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Costing biodiversity protection: payments for environmental services schemes in Lao PDR

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ABSTRACT

A Payments for Environmental Services (PES) scheme that involves setting a 'pseudo market price' requires the estimation of demand and supply. This paper presents the estimated marginal costs of anti-poaching patrols designed to enhance biodiversity in two protected areas in Lao PDR. This supply information was used in conjunction with environmental production functions and estimated demand for biodiversity to determine the 'price' paid per patrol. Marginal costs were estimated through uniform-price conservation actions: Teams of local people interested in being part of the PES scheme bid for the number of patrols they would like to provide in response to a range of offered prices. The auction process generated a sequence of well-behaved price-quantity pairs that track the individual marginal cost function of each bidding team accounting for both fixed and variable costs. The marginal costs vary across bidders. These variations can be explained by differences in competing employment and income opportunities across bidders, village locations and seasons. The results provide evidence of heterogeneous opportunity costs of supply and suggest an efficiency loss in assuming homogeneity.

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Anti-poaching patrols; biodiversity protection; conservation auction; marginal cost of supply; payments for environmental services schemes

1. Introduction

Payment for Environmental Services (PES) schemes have been implemented globally with the aim of increasing the supply of environmental services that are undersupplied by markets. PES schemes aim to link prospective suppliers of these environmental services with their potential buyers. The establishment of such a link requires information on supply and demand. The application of conservation auctions[1]. (Vickrey 1961; Vickrey 1962; Engelbrecht-Wiggans 1980; Holt 1980; McAfee and McMillan 1987; Kagel and Roth 1995; Latacz-Lohmann and van der Hamsvoort 1997; Latacz-Lohmann and van der Hamsvoort 1998; Klemperer 1999) is a well-established method of generating the requisite data on the marginal costs of environmental service supply. Two features characterise applications of the conservation auction method. First, in a typical single-round, sealed-bid conservation auction each potential supplier submits a single bid concealed to their competitors. The bids specify the quantity of supply actions that each participant is willing to perform (or environmental services they each are willing to supply) and the extent of the payment they each expect in exchange. In other words, each bidder is requested to choose both quantity and price. Second, typical conservation auctions use a 'paid-as-bid' rule: That is, the amount paid to each bidder selected under the auction to become a supplier is set at the level of their individual bids.

Both of these features act as obstacles to the use of the conservation auction method. The requirement for bidders to specify both price and quantity presents a quandary for them: without a

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specified price (or quantity) it is impossible for bidders to choose the quantity (or price) that maximises their producer surplus. Not even a monopolist has the power to choose both price received and quantity supplied. Bidders therefore find it difficult to answer the question asked in a typical conservation auction. Furthermore the 'paid-as-bid' rule means that the producer surplus is zero for any chosen price-quantity combination. The potential gains to bidders are limited to informational rents (Ferraro 2008)[2] and indirect benefits enjoyed (for example, benefits enjoyed personally from environmental improvements supplied). As a result, the surplus generated through the provision of supply actions (or environmental services) is enjoyed almost entirely by the buyers. Without the opportunity of securing a producer surplus, the incentives for participation rely on the opportunity to secure informational rent and indirect benefits. Low participation rates in conservation auctions (for example, Whitten et al. 2013; and Rolfe 2016) might be explained by this absence of incentive. Equally limited are the incentives for dynamic innovation. Without effective incentives in place, the potential for productivity improvements in environmental service supply over time through repeated auctions can be expected to remain unutilized. Distributing the entire surplus to the buyers raises questions of fairness and equity. Equity and fairness are of concern especially in countries where the potential environmental service suppliers belong to the poorest segments of society (for example, Martínez-Alier 2004; Muradian et al. 2010; Pascual et al. 2010, and Vatn 2010).

A further issue faced by typical conservation auction applications is the manner in which market supply curves are estimated. In 'paid-as-bid' conservation auctions, individual price bids (and associated informational rents) are interpreted by the analyst as the suppliers' individual marginal costs for the quantity increase they specify (for example, EcoTender reviewed by Eigenraam et al. 2005; CCFGP extension by Wang et al. 2012). The 'market' supply curve is constructed by an ordered compilation of the suppliers' individual bids, starting with the lowest marginal cost bid. The marginal unit is the change in additional quantity and the associated marginal costs of each additional supplier are added to form the 'market' supply curve. This contradicts the approach used in markets where market supply curves are represented by the horizontal sum of the marginal cost curves of individual suppliers.

This paper provides the results of the application of conservation auctions that were designed in accord with the principles set out by (Scheufele and Bennett 2017a) that addresses these challenges. The estimated marginal supply costs were used to inform the design and implementation of two pilot PES schemes that aim to supply wildlife protection actions to reduce biodiversity loss in Lao PDR (Scheufele, Bennett, and Kyophilavong 2017). The conservation auctions were conducted in 2016 and both schemes were initiated in December 2017. The remainder of this paper is structured as follows. Section 2 sets out the context of the two pilot PES schemes and provides an overview of the wildlife protection actions performed by suppliers. Section 3 details the methods used to estimate the marginal costs of supply. This section provides information on the conservation auction design and associated rules as well as the processes developed to aggregate over cost components and individual suppliers to estimate market supply. Section 4 then presents the results and discusses the challenges encountered. Section 5 closes with some conclusions.

2. Application

The first pilot PES scheme (PES-1) focusses on reducing biodiversity loss through the supply of wildlife protection actions in the Phou Chomvoy Provincial Protected Area (PCPPA). The PCPPA, located on the border with Vietnam within Bolikhamxay Province, covers about 22,300 hectares. It is part of the Northern Annamite Ranges, which is considered a biodiversity hotspot (Duckworth 1998). The restrictions on the use of wildlife resources within the PCPPA (stipulated by Lao PDR statutory legislation and customary laws) are not enforced and therefore ineffective. The PES scheme focusses on the protection of 19 wildlife species that are classified as Endangered or Critically Endangered (IUCN 2016). The wildlife protection actions are performed by residents of eight villages that are located in close proximity to the boundary of the PCPPA. Education levels in these

villages are generally low. Income and employment opportunities outside the agricultural sector are limited. The villagers are predominantly subsistence farmers. They produce crops (96% of households), vegetables and fruits (72%), and livestock (92%). Non-timber forest products are collected by 61% of the households, 36% of households hunt wildlife. Some households are engaged in handicraft production (32%), hired labour (38%), government employment (21%), private employment (8%), and other livelihood activities (13%). The annual cash income from farming and non-farming livelihood activities is about LAK 20,200,000 per average household[3], which comprises about seven individuals. The cash income is secured through livestock sales (23%), crop sales (25%), and government employment (19%). The contribution of any other livelihood activity is nine percent or less. Cash income varies within and across villages. One driver for the differences across villages is likely to be their relative distance to roads and thus access to markets[4].

The second pilot PES scheme (PES-2) focusses on reducing biodiversity loss through the supply of wildlife protection actions in the Green Peafowl Species Conservation Zone (GPSCZ). The GPSCZ is located in Vientiane Capital Province. The GPSCZ is part of the Phou Khao Khouay National Protected Area and covers about 8,000 hectares. It provides one of the last habitats in South-East Asia for the Green Peafowl (pavo muticus), classified as Critically Endangered (IUCN 2016). The restrictions on the use of wildlife and forest resources within the GPSCZ (stipulated by Lao PDR statutory legislation and customary laws) are not enforced sufficiently to be effective. In contrast to PES-1 that focusses on a range of wildlife species, PES-2 aims to protect a single wildlife species. Green Peafowl protection actions are performed by residents of six villages that are located south of the GPSCZ. Education levels in these villages are higher than in PES-1. Income and employment opportunities outside the agricultural sector are less limited than in PES-1. Most of the households engage in subsistence farming producing crops (82%), vegetables and fruits (68%), and livestock (89%). Non-timber forest products are collected by 67% of the households, 18% of the households hunt wildlife. Some households are engaged in handicraft production (29%), hired labour (53%), government employment (23%), private employment (17%), and other livelihood activities (26%). The annual cash income from farming and non-farming livelihood activities is about LAK 23,800,000[5]. per average household[6]. Cash income is secured through government employment (25%), private employment (15%), handicraft production (15%), and hired labour (11%). The contribution of any other livelihood activity is nine percent or less[7].

Individual villagers (including members of the village militia) have been contracted as supplier teams to perform anti-poaching patrols. The patrol contracts set out, among other things, the tasks they agreed to perform and the benefits they receive in return. The tasks are grouped into wildlife monitoring and law enforcement activities. The latter include, for example, the recording of poaching incidents, the confiscation of poaching gear, the issuing of warnings, the dismantling of poacher camps, and the removal of snare lines. Snare lines kill indiscriminately any ground dwelling wildlife species as long as they are installed. Their removal is a priority. The anti-poaching patrol effort of the teams is accompanied by community engagement, which is formalised through community action plans and community conservation agreements. The communities receive payments into their village development funds and recognition in return for supporting the anti-poaching patrolling scheme and protecting wildlife[8][9]. Supplier participation is voluntary in both schemes. All contracts, plans and agreements were developed with the communities through a process of consultation and negotiation. A core feature of both schemes is an impartial, accessible and fair mechanism for grievance, conflict resolution and redress (UN-REDD 2013). The mechanism is specified within the patrol contracts and community conservation agreements.

3. Methods

Sealed bid, single round conservation auctions were used to elicit the marginal costs of supply[10]. Potential supplier teams were invited to bid for three-year Patrol Contracts. The auctions were open to any team that met a set of basic eligibility criteria. These included a specified team size and

'Busy' season		'Quiet' season	
Price per patrol per team (US$)	Number of patrols per team per year	Price per patrol per team (US$)	Number of patrols per team per year
171	*0*	171	*2*
257	*1*	257	*4*
342	*3*	342	*6*
428	*4*	428	*8*
514	*5*	514	*9*
599	*6*	599	*10*

Figure 1. Example bidding forms (PCPPA).

composition as well as the ability of each team member to perform anti-poaching patrols. At least two members of each team had to be able to read and write.

The marginal costs of supply were estimated through an auction format based on that used in the Regional Greenhouse Gas Initiative (Regional Greenhouse Gas Initiative 2017) and the California Carbon Auctions (Carbon Credit Capital 2017). In these auctions, each bidder is required to submit a sequence of price-quantity pairs stating the amount of pollution permits they are willing to buy over a self-selected range of prices per permit (Lopomo et al. 2011).

This auction format was adjusted such that participants only had to state quantities, against a set of prices pre-specified by the auctioneer. Each team was requested to submit a bid that stated the number of patrols they would be willing to perform per year (for three years) against a sequence of six pre-specified prices per patrol (Figure 1). This allowed bidders to make clear uncomplicated choices of quantity only, as opposed to the price and quantity choices required in conservation auction formats used to date.

The obtained sequences of price-quantity pairs represent the marginal costs of patrolling at the team level. While the price range was the same for all teams, the number of patrols for each price was expected to differ across bids given teams' opportunity cost heterogeneity. Information gained through the consultation process suggested that the opportunity costs of potential suppliers would differ across the year. The opportunity costs were expected to be higher during the rice planting and harvesting seasons (four months) than during the rest of the year (eight months). This paper refers to the former as 'busy' season and to the latter as 'quiet' season. To account for potential differences, each team was asked to submit one bid for each season. This approach generated two marginal cost curves per team representing the marginal costs of patrol team employment. The format of these curves was well suited to the process of aggregating quantities offered across suppliers at the given price points to estimate market supply.

The auction applied a uniform pricing rule. The bidding teams were told that the price paid per patrol would be one of the six pre-specified prices[11]. The pricing rule stated further that each team would be offered the number of patrols they each bid at that price[12]. Supplier engagement is thus based on a self-selecting process. In addition, bidders could readily understand that the price they received could be in excess of the costs of their actions, thus allowing them to earn producer surpluses. Hence there was a clear incentive to participate in the auction.

The bidding teams were trained to factor all the costs associated with performing anti-poaching patrols into their bids. This includes any transaction costs, such as the costs of bidding. Transaction cost might therefore be included implicitly in the team bids, and therefore in their annual cost of patrolling. The benefits offered to potential suppliers included both monetary and non-monetary components[13]. Additional to the patrol payments offered in the bid sequence, patrol teams were promised bonus payments for removing snare lines and dismantling poacher camps[14], payments to travel to the protected area and back home, health and accident insurance covering patrolling activities, and social recognition. Teams were told that all of the equipment (but not food) required to perform the patrols would be provided through the scheme. Patrol teams might have factored these additional benefits into their bids, partially offsetting their costs.

The marginal costs of patrol team employment estimated at the team level were added horizontally to construct 'busy' season and 'quiet' season 'market' supply curves. Given the pre-specified price levels, 'market' supply is represented by discontinuous step functions.

Some of the costs of the anti-poaching patrol scheme were not included in the conservation auctions (henceforth called 'external costs'). They include the costs of employing a patrol manager to ensure each schemes' functionality, the costs of the bonus payments for removing snare lines and poacher camps, the costs of payments to village development funds, the cost of purchasing insurance, and the costs of purchasing equipment. A lack of access to markets as well as limited expertise meant that it was not feasible to ask the teams to include the costs of insurance and patrol equipment into their bids. The bonus payments, the variable component of the payments to the village development fund, and the patrol managers' salaries are paid directly through the scheme and were likewise not included in the conservation auctions. The costs of insurance, patrol equipment and employment of patrol a manager were estimated using market prices[15]. The costs estimations of the bonus payments[16] and the payments to the village development funds were based on expert opinion. The payments to the village development funds consist of a fixed and variable component[17]. The variable component is linked to the patrol effort associated with each village. It is calculated as 5percent (PES-1) and 10% (PES-2) of the patrol team payments (excluding bonus payments). The number of teams each village supports and their level of effort thus determines the extent of the variable village payments. The complete cost structure is visualised in Figure 2.

The marginal unit differs across the different components of the cost structure. The costs of patrol team employment, bonus payments, and the variable component of the payments to the village development funds were estimated as a cost 'per patrol'. The costs of insurance and the equipment issued to each team were calculated on a 'per team' basis, whereas the costs of the equipment shared among teams within each village were determined as a cost 'per village'. The costs incurred through the employment of the patrol manager were calculated on a 'per scheme' basis. The costs of insurance, equipment and patrol manager employment calculated for the three year contract term were averaged per year[18] and distributed across the 'busy' and the 'quiet' season in proportion to their respective duration.

The external costs were added to the market supply curves of each season[19]. This was straightforward for the costs of the bonus payments and the variable payments to the village development funds, both estimated as marginal costs per patrol. Adding the costs of insurance, equipment and

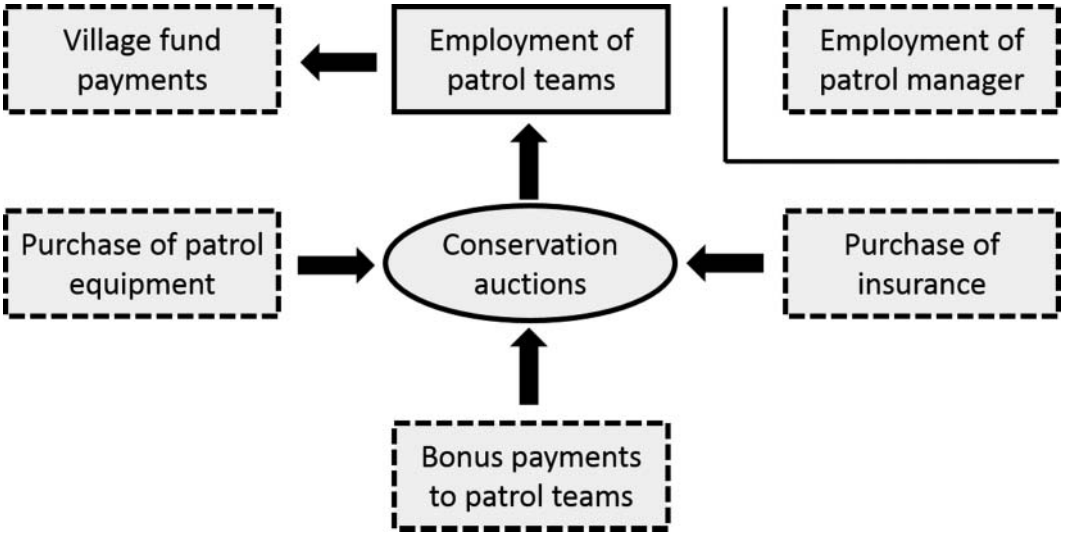

Figure 2. Cost structure.

the patrol manager required transforming marginal cost per team and marginal cost per village into marginal cost 'per patrol'. For the costs originally calculated on a 'per team' basis, this was achieved by dividing the total costs of all additional teams at each price level by the total number of patrols employed at the corresponding price level. The same approach was followed for the costs originally calculated on a 'per village' basis. Using average costs within a price level to represent marginal costs is justified due to the pricing rule of the auction format: each team was offered the number of patrols they said they would be willing to perform at the determined price[20]. A special case involved the costs of employing the patrol manager. Since the patrol manager had to be employed regardless of the number of teams engaged, the marginal costs per patrol (calculated as average costs) were added exclusively to the first price level[21].

4. Results

4.1. PES-1 (Phou Chomvoy Provincial Protected Area)

In total, 55 teams from all eight target villages submitted valid bids. As shown in Figure 3, the number of teams that participated in the auction differed across villages.

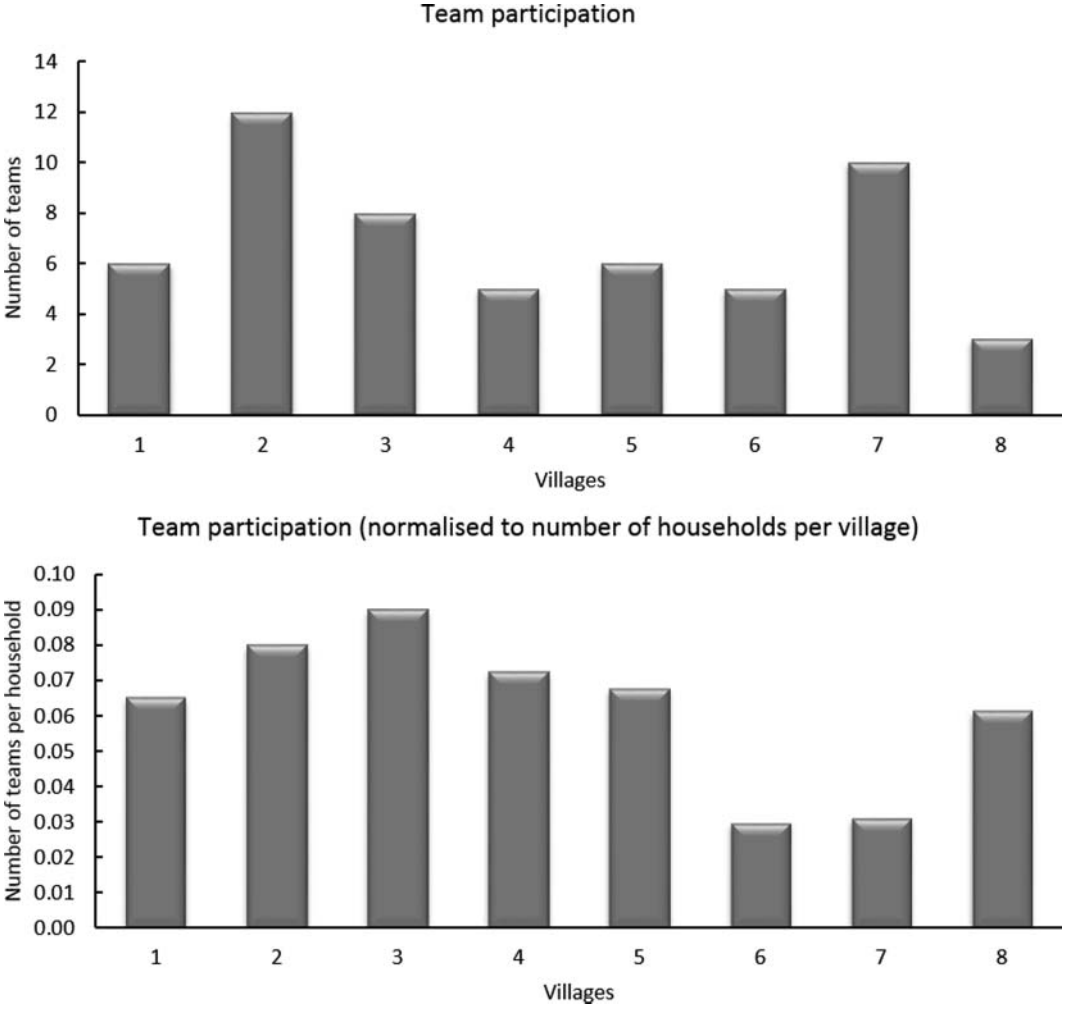

Figure 3. Team participation by village.

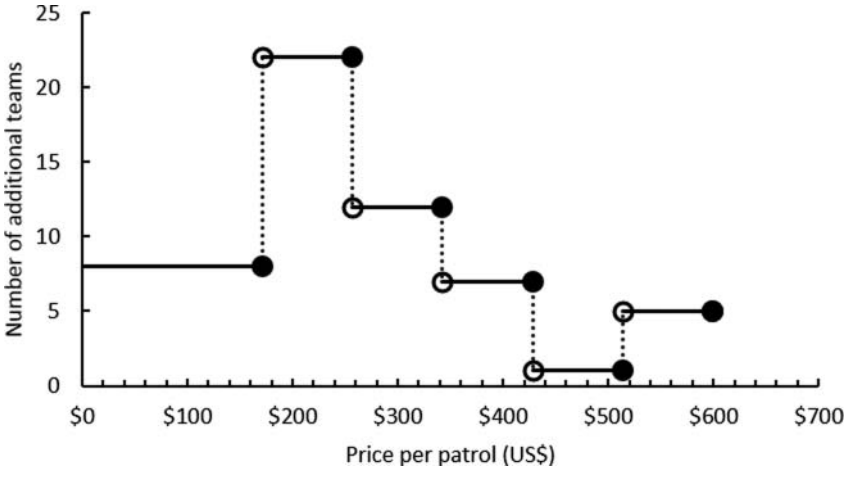

Figure 4. Team participation by price level[23].

The number of additional teams that entered the bidding at each price level is illustrated in Figure 4. The number of additional teams first increased and then decreased with an increasing price per patrol.

The data suggest that the marginal (opportunity) costs are heterogeneous within and across villages. This is illustrated by a sample of team level marginal cost curves (Figure 5).

The marginal costs of patrol team employment at the market level are illustrated in Figure 6. The teams' opportunity costs are higher during the 'busy' season than during the 'quiet' season for the first four price levels. This trend is reversed for the last two price levels.

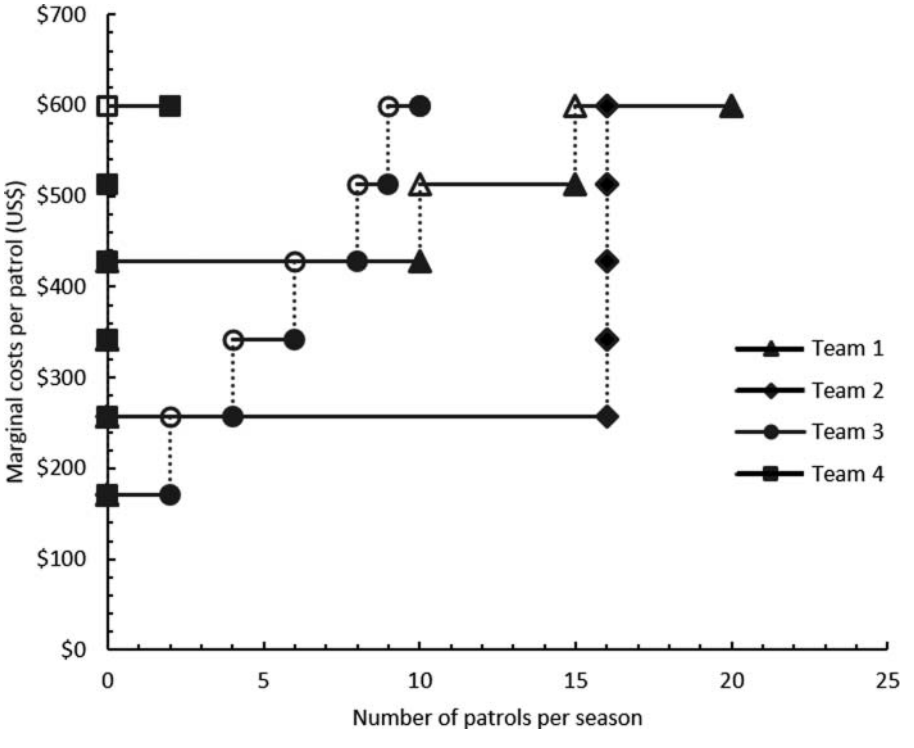

Figure 5. Sample of marginal costs of patrol team employment at the team level ('busy' season).

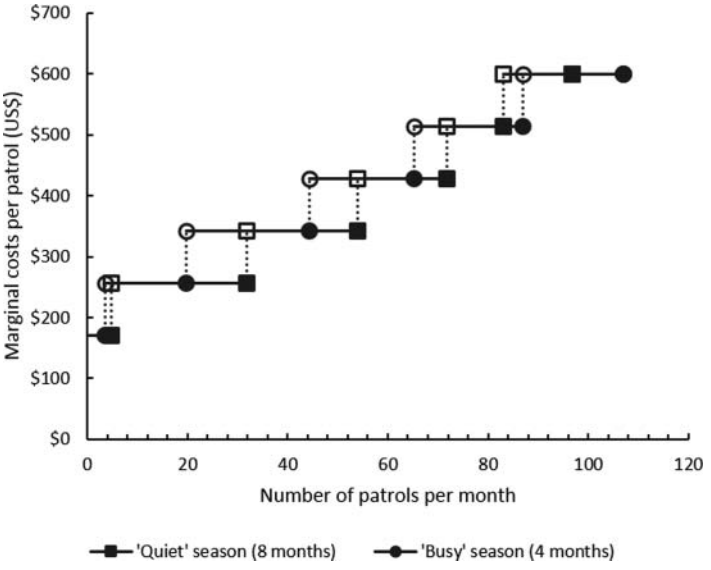

Figure 6. 'Market' marginal costs of patrol team employment by season.

The overall marginal costs at the market level are shown in Figure 7. Their disaggregation by marginal costs for patrol team employment and 'external' marginal costs is illustrated in Figure 8. The 'external' marginal costs are decreasing with a decreasing number of additional patrols[22]. The 'external' marginal costs (with the exception of the costs of employing the patrol manger) are

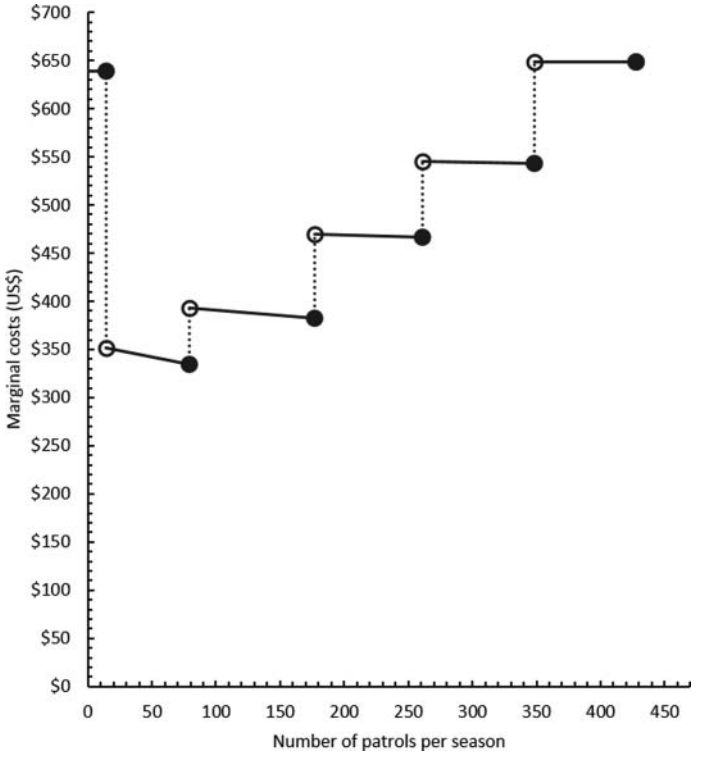

Figure 7. Overall marginal costs at the 'market' level ('busy' season).

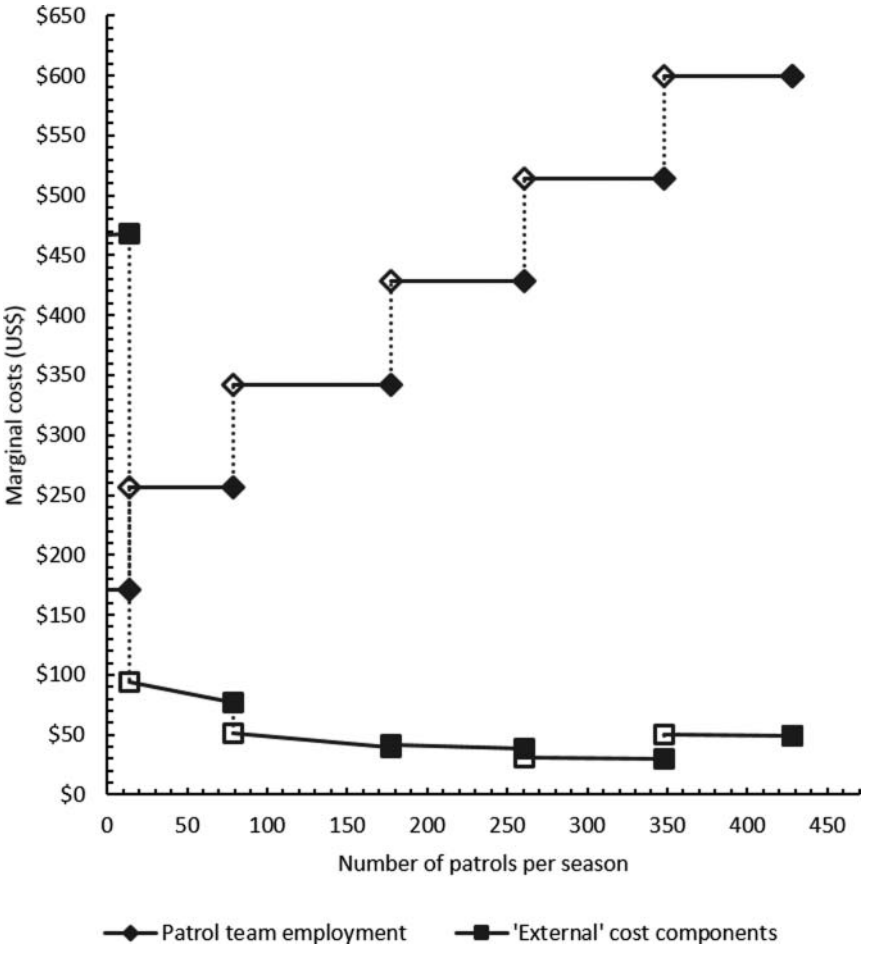

Figure 8. Marginal costs of patrol team employment and 'external' marginal costs ('busy' season).

relatively small compared to the marginal costs of patrol team employment. The decrease in the overall marginal costs between the first and second price levels is driven by the marginal costs of patrol manager employment embodied in the first price level (treated as a fixed cost). From the second price level onwards, the overall marginal costs are increasing at an increasing rate. This can be explained by the increase in the marginal costs of patrol team employment, which is partially offset by decreasing 'external' marginal costs as the number of patrols per team is increasing.

The overall marginal costs for both seasons are presented in Table 1.

Table 1. Overall marginal cost at the 'market' level.

	Busy season		Quiet season	
Price level (US$)	Overall marginal costs (US$)	Number of patrols	Overall marginal costs (US$)	Number of patrols
$171	$639	14	$532	39
$257	$334	79	$323	255
$342	$382	177	$388	432
$428	$466	261	$471	574
$514	$544	348	$544	664
$599	$648	428	$643	775

4.2. PES-2 (Green Peafowl Species Conservation Zone)

Teams of all six target villages submitted valid bids. In total, 30 teams participated. As shown in Figure 9, the number of participating teams varied across villages.

Figure 10 shows the number of additional teams that entered the bidding at each price level. The number of additional teams decreased with an increasing price per patrol. All teams entered the bidding above the 3rd price level.

As in PES-1, the data indicate that the marginal opportunity costs differed within and across villages (Figure 11). The marginal costs of patrol team employment at the market level are illustrated in Figure 12. The teams' opportunity costs are higher during the 'busy' season than during the 'quiet' season for all price levels.

The overall marginal costs at the market level are illustrated in Figure 13. Figure 14 shows their disaggregation by marginal costs for patrol team employment and 'external' marginal costs. The same pattern of results found in the PES-1 case are replicated for PES-2. The overall marginal costs for both seasons are presented in Table 2.

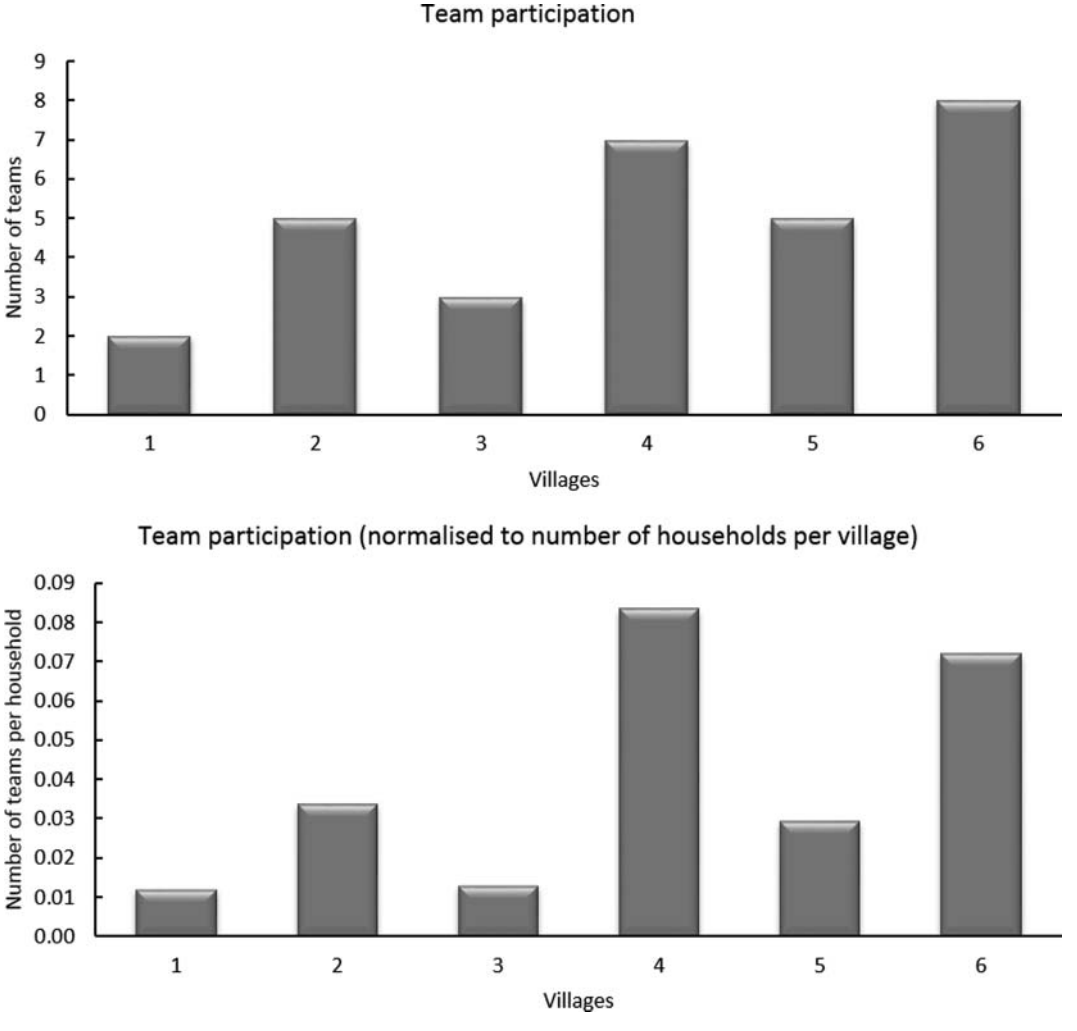

Figure 9. Team participation by village.

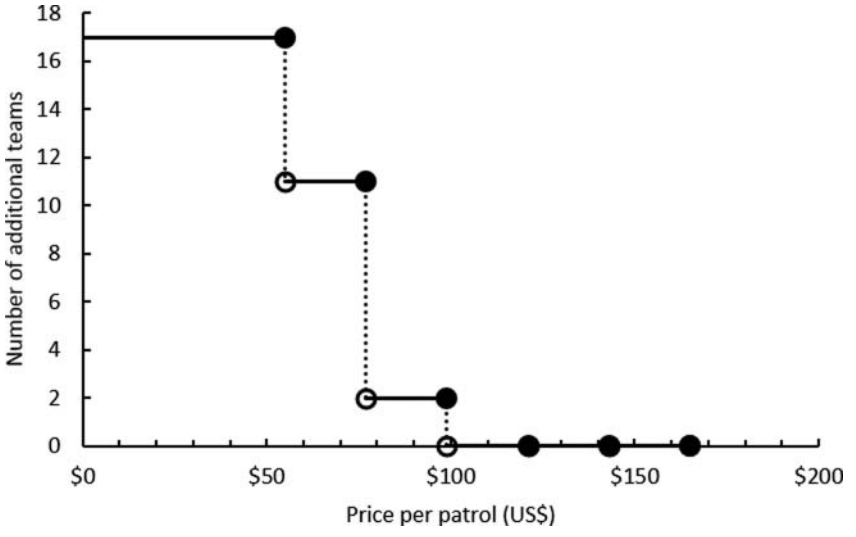

Figure 10. Team participation by price level.

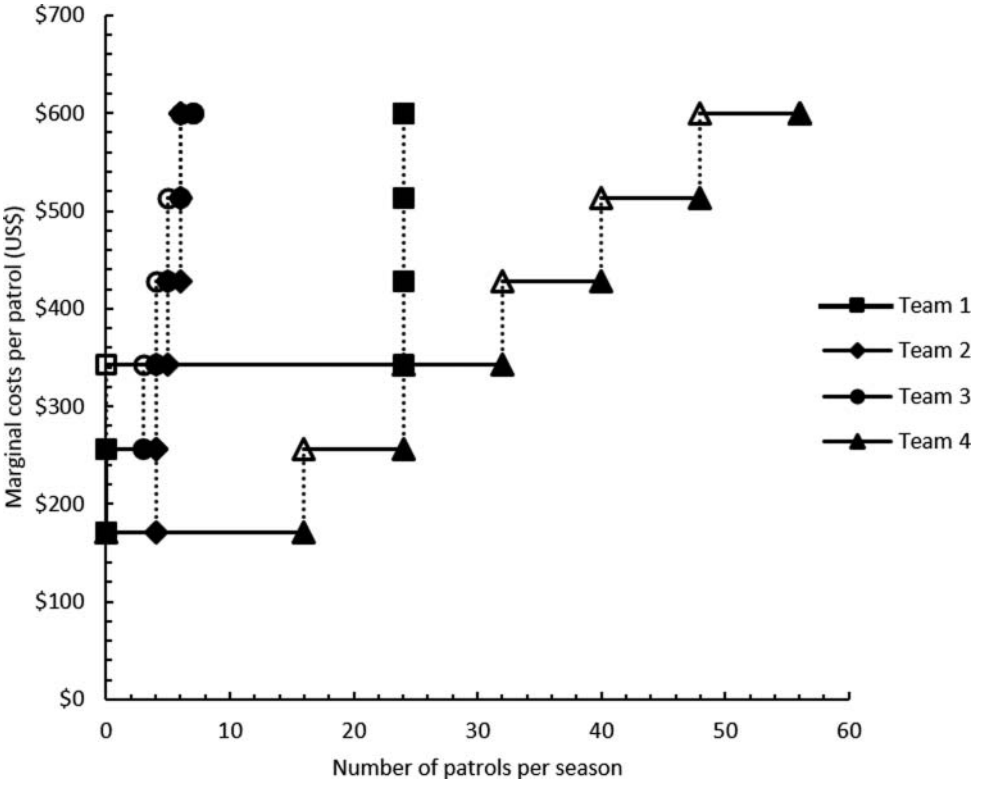

Figure 11. Sample of marginal costs of patrol team employment at the team level ('busy' season).

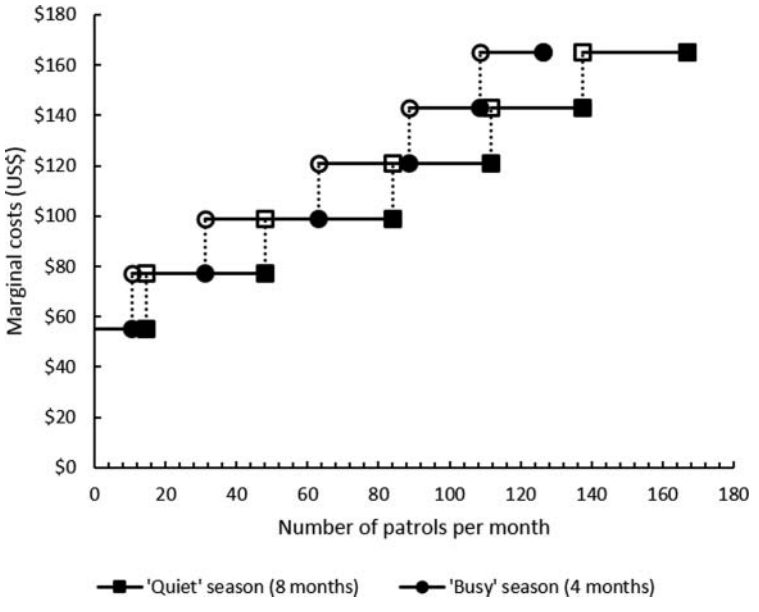

Figure 12. 'Market' marginal costs of patrol team employment by season.

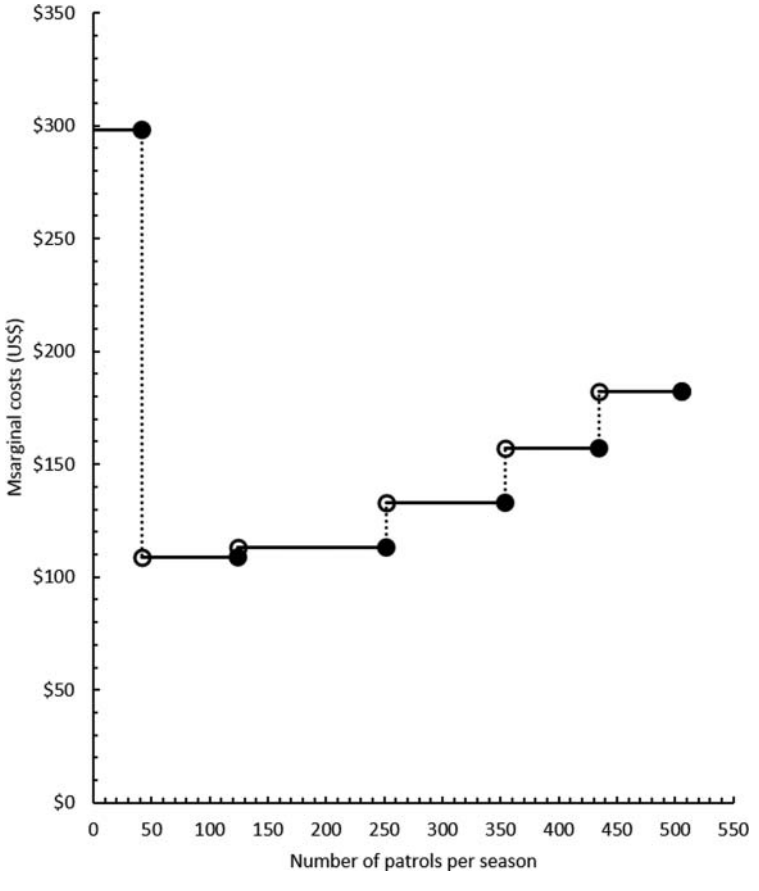

Figure 13. Overall marginal costs at the 'market' level ('busy' season).

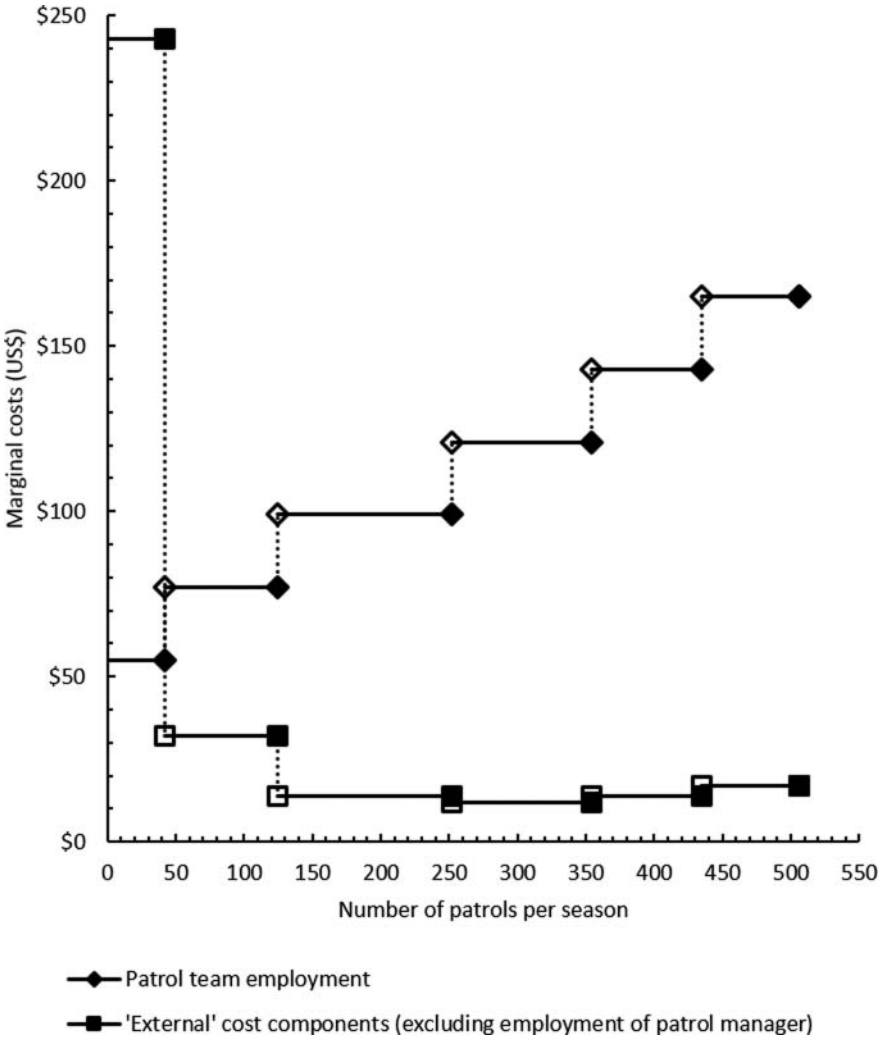

Figure 14. Marginal costs of patrol team employment and 'external' marginal costs ('busy' season).

Table 2. Overall marginal cost at the 'market' level.

	Busy season		Quiet season	
Price level (US$)	Overall marginal costs (US$)	Number of patrols	Overall marginal costs (US$)	Number of patrols
$55	$298	42	$180	117
$77	$108	124	$100	385
$99	$113	252	$111	671
$121	$133	354	$133	893
$143	$157	435	$157	1099
$165	$182	506	$182	1337

5. Conclusions

This study presented the results of two conservation auctions conducted to elicit the marginal costs of anti-poaching patrols in two protected areas in Lao PDR. The auction was especially designed to facilitate the use of the obtained supply data in the development and implementation of two pilot PES schemes.

The application involved an auction format that specifically addressed a number of issues that have proven problematic in the application of typical conservation auctions conducted to date. The format required each bidder to state the number of patrols they would be willing to conduct against a sequence of six pre-specified prices per patrol. This provided bidders with a choice that proved straightforward for potential suppliers to answer. This is particularly important given that those engaged in the PES schemes were relatively poorly educated with little exposure to market transactions. The validity of the estimated marginal cost curves is supported by their heterogeneity within and across villages as well as across seasons.

The individual marginal costs of patrol team employment estimated at the team level were ideally specified for horizontal addition to construct 'busy' season and 'quiet' season 'market' supply curves. However, given the use of pre-specified price levels to elicit auction bids, 'market' supply is represented by discontinuous step functions. This presents some challenges, particularly when adding other elements of cost into the marginal costs of patrol team employment. Some of the cost components of the anti-poaching patrol scheme were treated as 'external' costs. Some could not be included in the conservation auctions due to bidders' limited access to markets and information asymmetries. Others were costs associated with tasks assigned to agents others than the suppliers. The marginal units differed across the different components of the cost structure. Aggregating the marginal costs over all cost components required transforming marginal cost 'per team' and 'per village' into marginal cost 'per patrol'. It additionally required their distribution across the 'busy' and the 'quiet' season in proportion to their respective duration.

Not only was allowing prospective suppliers to bid in terms of quantities as a response to pre-specified prices a simplifying process but it also gave the opportunity for bidders to maximise their producer surpluses. The prospect of a surplus provided strong incentives to participate in the auctions. In addition, the self-selection mechanism applied in the auction made the bidding process socially inclusive: Anyone who met a set of basic eligibility criteria had the opportunity to participate. The uniform pricing rule ensured that low-cost suppliers were offered more patrols and earn a larger surplus than high-cost suppliers. Both, the self-selection mechanism and the uniform pricing rule addressed equity concerns in the Lao context. The results also support the claim that accounting for heterogeneity in marginal (opportunity) costs has the potential to improve PES scheme efficiency.

The results presented here show that the conservation auction format developed for the Lao PES schemes was practical in use. It simplified the bidding task in comparison to formats that request the bidder to specify both quantity and price. Such formats seem confusing since they make maximizing surplus with respect to either quantity or price impossible. A format that is plausible, simple and easy to understand is especially useful in contexts of low literacy and limited exposure to markets.

Notes

1. Synonymous terms include reverse auctions, procurement auctions and conservation tenders.
2. Informational rent, also called 'bid shading', is the difference between actual and stated marginal costs.
3. US$ 2,422 at exchange rate LAK 8,339.42 per US$ (27.1.2017 oanda.com).
4. The data presented in this section were sourced from on a household survey conducted in June 2015 by 'the National University of Laos within the project "Effective Implementation of Payments for Environmental Services in Lao PDR".'
5. US$ 2,854 at an exchange rate LAK 8,339.42 per US$ (27.1.2017 oanda.com).
6. An average household consists of about 5 individuals.
7. The data presented in this section were sourced from a household survey that was conducted in November 2015 by 'the National University of Laos within the project "Effective Implementation of Payments for Environmental Services in Lao PDR".'
8. The payments to the village development funds contain a fixed component calculated as a fixed amount per household, and a variable component based on a percentage of the patrol payments.

9. For a detailed discussion on group payments see Narloch, Drucker, and Pascual (2017) and Narloch, Pascual, and Drucker (2013).
10. Extensive training was offered to interested villagers before the auctions were performed. To ensure informed bids, only team members who completed the training were allowed to participate in the auctions. A team was allowed to submit a bid in the auction without requiring the presence of all team members. However, the bidding members needed to have the authority to represent the whole team. For bids to become valid all team members had to sign the submitted bidding form.
11. This price equates the marginal costs of supply with the generated marginal benefits.
12. As pointed out by an anonymous reviewer, the rule applied in this multi-unit conservation auction may best be described as an 'effort-as-bid' rule compared to a 'paid-as-bid' rule used in single-unit conservation auctions.
13. The incentive structure includes penalties for non-compliance to ensure the conditionality of payments.
14. Bonus payments were exclusively offered in PES-1.
15. The equipment costs were calculated without including a budget for replacements and repairs. The insurance is provided by the schemes (covering major injuries, disability and death) and by a commercial company (covering minor injuries and illness). The cost of the scheme-based insurance component was estimated as expected based on data from an anti-poaching patrol scheme in Vietnam. These costs were ignored given their insignificant magnitude.
16. The costs of the bonus payments for snare line removal were calculated on basis of a fixed price per snare wire (LAK 2,000 = $0.24 at an exchange rate LAK 8,339.42 per US$, 27.1.2017 oanda.com) and the predicted snare line densities and associated number of snare wires collected per patrol using a stochastic simulation model (Hay et al. 2017). The costs of the bonus payments for dismantling poacher camps were calculated on basis of a fixed price per camp (LAK 10,000 = $1.22 at an exchange rate LAK 8,339.42 per US$, 27.1.2017 oanda.com) and the estimated number of camps dismantled per patrol (based on expert opinion). The stochastic simulation models predicted a decline in the number of snare wires collected and camps dismantled with an increasing number of patrols. As a result, the probability of additional bonus payments earned by patrol teams is predicted to decline proportionally. The PES scheme is designed such that the price paid per snare wire and camp can be increased with decreasing snare density in subsequent auctions to keep the incentive structure functional.
17. The fixed component is calculated on a household basis. The fixed amount each village receives depends thus on the number of households. The costs of the fixed component are not included in the aggregated marginal costs of supply.
18. Annual equipment costs were calculated through depreciation over three years.
19. The benefits were quantified as the willingness to pay for wildlife protection (Scheufele and Bennett 2017b), which in turn was predicted as a function of, among other factors, deterrence effects, reduction in snare and camp density through anti-poaching patrols. The camp and bonus payments per camp and snare line were fixed on a per unit basis. This means that bonus payments varied across levels of effort. In addition, the associated benefits varied across bids due to different levels of effort. Hence, the bonus payments were added to the market supply curves.
20. The number of additional teams and villages in each season was calculated in 'equivalent' quantities to account for the fact that, at each price level, additional teams bid either for both seasons or for the 'quiet' seasons only.
21. At the inception of the PES schemes, all costs were variable. Once the schemes commenced with the appointment of the patrol manager, that cost became fixed and sunk.
22. As many of the 'external' costs are fixed elements, as more patrols are employed, the marginal component falls.
23. $US1 = ₭8,177.68 (27.01.2017 Oanda.com)

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