementing LUC.

*Corresponding author. Email: xuehong.wang@anu.edu.au

A similar problem of adverse selection arising from such information asymmetry has been documented in the European agri-environmental contracting policy under which a single, fixed payment for compliance with a pre-determined set of management prescriptions remains (Wu and Babcock 1996). Under that scheme, farmers who already manage their land in an environmentally-friendly way, have a greater incentive to join a conservation scheme, than farmers with less environmentally-friendly farming practices. This results in comparatively small additional environmental benefits, over-compensation and a non cost-effective policy.

The implication for the CCFGP is that improvements in net social welfare could be achieved if more resources could be diverted to areas where net benefits of LUC are likely to be the greatest. Put simply, the efficiency of the CCFGP could be improved through better targeting of the LUC sites to ensure that the policy goals of the Programme are achieved at lowest cost. In recent decades there has been increasing interest in the use of auctions or bidding schemes to deliver payments for environmental services, mainly in developed countries. These schemes have usually had a cost minimisation objective, with landholders competing to secure government funds to undertake LUC activities. 'Quasi-markets' for the provision of environmental goods and services can be created in this way: farmers voluntarily enter into agreements to produce pre-defined environmental public goods in return for a payment. Conservation auctions carried out or piloted worldwide include the Conservation Reserve Program (CRP) in the United States, Bush Tender, the Auction for Landscape Recovery (ALR) and EcoTender in Australia, Challenge Funds in the United Kingdom, and the Grassland Conservation Pilot Tender in Germany. These auction programmes differ in their objectives, auction designs and auction outcomes. They also have different ways of setting reserve prices, assessing environmental benefits and ranking bids (Heimlich *et al.* 2003, Stoneham *et al.* 2003, CJC Consulting 2004, Holm-Muller and Hilden 2004, Gole *et al.* 2005, Latacz-Lohmann and Schilizzi 2005, Eigenraam *et al.* 2006).

Theory suggests that auctioning conservation contracts is cost-effective and can help to reduce public spending on programmes for the provision of environmental goods and services. Because of competition, farmers have an incentive to reveal their true compliance costs. This reduces over-compensation and increases cost-effectiveness. Bids submitted by participating farmers are ranked on the basis of two key components. The first is the farmer's bid price, which normally comprises their compliance costs of the conservation contract, opportunity costs of their foregone benefits from previous land practices, and a risk premium in the case of output-based payment which will cover the farmer's losses arising from factors beyond farmers' control (such as droughts or pest invasions). The second component is the assessment of potential environmental outcomes from farmers' proposed conservation activities. Through the bidding scheme, the highest net benefit providers of environmental goods and services can thus be identified and selected into the conservation contracts.

Despite their potential cost-effectiveness, auctioning conservation contracts also involve complex incentive mechanisms that entail higher risks of failure compared to a simple fixed-rate payment. Insufficient bidding competition, including the prospect of collusion and the risk of learning on the part of bidders, especially in a multi-round auction setting, are potential problems. In addition, high transaction costs might undermine the cost-effectiveness of auctions for conservation contracts. Empirical studies of previous auction programmes and trials show that there have been both successful applications and failures.

In 2009, a trial application of an auction scheme for distributing funds to farmers engaging in LUC for environmental improvement was conducted in Sichuan Province in South West China. The objective of the trial was to provide a comprehensive analysis and understanding of whether the introduction of an auction scheme could improve the efficiency of LUC programmes in China. As these programmes involve substantial government funding, it is of policy significance for the Chinese Government to improve their efficiency. In addition, the trial application aimed to develop a modified approach to bid evaluation which involves the estimation of net benefits of each bid.

The auction involved farmers in Sichuan Province submitting bids to provide environmental goods and services through afforestation and related management activities on lands that were contracted to their households. The relative efficiency of the auction was assessed through a comparison of the area of LUC that could be achieved under the auction with that generated through fixed payments under the current CCFGP given the same amount of government funding. The structure of incentives for farmers to participate was examined and analysed under each policy scenario and the feasibility of introducing the auction in the Chinese context was explored.

This paper presents the findings of the trial application. It is structured as follows. The methods used in implementing the LUC auction are outlined in the next section. These include the case study approach, biophysical and environmental economic modelling, as well as the application of the net benefit bid assessment criteria through the use of benefit-cost ratios (BC ratio) in ranking the bids. Section 3 presents the results of the trial. In section 4, the cost saving potentials of the auction and the feasibility of its implementation are discussed. Some conclusions are drawn in section 5.

2. Method

2.1. Bid evaluation

In an auction, bids are evaluated and ranked based on the bid price information and the potential environmental benefits that the nominated conservation activities will generate. In evaluating bids, previous auction schemes such as the US Conservation Reserve Program (CRP) and the Australian BushTender programme were effectively limited to a cost-effectiveness approach. An environmental or biodiversity benefit index was used to reflect the funding agency's preferences for various environmental attributes. Bids were evaluated on a cost per index unit basis. In contrast, the LUC auction involved an analysis of the net-benefits arising from competing farmer bids. Bids with net benefits greater than zero were ranked based on their benefit-cost ratio. The benefit-cost ratio for each bid was estimated using bid price information and the predicted environmental benefits, measured in monetary terms, that the LUC activities nominated in the bid would generate.

The calculation of potential environmental benefits involved two stages. First, a biophysical model was developed at the individual bid level to predict the outcomes of each bid as measured by a sequence of environmental attributes (Li *et al.* 2010). Second, these environmental outcome predictions were converted to a monetary measure of benefits that can be compared against farmers' bids. The second step involved the estimation of the non-market values of each environmental attribute using choice modelling (CM) (Wang *et al.* 2010). In particular, respondents'

preferences for environmental improvements possible under the LUC programme were elicited in an urban household survey: Their choice behaviour was modelled to infer average household willingness to pay (WTP) for each environmental attribute for a three-year time period during 2009–2012, when the LUC activities proposed in the bids will be undertaken. Thus the LUC auction process embodies the preferences of the members of society who will benefit from the environmental services supplied by the farmers' LUC actions as well as the costs of those actions.

The biophysical model was used to predict environmental attribute changes resulting from LUC, undertaken at the single farm level (Li *et al.* 2010). Key attributes of the environmental improvements used in the biophysical model were identified by scientists at Sichuan Academy of Forestry as well as through two rounds of focus groups conducted in Chengdu and Shanghai in March and July 2009, respectively. These environmental attributes are water quality improvements, air purification and biodiversity conservation. Specific variables to measure these attributes were selected in consultations with scientists at Sichuan Academy of Forestry and were used as dependent variables in the biophysical modelling exercise (see Table 1).¹

The prediction of the environmental attribute levels resulting from LUC undertaken at the single farm level involves numerous conceptual complexities and heavy data requirements. The practicalities of application in the context of LUC in Sichuan required the development of a simplified modelling process. This involved the use of research results linking land use changes to environmental outcomes at a regional (Sichuan Basin) level and adjusting those results to reflect differential conditions that applied at the individual farm level. Essentially, regional average changes in the environmental outcome attributes per unit of land area involved in a change of management were used as reference points. These averages were then adjusted to reflect farm level divergences from the average. This adjustment process required the identification of farm level characteristics that would cause divergence and the quantification of that divergence.

Equation 1 sets out this process:

$$Q_n^i = R_n \times A^i \times D_n^i, \quad (1)$$

where Q_n^i is the farm level impact of LUC on attribute n (quantity change of attribute n), for farm i ,

R_n is the per μ^2 impact of LUC on attribute n at the regional level,

A^i is the area of land use change on farm i , and

D_n^i is the divergence factor between farm level impact and regional level impact for farm i .

Table 1. Dependent variables used in the biophysical models.

Environmental attributes	Dependent variables
Water quality	Reduction in soil erosion
Air purification	Sequestration of SO ₂ , Oxalyl, noxious gases and dust
Biodiversity conservation	Shannon-Wiener index ^a

Note: ^aA quantitative indicator to measure the richness of species in the ecosystem and the evenness of the distribution of species (Wang *et al.* 2008).

The divergence factor (D_n^i) for each of the n attributes is a ratio of an index of farm performance in achieving improvements in attribute (I_n^i) and the average index of all farms' performances ($\bar{I}_n$). The operation of the divergence factor requires the assumption that the mean index for each attribute n of the LUC bid proposals submitted corresponds to the regional average performance level. The divergence factor then positions each bid proposal relative to the regional performance R_n .

$$D_n^i = I_n^i / \bar{I}_n \quad (2)$$

The index I_n^i is a function of j farm-level parameters, X_j^i :

$$I_n^i = f(X_j^i) \quad (3)$$

Farm level parameters used in the functions to derive the performance indices and hence divergence factors are associated with site condition and the nominated LUC. The selection of parameters and the development of the biophysical models were based on site visits by scientists to the farms that were nominated for LUC by participants. Seven parameters were selected for the biophysical models, including land type before ecological restoration, slope gradient, thickness of soil, position of land slot on the slope, tree species, planting density and maintenance measures. Different parameters were chosen for the different environmental attributes, n , taking into consideration their contributions and biophysical links to each specific environmental attribute. The contribution of each parameter to the overall impact on environmental attributes is then modelled via the performance index I_n^i (Li *et al.* 2010).

To convert the environmental attribute predictions to monetary measures of benefits, several main parameters were used (see Table 2). First, there are the implicit prices (IP) for the environmental attributes estimated in the CM study. In particular, the IP for air quality represents the per household value estimates of urban households in Shanghai and Chengdu for one more day with good to excellent air quality per year. The IP for water quality shows the value for a reduction of 1 million tonnes of sediment discharge into the Yangtze River per year, and the IP for species gives the value of one more plant species being present as a result of the implementation of ecological restoration programme in China. These per household value estimates were then used to derive the aggregate value that urban households in Shanghai and Chengdu hold for the environmental changes generated by the proposed land management activities under the LUC auction.

Table 2. Main parameters used in environmental benefit estimation.

	Shanghai	Chengdu
IP for air quality (yuan ^a)	5.48	4.75
IP for water quality (yuan)	50.08	0
IP for species (yuan)	0.79	0.65
Urban population (million)	16.48	5.96
Household size (persons)	2.7	3.0
Extrapolation rate (%)	0.75	0.25

Note: ^a1 yuan is equal to US\$0.15.

The CM survey extrapolation rate is one of the key parameters used to estimate these aggregate values. The relatively low extrapolation rates recorded (less than 1% of the population) can be explained by a number of factors. First, response rates in stated preference surveys are sometimes low, because they involve scenarios that are unfamiliar to the respondents (Loomis 1987). Second, given that China's urban population has a relatively low income level,³ environmental goods and services are luxury goods to most urban households. Hence their interest in participating in a CM survey on environmental issues is limited. The derivation of the extrapolation rate for Shanghai is illustrated here. The survey was web-based and the sample was drawn from the panel of the survey company. In total there are 10 million people in Shanghai who have Internet access, and among them only 100,000 people (a fraction of 1%) were registered in the panel who indicate an interest in social surveys. Within the panel only 75% were interested in taking this specific CM survey. This gives an overall extrapolation rate of 0.75%.

The calculation of the environmental benefits generated by each bid is demonstrated in Equation 4:

$$V_n^i = IP_{n,sh} \times Q_n^i \times P_{sh}/HS_{sh} \times E_{sh} + IP_{n,cd} \times Q_n^i \times P_{cd}/HS_{cd} \times E_{cd}, \quad (4)$$

where V_n^i denotes the environmental benefits from attribute n , for farm i ,

IP_n is the implicit price for attribute n for Shanghai (sh) and Chengdu (cd),

Q_n^i is the quantity change for attribute n , for farm i ,

P is the population for Shanghai (sh) and Chengdu (cd),

HS is the household size in Shanghai (sh) and Chengdu (cd); and,

E is the extrapolation rate in Shanghai (sh) and Chengdu (cd).

As the soil erosion reduction model predicts the quantity of reduction in soil erosion for each bid, the IP derived from the CM study (i.e. IP for soil erosion reduction per tonne) can be used directly in Equation (4) to calculate the environmental benefits from water quality improvements. The calculation of environmental benefits from air quality improvement is based on a modified formula expressed in Equation (5). The IP for air quality represents the per household value estimates for one more day with good to excellent air quality per year. According to research conducted in Sichuan Province (Li 2009, personal communication), a total area of 1.2 million hectares (or 18 million mu) of afforestation across the province will bring about 35 more days with good to excellent air quality per year. Hence the quantity change for each farm can be expressed as:

$$Q_{AIR}^i = 35/1,200,000 * A^i * D_{AIR}^i \quad (5)$$

where A^i is the area of land use change on farm i , and

D_{AIR}^i is the divergence factor for farm i that differentiates the impact of farm i LUC activities on air quality improvements from the regional average.

The Q_{AIR}^i thus derived can then be used in Equation (4) to derive the environmental values for air quality improvement arising from LUC activities nominated in each bid.

The calculation of biodiversity benefits uses a similar approach. As the impact of individual farm level LUC on biodiversity will be minimal, it is not feasible for the

biophysical model to predict changes in species resulting from LUC activities at the farm level. Therefore, the approach taken is to apportion the likely impact on biodiversity of the overall change in land use over the project area amongst the participating farmers. Thus the average per mu impact on biodiversity is the total number of species gain – estimated at 30 – divided by the total number of mu involved in the LUC. This quantity change is then substituted into Equation 4 to derive the environmental values for biodiversity conservation achieved under each bid.

Bids were then ranked on the basis of their benefit-cost ratios, with the highest benefit-cost ratio providers of environmental goods and services being identified and selected for contract until the available government funding was exhausted. For further policy analysis, the total area of afforested land included in the LUC auction was also used as a proxy for the potential environmental benefits arising from the land use change achieved under the auction. The efficiency of the LUC auction was then assessed through a comparison of these potential environmental benefits with those achieved through direct government funding provided consistent with the current CCFGP system.

2.2. Case study

The auction was trialled in Sichuan Province, which covers a total area of 485,000 km² and has a population of 87.5 million. Sichuan Province is of agricultural and ecological significance in China. It is where the pilot phase of the CCFGP was implemented. In 2009, the Sichuan Government initiated a new ecological restoration programme. This three-year programme aimed to encourage local farmers to plant ecological trees on barren land, harvested sites, degraded arable land and sloped lands in the Province. The LUC auction was conducted for the implementation of the new ecological restoration programme.

Four villages in two counties in Sichuan Province were selected for the trial application of the LUC auction. In particular, bidding was conducted at the farm household level in Dishui and Zhongba villages of Pengzhou County and in Shunhe and Wenshan villages of Hongya County. The geographical location of these villages and the socio-economic characteristics of participating farmers are detailed in Xu *et al.* (2011). The insecurity of property rights and potential high transaction costs due to the small scale of the rural household economy in China suggest that the efficiency of the trial would have been improved if it had been conducted at the township or county level. Moreover, a random sample of counties and villages from Sichuan Province would have provided more representative results. However, concerns of local officials about the potential discontent of farmers arising from differential payment levels under the auction precluded this approach (Wang and Bennett 2009). Hence the trial application was conducted at a smaller scale in villages where farmers have more experience with the CCFGP.

Under the LUC auction, farm households were invited to submit proposals to carry out afforestation and related management activities during 2009–2012 on lands that were contracted to them from the village collective. An overall approach to afforestation and associated management activities was developed by local technical staff. This included the setting of standards such as tree species that could be selected, planting densities and times for maintenance to ensure the environmental values of the area would be protected. Within these overall settings, farm households were able to propose specific afforestation and management activities that best suited them.

Information sessions and the bidding process itself were conducted through villagers' meetings in the four pilot villages. Details of the auction, including pricing and enrolment rules, were provided to participants during the information sessions. The bidding documentation, including a form for proposed afforestation and management activities by the farmers and a bid form with cost information, was distributed to interested farmers. There was time for questions after these information sessions. The auction trial was then carried out immediately after the villagers' meetings in each village. Local technical staff and research team members were present during these sessions in case farmers needed further information on the technicalities of afforestation and management or on bid formulation.

Ideally, laboratory experiments should be conducted to test for key auction design issues relevant to the specific bidding programme before the trial takes place. However, due to time and resource constraints, this process was not possible and a simple single price auction design was implemented. Joint bidding was allowed to encourage households to share efforts where there was a shortage of labour in individual households. Table 3 shows the bidding characteristics.

Net benefits were estimated for each bid proposal. Bids that had a negative net benefit were discarded. The remaining bids were then ranked on the basis of their benefit-cost ratios and selected within the limit of the budget made available by the government for each village. An official notification letter was sent by the local governments to successful bidders specifying the time and venue for farmers to sign written contracts with the county forest bureaus. Farmers were required to bring their land lease contracts to prove that the period of their lease covered the whole project cycle from 2009–2012. This ensured that participating farmers had the necessary property rights to undertake the land contract and were responsible for decisions regarding the use of the specified lands.

Contracts were signed between the county forest bureaus and successful farm households in August 2009. Based on the contract, government payments are to be made in three instalments, with the second and third payments conditional on verification of compliance. This provides incentives for compliance for the duration of the contract. Initial payments were disbursed immediately after the contracts were signed to ensure that farmers could start planting in the autumn season. During the course of the contract, compliance was monitored by local forest bureaus with facilitation by the Sichuan Forestry Department.

Finally, the incentives structure for land improvement providers was analysed. A post-bidding survey was conducted to find out the key factors that affect farmers' decisions to participate in the auction. The key factors that may influence farmers' choices include their socio-economic conditions, experiences with previous CCFGP

Table 3. Auction characteristics.

Issue	Characteristics
Type of bidding	Single-round, sealed bid
Budget limit	Predetermined, concealed
Pricing rule	Discriminatory pricing
Activities contracted	Determined in advance and outlined in the afforestation and management plan
Reserve price	Not considered
Joint bids	Allowed

programmes, perceptions of the auction such as distrust and uncertainty about the scheme, and environmental attitudes. Issues of interest also included the influence of information dissemination on farmers' participation choices and the role of technical assistance from county forest bureaus. Whether farmers are able to develop their own bids was another issue to note during the bidding process. For example, while farmers may be able to develop a bid price for afforestation and management options, they may find the concept of quoting on the basis of their opportunity costs confusing. Based on these analyses, the feasibility of introducing the auction for land improvements activities in rural China is explored.

3. Results

The auction was conducted in July 2009. In each of the villages, the bidding lasted for half a day to one whole day. In one of the villages in Pengzhou, farm households submitted their bids immediately after the villagers' meeting. In other villages, farmers lodged their bids the next day. During the bidding sessions, farmers made minimal requests for assistance as they were relatively familiar with the type of activities that suited them best and with the estimation of the costs of such activities.

Table 4 provides summary statistics of participation in the LUC auction. A total of 364 bids were received from 303 farm households in the four pilot villages, covering a total land area of 5205.4 mu. There was a wide range of bids in terms of the land area nominated and the bid prices. Bid areas ranged from 0.5 mu to 280 mu, with bids ranging from 20 yuan (US\$3) per mu to 1500 yuan (US\$225) per mu. The total amount of these bids was 1.07 million yuan (US\$160,500).

As a first step in the analysis, the marginal cost (supply) curves arising from the auction in each of the four villages are shown in Figures 1 to 4. These illustrate the costs of securing LUC on an additional mu of land. As such, they do not measure environmental benefit on the horizontal axes but rather use area as an interim surrogate for the three attributes of environmental benefit. Thus the horizontal axis depicts the cumulative area of LUC supplied when the bids received are assembled in ascending unit cost order.

Table 4. Summary of the auction results.

	Hong Ya County		Peng Zhou County		Total/ average
	Caoyutan Township, Wenshan Village	Caoyutan Township, Shunhe Village	Cifeng Township, Dishui Village	Xiaoyudong Township, Zhongba Village	
Number of bidding households	79	66	90	68	303
Number of nominated sites	80	67	93	124	364
Total bid area (mu)	985	330.7	3226.5	663.2	5205.4
Total bid price (1000 yuan)	150.2	28	737.6	149.7	1065.5
Average bid price (yuan/ mu)	152.4	84.5	228.6	225.7	172.8
Successful bid area (mu)	985	330.7	1336	661.2	3312.9
Allocated funds (1000 yuan)	150.2	28	250.3	149.4	577.9
Minimum area nominated (mu)	1	0.5	1.0	0.5	NA
Maximum area nominated (mu)	35	30	280	50	NA
Minimum bid price (yuan/mu)	126	49.2	154	20	NA
Maximum bid price (yuan/mu)	315	210	324	1500	NA

Figure 1. Marginal cost curve for LUC land in Wenshan Village.

Figure 2. Marginal cost curve for LUC land in Shune Village.

These marginal cost curves show that across the four villages, the marginal costs of LUC land increase with the progressive expansion of LUC, with the subsidies required for more land to be converted under the LUC auction becoming higher and higher. The supply curve for environmental benefits in Wenshan Village is relatively flat over much of the area of land converted, with unit price ranging from 130 yuan to 160 yuan. The supply curve then becomes relatively inelastic as the cumulative area of LUC activities exceeds 900 mu. At this point the unit price required for the supply of an additional unit of LUC rises steeply. In Shunhe Village, the unit price remains below 100 yuan up to a cumulative LUC area of 300 mu. In Dishui Village in Pengzhou County, the supply curve remains flat until the cumulative LUC area reaches 600 mu, with the unit price ranging between 150 and 160 yuan per mu. The cost of an additional unit of LUC land then goes up steadily as more area is being included in the auction. In Zhongba Village in Pengzhou County, the unit cost

Figure 3. Marginal cost curve for LUC land in Dishui Village.

Figure 4. Marginal cost curve for LUC land in Zhongba Village.

for LUC remains under 400 yuan per mu until the cumulative LUC area reaches 630 mu. Thereafter, the price for an additional unit of LUC land increases rapidly.

Some initial conclusions can be drawn from these supply curves. First, the cost for the provision of LUC land is higher in Pengzhou County compared to that in Hongya County in general. If government funds are to be allocated across the counties in Sichuan Province, then Hongya County should be favoured over Pengzhou County if land area is a successful proxy for environmental benefit on the basis of economic efficiency, at least for the levels of LUC considered in this trial. Second, the slopes of the marginal cost curves for the provision of LUC land in the pilot villages suggest that setting a fixed price payment would be inefficient.

This analysis of marginal costs of provision is based on land as the unit of supply. Missing from that analysis is recognition of variations in the environmental benefits

provided by different areas of land. This requires the integration of benefit values alongside the cost information through the estimation of benefit-cost ratios for each bid. Table 5 provides an overview of the variations in farm level environmental performance in the case study villages. It gives the range of the performance index for each environmental attribute that is estimated with farm level parameters associated with site condition and the nominated LUC.

Almost all the bid proposals have benefit-cost ratios greater than 1.0 (see Table 6), implying that community well-being would be enhanced by funding the nominated activities outlined in the bids. In three of the pilot villages – the exception being Dishui Village in Pengzhou County – almost all submitted bids⁴ were successful as the bid total in each village was within the government budget limit. In Dishui Village of Pengzhou County where the total bid area was larger (approximately 3226.5 mu), only 1336 mu of land use change was funded from the limited government budget allocated for ecological restoration. This amounts to 50 successful bids, out of the 93 bids collected from this village. Across the four villages, a total of 320 of these bid proposals were allocated contracts. This means that 3312.9 mu of land will be afforded and managed under the scheme at a cost of 577,900 yuan across the four villages over a three-year period from 2009 to 2012.

Figure 5 shows the benefit-cost ratios of all the nominated bids across the four pilot villages. The benefit-cost ratios vary the most in Zhongba Village, with the lowest ratio being less than 1.0 while the highest was 48.6. Variation is also evident in Shunhe Village, while less so in both Dishui and Wenshan villages. Theory suggests that the greater the heterogeneity in the costs and benefits of the landholders, the greater are the potential gains from introducing trade relative to a uniform subsidy. This indicates that the greatest potential for efficiency gains is in Zhongba Village, followed by Shunhe Village where heterogeneity across bidding households is also significant. Even though most bids were accepted, efficiency gains from the auction

Table 5. Environmental performance indices of bids.

Index		Dishui Village	Zhongba Village	Shunhe Village	Wenshan Village
Soil erosion index	Highest	1.27	1.28	1.04	1.10
	Lowest	0.67	0.72	0.95	0.79
Air purification index	Highest	1.25	1.27	1.03	1.16
	Lowest	0.74	0.7	0.97	0.64
Biodiversity index	Highest	1.36	1.37	1.00	1.19
	Lowest	0.68	0.74	1.00	0.78

Notes: The biodiversity index in Shunhe is identical across all bids due to the same species, land type before planting, planting density and times of maintenance nominated in the bids.

Table 6. Benefit-cost ratio of bids.

	Wenshan Village	Shunhe Village	Dishui Village	Zhongba Village
Highest BC ratio	9.7	22.4	8.3	48.6
Lowest BC ratio	2.8	5.2	2.9	0.6
Average BC ratio	7.2	11.6	5.1	5.7
Coefficient of variation	0.24	0.33	0.27	0.80

relative to a fixed payment arrangement are experienced through the lower overall costs of achieving more targeted environmental improvements.

The analysis to this point has assumed that the activities proposed in farmers' bids will have a 100% success rate in producing the predicted environmental benefits. A sensitivity analysis was conducted to determine the impact on the benefit-cost ratios of the various factors that may affect this success rate. These factors include the survival rate of plantings, the extent of maintenance after the three-year project period, and weather conditions that may increase the risks of forest fires and pests, as well as growth rates. The probability of successful delivery of environmental improvements resulting from land use change was assumed to vary between 50% and 75%. Table 7 shows that across this range of probabilities, the benefit-cost ratios of bid proposals across Wenshan, Shunhe and Dishui villages are still greater than 1.0. However, there are five bids in Zhongba Village that would produce benefit-cost ratios lower than 1.0 if the probability of success was 50%. This number drops to two when the probability of success rises to 75%.

Apart from Dishui Village bids, most farmers were allocated contracts, with benefit-cost ratios ranging from 48.6 to 1.3. However, only 50 out of the 93 bid proposals from Dishui Village farmers were funded, not because of benefit-cost ratios less than one but due to government budget constraints. The lowest benefit-

Figure 5. Benefit-cost ratios of bids across the pilot villages. (Colour version online.)

Table 7. Sensitivity analysis of benefit-cost (BC) ratio.

		Wenshan Village	Shunhe Village	Dishui Village	Zhongba Village
50%	Highest BC ratio	4.8	11.2	4.2	24.3
	Lowest BC ratio	1.4	2.6	1.5	0.3
	Average BC ratio	3.6	5.8	2.5	2.8
75%	Highest BC ratio	7.3	16.8	6.2	36.5
	Lowest BC ratio	2.1	3.9	2.2	0.4
	Average BC ratio	5.4	8.7	3.8	4.2

cost ratio of the selected bid proposal in Dishui was approximately 4.6. This indicates that there is greater cost saving potential if government funds could be re-allocated between townships or even counties to take further advantage of differentials in benefit-cost ratios between household level bids. More bid proposals would have been selected in Dishui Village if bid proposals were selected at the county or provincial level.

In addition, the method employed allows for the testing of sensitivity to variations in the parameters that populate the biophysical models. Testing in the LUC context showed that reasonable variations in these parameters did not impact the funding decisions.

4. Discussion

4.1. Cost-effectiveness

The cost-effectiveness of the LUC auction is assessed by comparing the outcomes of the scheme with those that would have been achieved under the fixed payment arrangements of the CCFGP. A strict counterfactual comparison between the two schemes cannot be made, as the different selection processes used in the two schemes would result in different land plots being accepted with different afforestation and management activities. However, a comparison can be made of the amount of government spending under the LUC auction with that which would have been allocated under the fixed payment CCFGP to achieve the same area of afforestation and associated management activities, ignoring the diversity of outcomes that may come from any given area of land. It can be argued that the LUC auction will perform better than the CCFGP in terms of environmental performance. Bid proposals under the auction were ranked and selected based on their benefit-cost ratios that embody a biophysical model that relates activity to environmental performance. This ensures that environmental improvements are specifically targeted. This can be contrasted with the CCFGP approach which is based more on the views and opinions of local officials who may be involved in rent-seeking behaviour. The expected environmental outperformance of the LUC auction implies that the cost saving potential of the scheme is rather conservative using the above approach which takes into account only the cost aspects of the two schemes.

As Table 8 shows, it costs 577,900 yuan under the LUC auction to carry out afforestation and management activities on 3312.9 mu of land in the pilot villages. If the same area had been submitted under the CCFGP it would have cost 662,500 yuan. This is a 15% cost premium for the fixed payment scheme compared to the

Table 8. Cost saving potential of the LUC auction.

	Wenshan Village	Shunhe Village	Dishui Village	Zhongba Village	Total/ average
Successful bid area (mu)	985	330.7	1336	661.2	3312.9
Allocated funds under LUC scheme (1000 yuan)	150.2	28	250.3	149.4	577.9
Allocated funds under CCFGP (1000 yuan)	197.0	66.1	267.2	132.2	662.5
Cost saving (1000 yuan)	46.8	38.1	16.9	−17.2	84.6

auction. The overall bidding payment represented an average cost of 172.8 yuan per mu, compared with a fixed cost of 200 yuan per mu under the CCFGP scheme.

The negative cost saving shown for Zhongba Village in Table 8 arises because the availability of funds meant that bid proposals with relatively low benefit-cost ratios were selected and allocated contracts.⁵ This occurred because the total area covered by bid proposals was much smaller than expected. Hence the authorities in the pilot villages (except Dishui Village) did not set any limit to their budget. All bids were accepted. This undermines the potential gain of the auction across the pilot villages. This is especially the case for Zhongba Village, where the sensitivity analysis shows that a 50% probability of successful delivery of environmental outcomes would result in five bids having benefit-cost ratios lower than one.

The cost saving potential of the auction is also reduced by the bid proposals being submitted at the farm household level. The auction could have been carried out at the village, township or county level. This may have reduced the transaction costs of the auction and increased the heterogeneity of environmental benefits across the bid proposals. Because of the small scale of rural households, land plots in the same villages have similar physical conditions such as topography, climate and tree species suitable for planting in the area. These may differ more across different villages, townships and counties. However, concerns amongst local officials regarding the need for sub-contracts between the higher aggregation unit (village, township etc.) and the individual farm households responsible for implementing the proposals precluded the use of this approach. Transaction costs may have been increased. The prospect of discontent amongst the farmers because of differential payment levels under the auction was another concern of local officials (Wang and Bennett 2009).

The implementation of the auction at the farm household level did increase transaction costs compared to the existing CCFGP according to officials from Sichuan Department of Forestry and county forest bureaus. The institutional structure used to administer this auction spreads across three levels of government:

- provincial government (Sichuan Department of Forestry) to co-ordinate the auction and provide overall guidance;
- local government (county forest bureaus) to organise various activities under the scheme and co-ordinate funding; and,
- village committee to implement the bidding activities at the field level.

There were also a number of technical extension support groups involved at these levels. This implies that it may be difficult to co-ordinate changes in mechanisms across a complex institutional structure. Because of the low level of knowledge and understanding of the mechanism among the local officials, there were extra costs incurred in assisting them to design, develop and implement the auction, and in assisting landholders formulate their proposals. High transaction costs also include applying the biophysical model, collecting biophysical data, organising village meetings for information dissemination, etc. It is estimated that transaction costs for the auction are one-third higher than the administrative costs associated with the afforestation under the CCFGP. Hence, the magnitude of the cost saving potential of the auction will not be as significant if the potentially higher transaction costs are taken into account.

However, studies show that once the initial costs of design had been incurred, the operational costs of running a tender are similar to those of a grant scheme (Bryan

et al. 2005, Gole *et al.* 2005). The skills and knowledge obtained from this auction would considerably reduce the cost of implementing another auction in the region, especially if the focus remains on afforestation and associated management activities for the purpose of ecological restoration. Officials from Sichuan Department of Forestry and local forest bureaus also confirmed that the transaction costs of the auction are likely to fall with further implementation similar to the pattern of transaction costs witnessed at the beginning phase of the CCFGP. They believed that once the start-up administrative costs of the new mechanism have been incurred, it would be easier for a future similar auction to be implemented. The initial scheme has helped to build up local knowledge and capacity. Participating farm households considered that their transaction costs were also higher under the auction compared to the CCFGP, but they also said that the initial phase of the CCFGP was as difficult as the initial phase of auction. In addition, the scale of the current auction is small, so the increase in transaction costs for the improvements in capital efficiency appears higher. With the expansion of the auction, the increase in transaction costs may no longer be significant.

4.2. Feasibility

Information gathered from the post-bidding survey provides some insights into the feasibility of implementing LUC auctions in China. The post-bidding survey covered 194 farm households, of which 152 households were bidders and 42 households did not participate in the auction. Survey results show that the auction was well accepted by farmers in the pilot area. Almost all participating farmers expressed their willingness to participate in future auctions. Among the surveyed participants, 97% indicated that they participated on a voluntary basis. Only 3% of participants were asked by their village leaders to participate in the auction. Farmers participated for three main reasons. First, barren lands can be utilised under the auction while only degraded cultivation lands are eligible under the CCFGP. This will bring additional income to the farmers. Most of surveyed participants believe that their lands are better suited to growing trees rather than crops. Second, almost half (45%) of surveyed participants believed that the subsidy under the auction would be higher than under the CCFGP. Third, some farmers consider that more technical assistance would be available under the auction. A small number (approximately 11%) participated for other reasons; including environmental conservation, sustainable land management and increasing their income levels. Most participating farmers were able to develop their bids by themselves, with only 28% receiving assistance to complete the bidding form from the village head or technical staff.

For those surveyed non-participants, almost all of them were willing to participate in the auction. They did not participate for various reasons. Among these non-participants, 26% were unaware of the auction. Other reasons for non-participation include that their lands were not suitable for forests, none of their lands were available for the auction, lack of labour force in the households and a combination of other reasons such as concerns about not having convenient transportation. The lack of information about the auction indicates problems associated with information dissemination during its implementation. More effort should be devoted to project publicity so that everyone who is eligible is aware of any future LUC auction.

The potential for social disputes to arise from different payment levels was explored during the post-bidding survey to address the concern of local officials. Survey results showed that 82% of the successful participants who compared payments with other successful landholders did not care if other landholders received higher payments through the bidding process, as they appreciated that each landholder had different costs. This demonstrates that even though China has long been an egalitarian society in which farmers share the costs and benefits of agricultural production on an equal basis, farmers' perceptions and attitudes are changing as China moves to a more market-oriented open economy. On the basis of this finding, it is possible to scale up the auction to expand it to a wider area in Sichuan Province. To potentially reduce transaction costs and ensure greater heterogeneity across bids, future auctions could be conducted so that budget allocation occurs at the village, township or county level.

The long-term provision of the environmental services generated through the LUC contracts under the auction is of concern, given that the term of these conservation contracts is only three years. Two-thirds of the surveyed participants confirmed that the bids they put forward reflected the costs they would incur during the first three years following plantation as stated in the contract. Only 21% of participants were informed of avenues for accessing additional financial support from other sources following the expiration of the three-year contract. These findings present a challenge to the long-term sustainability of afforestation and associated management activities achieved under the auction. Continuous efforts and inputs will be required to maintain the forests established under the scheme. It is therefore of policy significance to relate the contracts signed for the auction to other preferential forest policies such as the Forest Ecological Compensation Programme to protect long-term environmental gains.

The anchoring effects discussed in the reserve price literature (Reichelderfer and Boggess 1988) can limit the efficiency gains from conservation auctions as bidders act strategically instead of revealing their true costs in their bid proposals. This potential problem was explored in the context of the auction. According to the survey results, almost all the participants (99%) surveyed had previous experience with the CCFGP. More than half of them referred to the subsidy level provided through the CCFGP when formulating their bid price under the LUC auction and submitted bids that were higher than the subsidies they received from the CCFGP. Other bids offset these higher than CCFGP subsidy bids. Approximately 90% of participants considered input costs for production when formulating the bids, 34% considered labour costs, and 31% further considered foregone income sources. Future LUC auctions in China need to be designed in such a way to allow for the testing of anchoring bias and to minimise this potential bias.

5. Conclusions

Even though conservation auctions have already been piloted and conducted in a number of countries for the past decade, experiences are rare in developing countries. The LUC auction presented in this paper is one of the first pilots to be conducted in a developing country context. Results show that an auction can be both practically feasible and efficient in China. There is potential to increase the efficiency gains of government funding in ecological restoration through a competitive bidding process. Cost benefit analysis of each bid shows that almost all the bid proposals result in a

positive net social benefit, indicating the efficiency of the auction. Further, a comparison between the LUC auction and the fixed payment CCFGP revealed that the auction is at least 15% more cost-effective than the CCFGP. However, if differential transaction costs are factored in, this potential gain may not be as large.

The potential efficiency gain and the implications of the transaction costs involved need to be interpreted with caution. The magnitude of the cost saving potential of the auction is limited by the small geographical coverage of the pilot project. As bid proposals were submitted and selected at the village level under the bidding trial in four villages across two counties in Sichuan Province, there was a lack of heterogeneity across the land plots included. This undermines the potential efficiency gains available from a competitive bidding mechanism. The small scale of farm land involved also increased the per unit transaction costs. This indicates that future LUC auctions could be designed and implemented at a larger scale to enable a wider variety of land types and land management and conservation activities in order to ensure heterogeneity across bid proposals. Transaction costs may also be reduced if bids were proposed at the village, township or county level instead of at farm household level. Furthermore, the post-bidding survey results show that farmers perceived little difference in their costs of involvement with the auction compared with the CCFGP, and the design and development costs will decline in future applications.

An expansion of the auction looks to be feasible. At the inception of the LUC auction, local officials indicated concerns about the social disputes that might arise due to differential payments being made under the auction. Hence the bidding approach was piloted on a small scale. The post-bidding survey results show that the auction was well received by local farmers and almost all surveyed participants believed that they would participate in future applications. The majority of participating farmers were aware of the different subsidy levels they received under the auction, but did not mind the difference as they appreciated that different costs were experienced by different landholders with different projects. This finding provides further assurance to local officials that social conflict will not be an issue if the auction is expanded to a larger scale.

In addition to its cost saving potential and superior environmental targeting, the auction was found to bring a number of indirect social benefits. These included local capacity for officials, technicians and farmers building up the trust between officials and farmers; increased environmental awareness of local farmers; and more decision-making power being given to local farmers in land use management. Finally, the auction needs to be tested in a variety of landscapes and institutional settings before it can be widely applied in China. Issues that need to be addressed in future applications include better project publicity and information dissemination; building long-term incentives into the contract design; and the minimisation of potential anchoring effects in bidding design.

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Notes

1. The environmental attributes were also used in the choice modelling valuation exercise. In this way, the biophysical model is linked to the bid evaluation stage.
2. One mu is equivalent to 0.067 hectares.
3. The average disposable income is 28,838 yuan (USD 4325.7) in Shanghai and 18,659 yuan (USD 2798.9) in Chengdu (Shanghai Statistics Bureau 2010, Chengdu Statistics Bureau 2010).
4. One bid in Zhongba Village had a benefit-cost ratio of less than 1.0 and so was excluded.
5. Note that the existence of a negative cost saving does not necessarily imply that the CCFGP scheme is more economically efficient. The environmental benefits secured by the better targeted LUC scheme may outweigh its cost disadvantage.

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