Effective Implementation of Payments for Environmental Services in Lao PDR

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PRICING BIODIVERSITY PROTECTION: PAYMENTS FOR ENVIRONMENTAL SERVICES SCHEMES IN LAO PDR

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Gabriela Scheufele[a], Jeff Bennett[a] and Phouphet Kyophilavong[b]

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a Crawford School of Public Policy, Australian National University
b Faculty of Economics and Business Management, National University of Laos

Abstract

A failure of markets to coordinate demand with supply indicates that the transaction cost of engaging in an exchange outweigh the benefits that buyers and suppliers expect to gain from trade. As a result, some goods and services are not traded in markets, despite potential demand and prospective supply. This is the case for some environmental services given the transaction costs associated with defining, defending, and trading property rights. Payment for Environmental Services (PES) schemes are being used around the world in an attempt to facilitate the operation of markets. However, few PES schemes involve the 'negotiation' of prices based on comparable estimates of demand and supply. This report presents the development and application of a PES schemes design that aim to mimic market processes for traded goods and services to an extent beyond existing attempts. It demonstrates how 'efficient' prices can be 'negotiated' through agent intervention and discusses the challenges and limitations encountered in the process. Supply information (elicited through conservation auctions) was used in conjunction with information on demand (estimated using discrete choice experiments) and environmental production functions (predicted through dynamic population models) to determine an 'efficient' price. The application of the innovative process involved two pilot PES schemes that aim to increase the supply of biodiversity in the Lao People's Democratic Republic (Lao PDR).

Keywords: conservation auctions; biodiversity protection; discrete choice experiments; environmental production function; Lao PDR; payments for environmental services scheme

Table of Content

1. Introduction

A Payment for Environmental Services (PES) scheme that involves setting a ‘pseudo market price’ requires agents to ‘negotiate’ the price per unit of environmental service paid by the buyers to the suppliers. This report demonstrates how ‘efficient’ prices can be ‘negotiated’ through agent intervention and discusses the challenges and limitations encountered in the process. The application of the innovative process involved two pilot PES schemes that were developed within the project ‘Effective Implementation of PES in Lao PDR’[1].

This report draws on Research Report 3: Development of a ‘virtual’ PES scheme for the Nam Ngum River Basin (Scheufele et al. 2014), Research Report 11: Modelling the effects of anti-poaching patrols on wildlife diversity in the Phou Chomvoy Provincial Protected Area (Hay et al. 2017), Research Report 12: Modelling the effects of anti-poaching patrols on Green Peafowl populations in the Phou Khao Kouay National Protected Area (Renton et al. 2017), Research Report 13: Valuing biodiversity protection: Payments for Environmental Services schemes in Lao PDR (Scheufele and Bennett 2017c), and Report 16: Costing biodiversity protection: Payments for Environmental Services schemes in Lao PDR (Scheufele and Bennett 2017g).

[1] https://ipesl.crawford.anu.edu.au/

2. Background

A failure of markets to coordinate demand with supply indicates that the transaction cost of engaging in an exchange outweigh the benefits that buyers and suppliers expect to gain from trade. This reasoning follows Coase (1960) who analysed the role of transaction costs in market transactions[2]. As a result, some goods and services are not traded in markets, despite potential demand and prospective supply. This is the case for some environmental services[3] given the transaction costs associated with defining, defending and trading property rights. Payment for Environmental Services (PES) schemes are being used around the world in an attempt to facilitate the operation of markets where they otherwise have not developed.

A PES scheme is a mechanism that establishes and sustains a financial link[4] between potential buyers and prospective suppliers of environmental services that markets fail to provide; this is achieved by lowering the transaction costs borne by buyers and sellers through the involvement of one or more agents (Scheufele 2016)[5]. Following this rationale, PES scheme design and implementation can be seen as an attempt to mimic market processes such that an exchange of environmental services becomes beneficial for both buyers and suppliers (Scheufele and Bennett 2017a). In some cases, transaction costs can be lowered sufficiently to facilitate direct negotiations between both parties regarding the pricing of environmental service supply. Otherwise, pricing needs to be 'negotiated' through an agent. This may be the case if, for example, a large number of suppliers face a large number of buyers. Ideally, agents, on behalf of buyers and suppliers, 'negotiate' efficient pricing[6] based on estimates of demand and supply that use comparable units of measurement. Efficient pricing facilitates PES schemes in their capacity to generate a net social benefit.

However, few PES schemes incorporate 'negotiated' prices based on comparable estimates of demand and supply. Alternative approaches include setting prices independently of demand and supply, relying on incomparable estimates of demand and supply (often involving an

[2] Transaction costs are defined as 'the resources used to define, establish, maintain and transfer property rights' (McCann et al. 2005, p.530).
[3] The term "environmental services" is used as a synonym for "ecosystem services" defined as 'the benefits people obtain from ecosystems [ ]' (Millennium Ecosystem Assessment, 2005a, 2005b, p.27). A discussion of suggested differences between the two terms is provided by Wunder (2015).
[4] Financial link refers to monetary and in-kind payments.
[5] For a discussion of PES definitions see, for example, Wunder (2015).
[6] Efficient price is defined as that which equates supply and demand.

environmental benefit index), and using one of either demand or supply. None of these approaches enables the 'negotiation' of efficient pricing[7]. Examples are discussed by Brimont and Karsenty (2015), Eigenraam et al. (2005), Guerra (2016), de Leeuw et al. (2014), Pagiola (2008), and Nguyen (2011). Examples of approaches that 'negotiate' pricing based on comparable estimates of demand and supply include the provision of Mediterranean forests (Górriz-Mifsud et al. 2016) and the extension of the Conversion of Cropland to Forests and Grassland Program (CCFGP) in the Sichuan Province, China (Wang et al. 2012). Górriz-Mifsud et al. (2016) estimated 'price boundaries'. The marginal costs to private forest owners of supplying environmental services through a change in management practises were estimated as changes in profitability. The marginal benefits of those services to potential buyers were estimated using discrete choice experiments. However, the study does not provide guidance on how a price should be set within the estimated boundaries. Wang et al. (2012) applied perfect price discrimination through a 'paid-as-bid' conservation auction, with the number of suppliers capped by demand. However, perfect price discrimination prevents suppliers from extracting the type of net returns (producers' surplus) that are enjoyed by suppliers in competitive markets for traded goods and services. The net returns are secured entirely by the buyers (or their agents).

This report presents the application of a PES scheme design (Scheufele and Bennett 2017a) that aims to mimic market processes for traded goods and services to an extent beyond existing attempts. It demonstrates how efficient prices can be 'negotiated' through agent intervention and discusses the challenges and limitations encountered in the process. The application of the innovative process involves two pilot PES schemes that aim to reduce biodiversity loss through the supply of wildlife protection actions in the Lao People's Democratic Republic (Lao PDR)[8]. Both schemes have been implemented and are scheduled to be operational in August 2017.

[7] A detailed discussion on this issue is provided by Scheufele & Bennett (2013).

[8] The two pilot PES schemes were designed and implemented through the project 'Effective Implementation of Payments for Environmental Services in Lao PDR'. The project was funded by the Australian Centre for International Agricultural Research within the Australian Government and is conducted by the Australian National University in collaboration with the Ministry of Natural Resources and Environment (Lao PDR), the Department of Forestry within the Ministry of Agriculture and Forestry (Lao PDR), the National University of Laos and the University of Western Australia. For further information visit https://ipesl.crawford.anu.edu.au/.

3. Application

The first pilot PES scheme (PES-1) has been established in the Phou Chomvoy Provincial Protected Area (PCPPA). The PCPPA is part of the Northern Annamite Ranges on the border between Lao PDR and Vietnam. The mainly mountainous area is located within Bolikhamxay Province and covers about 22,300 hectares. The use of wildlife resources within the PCPPA is restricted by Lao PDR statutory legislation and customary laws. However, law enforcement against poaching is known to be largely ineffective. PES-1 aims to reduce biodiversity loss (output) through the supply of wildlife protection actions (inputs). The scheme focusses on the protection of 19 wildlife species that are classified as Endangered or Critically Endangered (IUCN 2016). The suppliers of wildlife protection are inhabitants of eight villages located in close proximity to the protected area. The suppliers are mainly subsistence farmers with limited income and employment opportunities outside the agricultural sector.

The second pilot PES scheme (PES-2) focussed on the Green Peafowl Species Conservation Zone (GPSCZ) covering about 8,000 hectares. It is part of the Phou Khao Khaouy National Protected Area located within Vientiane Capital Province. As in the PCPPA, the Lao PDR statutory and customary laws restrict the use of wildlife resources within the GPSCZ. The effectiveness of the law enforcement effort is limited. PES-2 aims to reduce biodiversity loss (output) through the supply of wildlife protection actions (inputs). Unlike the PCPPA scheme that covers a range of wildlife species, this scheme focusses on only one species, the Green Peafowl (*Pavo muticus*), which is classified as Critically Endangered (IUCN 2016). The suppliers are inhabitants of six villages located at the south-western boundary of the GPSCZ. As in PES-1, the suppliers' livelihoods are mainly based on subsistence farming augmented with some income secured through employment outside the agricultural sector.

Supplier engagement is voluntary in both schemes. Teams of individual villagers as well as the villages as a whole are engaged. Teams are contracted within the PES schemes to perform anti-poaching patrols that involve law enforcement and wildlife monitoring tasks. Team engagement is formalised through patrol contracts, whereas village engagement is formalised through conservation action plans and community conservation agreements. The contracts, plans and agreements, negotiated through several stages of community consultation, are based on the 'guidelines on free, prior and informed consent' (UN-REDD Programme 2013). Models that predict the cause-effect relationship between inputs and outputs facilitate an assessment of supply additionality of output by monitoring supply additionality of input (Hay et al. 2017;

Renton et al. 2017). The supplier incentive structure includes monetary and in-kind payments, recognitions, and penalties for non-compliance (Scheufele et al. 2016a; Scheufele et al. 2016b). Penalties for non-compliance ensure the conditionality of payments. The villages are incentivised through recognitions and payments made to their village development funds in return for supporting the anti-poaching patrolling scheme and the protection of wildlife. Dissemination of information on current legal restrictions in the use of wildlife resources within protected areas aims to reduce poaching as a result of ignorance. An impartial, accessible and fair mechanism for grievance, conflict resolution and redress (UN-REDD Programme 2013) is an integral part of both schemes.

In both schemes, the buyers enjoy the benefits from knowing that wildlife species are protected (existence and bequest values). The buyers are international tourists visiting Lao PDR and the population of the urban districts[9] of the Lao PDR Capital, Vientiane City[10]. "International tourists are tourists who enter Laos with a valid passport and visa obtained from a Lao embassy or consulate abroad, or a visa obtained on arrival at an international border checkpoint" (Tourism Development Department 2016, p.2)[11].

Agents establish and sustain the links between the suppliers and the buyers. They act as 'brokers' with the capability of reducing transaction costs of the exchange. Drivers of prohibitively high transaction costs are associated with defining, defending and trading property rights and include free-riding (benefiting without bearing any cost of supply) due to the public good character of biodiversity[12]; lack of trust between buyers (regarding the delivery of biodiversity) and suppliers (regarding the receipt of payment); limited knowledge of the cause-effect relationships between inputs (anti-poaching patrols) and outputs (biodiversity); a large number of buyers facing a large number of suppliers; and non-viable payment transfer options. In both pilot schemes, the agents are research bodies, the Government of Lao PDR (on

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[9] Chanthabuly, Sikottabong (partially), Xaysrtha, and Sisattanak.

[10] The demand estimates are based on the results of a Discrete Choice Experiment involving international tourists and urban residents of Vientiane City. However, the financial link between buyers and suppliers has not yet been established. Until this link is in place, the funding comes from the 'international community' provided by the WorldBank as a loan to the Lao PDR Government.

[11] Foreign visitors who may be exempt from a visa requirements but are not regional tourists are included in this definition. "Regional tourists are foreign visitors from neighbouring countries such as: Thailand, China, Myanmar, Vietnam and Cambodia, which share borders with Laos. They enter Laos with valid border passes or passports" (Tourism Development Department 2016, p.2)

[12] Public goods are characterized by non-excludability and indivisibility: 'Non-excludability refers to a circumstance where, once the resource is provided, even those who fail to pay for it cannot be excluded from enjoying the benefits it confers. Consumption is said to be indivisible when one person's consumption of a good does not diminish the amount available to others' (Tietenberg and Lewis 2009, p.76).

the national, provincial and district levels), local authorities (village heads and village committees), and wildlife conservation organisations (international and local)[13].

4. Methods

In both schemes, pricing was 'negotiated' through agents by matching comparable estimates of demand with supply.

Information on demand was estimated through discrete choice experiments (Scheufele and Bennett 2017c). For PES-1, the marginal benefits enjoyed by the buyers were estimated in terms of implicit prices per 'target species present' (an indicator for species diversity) and 'percentage reduction of animals poached' (an indicator for population sizes). For PES-2, the marginal benefits were estimated in terms of an implicit price per 'Green Peafowl present' (an indicator for population size).

The implicit prices estimated in 'output space' were converted into 'input space' by means of marginal production functions that quantify the cause-effect relationship between inputs and outputs. The marginal production functions were estimated through dynamic population models developed by Renton et al. (Hay et al. 2017; Renton et al. 2017). Predictions of outputs were simulated over three years for different levels of effort (number of anti-poaching patrols)[14]. The level of effort ranged from zero patrols (baseline) to the total number of patrols teams bid in the conservation auctions at the highest price offered. The output predicted over three years was expressed as the average output per year. Padé-approximations (Abramowitz and Stegun 1970) were used to fit functions[15]. Total products (output per level of patrol effort) were estimated by subtracting the baseline predictions from the predictions of positive effort levels. Total production functions were differentiated[16] to estimate marginal products (output per additional patrol). In a data-poor context, such as Lao PDR, the initial predictions of the models are understood as the first approximation of reality. Both schemes were designed to

[13] The two pilot PES schemes were developed within the research project 'Effective Implementation of Payments for Environmental Services in Lao PDR' funded by ACIAR involving the Australian National University, the National University of Laos, the University of Western Australia, the Ministry of Natural Resources and Environment (Lao PDR), and the Department of Forestry within the Ministry of Agriculture and Forestry (Lao PDR). The ongoing operation of the schemes is being overseen by the National University of Laos and the Environmental Protection Fund (Lao PDR).
[14] Values averaged over 2,000 runs.
[15] Spider (Phython 3.5) and Excel Solver (Excel 2013) were used to fit functions.
[16] Differentiation was conducted with SageMath 7.6.

allow periodic adjustments as more data has been collected through wildlife monitoring, which is an integral part of the patrol team tasks. The accuracy of the model predictions is thus expected to increase over time.

'Market' demand in input space was estimated by aggregating the implicit prices per patrol over the number of buyers of each buyer type'[17]. The number of international tourist arriving in Lao PDR was predicted to be 391,599 per year averaged over a three year contract period from 2017 to 2019. The prediction is based on data from 2009-2015 (Tourism Development Department 2016). The prediction was qualified by the choice experiments' response rates (Scheufele and Bennett 2017c)[18]. The number of households in the urban districts of Vientiane City was predicted to be 34,008 averaged over a three year contract period from 2017 to 2019. The prediction is based on population data from 2015, an average growth rate of 1.6% per year (2005 – 2015) and an average household size of 4.6 in 2015 (Government of Lao PDR 2016). Non-Lao PDR citizens were excluded. The prediction was qualified by the choice experiments' response rates (Scheufele and Bennett 2017c)[19].

For both schemes, implicit prices were estimated as benefit streams in perpetuity. The implicit prices estimated for the population of the urban districts of Vientiane City were based on respondents' an ongoing monthly willingness-to-pay aggregated per year. The implicit prices estimated for international tourists visiting Lao PDR were based on respondents' one-off willingness-to-pay. Given a continuous stream of international tourists, the implicit prices aggregated per annum were interpreted as an ongoing annual willingness-to-pay. The ongoing benefit stream for which they would be willing to pay would be secured through a continuous stream of new cohorts of international tourists arriving each year.

The extent of supply was estimated using conservation auctions as a base (Scheufele and Bennett 2017g). Potential anti-poaching patrol teams were invited to participate in conservation auctions and bid for three-year patrol contracts. Any team that met a set of basic eligibility criteria, such as having the ability to perform anti-poaching patrols, was given the opportunity to participate in the conservation auction. Suppliers were thus chosen through a self-selecting

[17] It is expected that the patrols will generate additional benefits currently not included in the dynamic population models that predict the cause-effect relationship between input and output. These may include habitat protection through a reduction of illegal logging and illegal collection of non-timber forest products.
[18] To obtain conservative estimates of aggregate demand the lower response rate of 60% associated with the PCPPA survey data (PES-1) was applied to the GPSCZ survey data (PES-2).
[19] To obtain conservative estimates of aggregate demand the lower response rate of 42% associated with the PCPPA survey data (PES-1) was applied to the GPSCZ survey data (PES-2).

process. Each team submitted bids indicating how many patrols they would each like to perform per year given a sequence of six pre-specified prices per patrol (henceforth called 'price level'). The obtained sequences of price-quantity pairs tracked the teams' marginal costs of patrolling. A year was divided into two seasons to account for potential differences in marginal (opportunity) costs: a 'busy' season (four months during the rice planting and harvesting season) and a 'quiet' season (the remaining eight months). Each team submitted one bid for each season generating two marginal cost curves per team. Some cost components were not included in the conservation auctions but are borne by the agent. They were estimated through market prices (insurance; patrol equipment, employment of a patrol manager) and expert opinion (patrol team payments for snare collection and dismantling of poacher camps, and payments to village funds). These 'external' costs were added to the teams' marginal costs curves[20]. The teams' marginal cost curves 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.

Efficient prices and quantities were estimated by equating 'market' supply and 'market' demand in input space (number of patrols per season)[21,22]. Consumer surplus was calculated as the annual total benefit for each buyer group at the efficient quantity less the associated annual aggregate buyer payment. The aggregate buyer payment is shared among the international tourists (proposed as an 'environmental levy' on the visa fee) and the population of urban districts of Vientiane City (proposed as a surcharge on households' electricity bills) using their respective marginal benefits as weights. The payment required from individual buyers is calculated as the aggregate buyer payment divided by the number of buyers of each buyer type[23]. Producer surplus was calculated as the annual aggregate buyer payment to the suppliers less the annual total cost of supply. Producer surplus was disaggregated by surplus earned by patrol teams and surplus earned by the agent. 'Patrol team' surplus was calculated as their annual revenue less the annual total cost of patrolling estimated through the conservation

[20] In contrast to the PES-1 scheme, teams do not receive bonus payments for snare collection and dismantling poacher camps.
[21] The estimation is made under the assumption of complete contract compliance. Incomplete compliance would result in an efficiency loss.
[22] Since 'market' supply is represented by discontinuous step functions, no solution exists for quantity between price levels.
[23] The aggregate buyer payment was calculated based on population predictions qualified by the Choice Modelling response rate. The payment required from individual buyers was calculated by dividing the aggregate buyer payment by the population prediction.

auctions[24,25]. The revenue included the patrol and the bonus payments. The patrol payments were calculated as the uniform price per patrol paid to patrol teams multiplied by the number of patrols per year. The bonus payments were calculated as the number of snares collected and camps dismantled per year predicted through the dynamic population model multiplied by a fixed price per snare and camp[26]. 'Agent' surplus was calculated as annual 'external' revenue less the annual total 'external' costs. The 'external' revenue was calculated as the difference in the price paid by the buyers less the price paid per patrol, multiplied by the number of patrols per year. By design, the 'agent' surplus is negative since part of the aggregate buyer payment is spent twice: as surplus to the patrol teams and partially to cover the 'external' cost, which are not borne by the patrol teams but by the agent. Surplus was redistributed from the buyers to the agent to ensure the aggregate buyer payment cover the total cost.

[24] It could be argued that the transaction costs faced by the patrol teams (such as the costs of bidding in the conservation auctions) are included implicitly in their bids, and therefore in their annual cost of patrolling. Following this logic, producer surplus then represents a surplus net of these transaction costs.

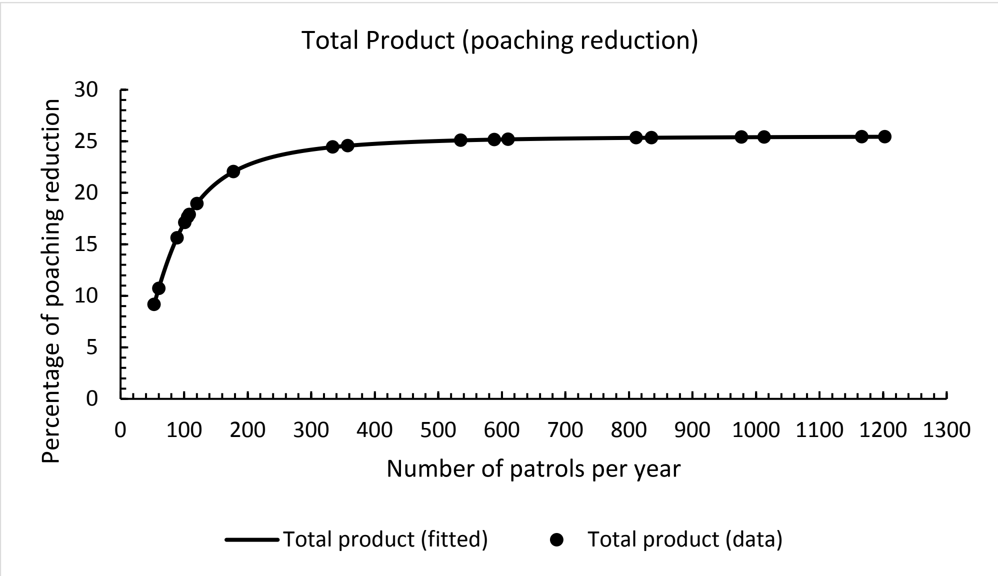
[25] Benefits associated with the insurance and the recognitions are ignored. The bids may have been lower in recognition of these 'extra' benefits obtained.

[26] The scheme design allows the price per snare and camp to be increased over time by an amount that compensates for a decrease in snare and camp densities.

5. Results

5.1 PES-1 (Phou Chomvoy Provincial Protected Area)

The total product of patrolling, estimated based on the predictions of the dynamic population model, are presented in Figure 1. The data indicate diminishing marginal returns with an increasing number of patrols. Patrol productivity decreases until a plateau is reached where no further returns, in terms of increased wildlife protection, are achieved through additional patrols.



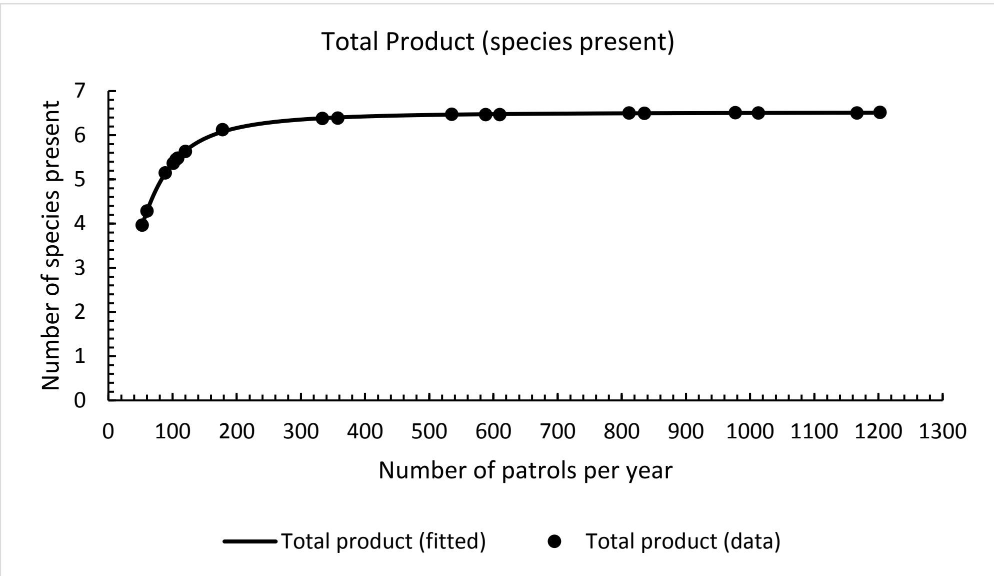


Figure 1: Total product of anti-poaching patrolling

The extent of the 'market' demand and supply in 'input space' (anti-poaching patrolling) in each season are provided in Table 1. The marginal benefit are downward sloping indicating diminishing marginal benefits. The marginal costs are u-shaped reflecting diminishing marginal returns beyond the second price level.

Table 1: 'Market' demand and supply in 'input space'

Busy season		
Number of patrols per season	Marginal benefits	Marginal costs
14	$166,639	$639
79	$4,322	$334
177	$755	$382
261	$296	$466
348	$167	$544
428	$100	$648

Quiet season		
Number of patrols per season	Marginal benefits	Marginal costs
39	$166,639	$532
255	$4,322	$323
432	$755	$388
574	$296	$471
664	$167	$544
775	$100	$643

Supply meets demand at the efficient price (p^e) and efficient quantity (q^e) (Figure 2). The efficient price does not differ across seasons. This indicates that any seasonal difference in the estimated marginal costs is smaller than the difference in the pre-specified price levels. Marginal cost differences are represented through season-specific efficient quantities only. In both seasons, the efficient number of patrols is smaller than the number of patrols offered by teams at the efficient price. This can be explained by the discontinuity in supply created by the 'skipping' of prices. The promise given during the auctions that each team would be offered the number of patrols they each bid at the determined price provided a challenge[27]. Contracting the offered number of patrols at the efficient price (fourth price level) to keep the agreement

[27] 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'. Given the promise that each team would be offered the number of patrols they each bid at the determined price, the transformation of the marginal cost 'per team' and marginal cost 'per village' into marginal cost 'per patrol' was achieved by dividing the total costs of all additional teams (additional villages) at each price level by the total number of patrols employed at the corresponding price level. The values of the estimated efficient price and quantity (which is less than the total number of patrols at that level) are therefore an approximation, overestimating the efficient price and underestimating the efficient quantity.

would result in employing patrols beyond the efficient quantity (Scenario 1). Moving to the next lower price (third price level) would have the opposite effect (Scenario 2). Either scenario would result in an allocative inefficiency (dead weight loss). The outcomes predicted for both scenarios are summarized in Table 2.

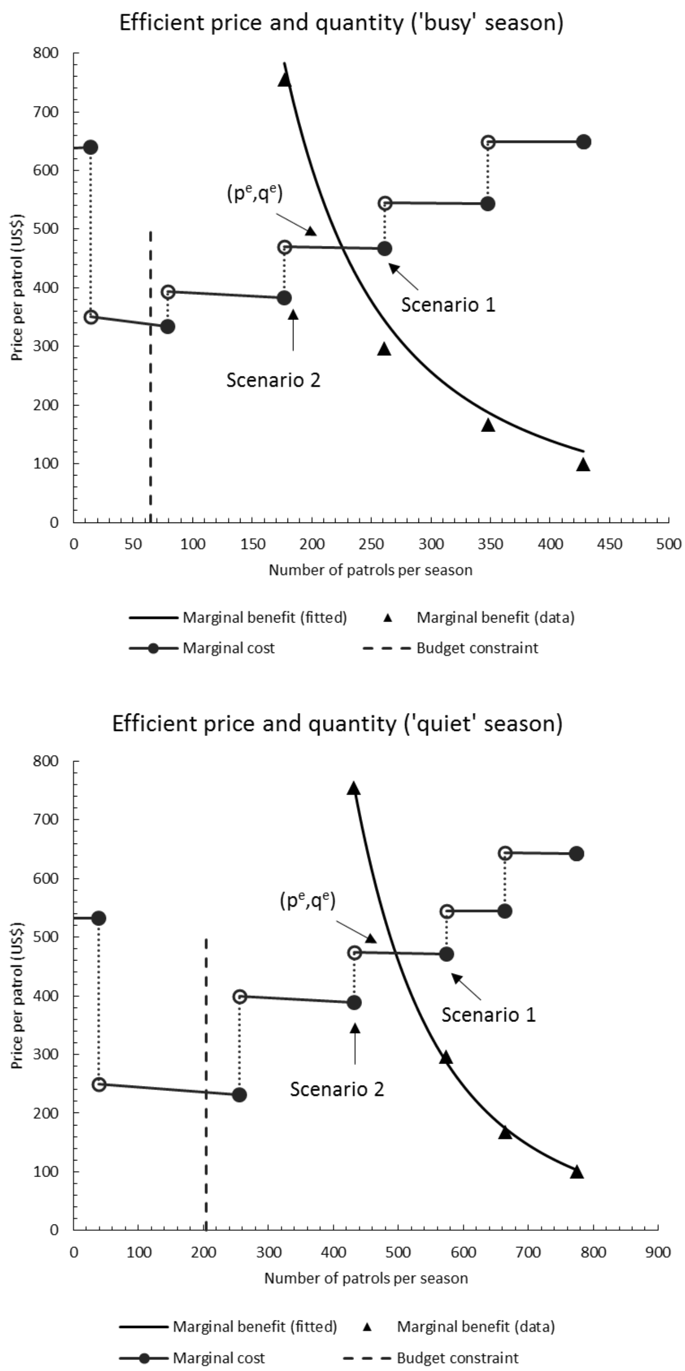


Figure 2: Efficient price and quantity in ‘input space’

The total surplus predicted for Scenario 2 outweighs that for Scenario 1. The higher total benefits predicted for Scenario 1 are off-set by higher total costs. The aggregate payment required from the international tourists is about ten times larger than the payment required from the urban residents of Vientiane City. This differences is largely driven by differing population numbers of the two buyer groups. The negative value of the producer surplus allocated to the agents is a direct result of having 'external' costs not born by the teams (the suppliers) but the agents. The generated revenue is partly spent twice: as payments to the patrol teams and to cover the 'external' costs. One way to balance the producer surplus allocated to the agents is to redistribute surpluses enjoyed by the buyers to the agents. The results of this redistribution are provided in Table 2 in parenthesis.

Table 2: PES scheme outcomes predicted per year (under Scenario 1 and Scenario 2)

	Scenario 1		**Scenario 2**	
Number of villages with patrol teams	7		6	
Number of patrol teams	49		42	
Number of patrols	835		609	
Average patrol frequency per km2 and month	4.6		3.3	
Total benefits	$5,331,865		$5,315,034	
Total costs	$337,594		$231,290	
Total cost to teams	*$272,119*		*$175,392*	
Total cost to agents	*$65,475*		*$55,898*	
Total net benefits (total surplus)	$4,994,271		$5,083,744	
Aggregate buyer payment	$391,855	($425,112)	$235,344	($267,982)
Aggregate payment from urban residents	*$36,186*	*($39,257)*	*$21,720*	*($24,732)*
Aggregate payment from international tourists	*$355,669*	*($385,855)*	*$213,624*	*($243,250)*
Aggregate supplier revenue	$391,855		$235,344	
Aggregate supplier revenue to teams	*$359,636*		*$212,084*	
Aggregate supplier revenue to agents	*$32,219*	*($65,475)*	*$23,260*	*($55,898)*
Consumer surplus	$4,940,010	($4,906,754)	$5,079,690	($5,047,052)
Producer surplus	$54,261	($87,518)	$4,055	($36,692)
Producer surplus to teams	*$87,518*		*$36,692*	
Producer surplus to agents	*-$33,257*	*($0)*	*-$32,637*	*($0)*
Variable payments to village development funds	$17,869		$10,426	

*Total cost to agents includes variable payments to village development funds

The extent of the marginal benefit generated at a large number of patrols is driven mainly by the number of buyers rather than the marginal product of patrolling, with marginal product differences diminishing with an increasing number of patrols. Due to a lack of data, the underlying dynamic population model did not account for potential negative effects on wildlife protection outcomes associated with high patrol densities (e.g. disturbance). Accounting for potential negative effects might result in the marginal product falling to zero or becoming negative. This would reduce the marginal benefits and thus the efficient price and quantity in 'input space'.

So far, this analysis has been conducted under the assumption that the financial link between buyers and suppliers has been established. This is not yet the case. Until a sustainable funding mechanism is in place, seed funding provided by the WorldBank as a loan to the Lao PDR Government[28] is being used. This introduced a budget constraint (Figure 2) since the seed funding available was less than the aggregate buyer payment under both scenarios. This constraint reduced the total number of patrols[29] that could be afforded. The available budget allowed the purchase of either the total number of patrols offered by teams at the first price level or about 80 percent of patrols offered at the second price level. The former would have resulted in only eight of fifty-five teams being engaged in the scheme. That outcome would have been perceived as 'unfair' among suppliers, would have created a range of perverse incentives, and was therefore rejected in favour of the latter. The required reduction of the total number of patrols offered at the second price level was achieved by a 20 percent cut across 32 teams.

[28] The seed funding is provided through the Environmental Protection Fund through their Protected Area and Wildlife Project.
[29] It also reduces the price paid per patrol to a level at which teams from a strategically located village (Nam Pan) would not be allocated any patrols. Encouraging their participation required the offering of a supplement payment. The supplement payment increased the price paid per patrol by $85.60 and the variable village payment by $4.28 per patrol.

Table 3: PES scheme outcomes predicted per year (purchased patrols)

	Purchased patrols	
Number of villages with patrol teams	5	
Number of patrol teams	17	
Number of patrols	196	
Average patrol frequency per km2 and month	1.1	
Total benefits	5,037,217	
Total costs	$80,999	
Total cost to teams	*$49,647*	
Total cost to agents	*$31,352*	
Total net benefits (total surplus)	$4,956,218	
Aggregate buyer payment	$67,748	($88,018)
Aggregate payment from urban residents	*$6,188*	*($8,040)*
Aggregate payment from international tourists	*$61,559*	*($79,978)*
Aggregate supplier revenue	$67,748	
Aggregate supplier revenue to teams	$56,666	
Aggregate supplier revenue to agents	*$11,082*	*($31,352)*
Consumer surplus	$4,969,470	($4,949,199)
Producer surplus	-$13,252	($7,019)
Producer surplus to teams	$7,019	
Producer surplus to agents	*-$20,271*	*($0)*
Variable payments to village development funds	$2,568	

*Total cost to agents includes variable payments to village development funds

About seventy-two percent of the offered patrols were purchased by the agents (on behalf of the buyers) since some suppliers withdrew their bids[30]. The difference between the offered and the purchased number of patrols might be explained by rumours of the establishment of a new mining operation in close proximity to the communities. Some suppliers might have expected a change in their opportunity costs of time. They might have expected the wages earned through a mining employment to outweigh the returns from patrolling. The outcomes predicted to be achieved by the purchased number of patrols are summarized in Table 3. As in Table 2, the results of a surplus redistribution are provided in parenthesis.

5.2 PES-2 (Green Peafowl Species conservation Zone)

[30] The patrol contracts are scheduled to be signed in August 2017.

The process used to determine the efficient price and quantity for PES-2 replicated that used in PES-1. However, different conditions and constraints prevailed. Figure 3 illustrates the total product of patrolling. The data suggest that as the number of patrols increases, patrol productivity decreases at a decreasing rate towards a zero return.

Table 4 shows the extent of the aggregated 'market' demand and supply in 'input space' in each season. The marginal benefits are diminishing at a decreasing rate. The marginal costs are diminishing at an increasing rate once the number of patrols surpasses the number associated with the second price level.

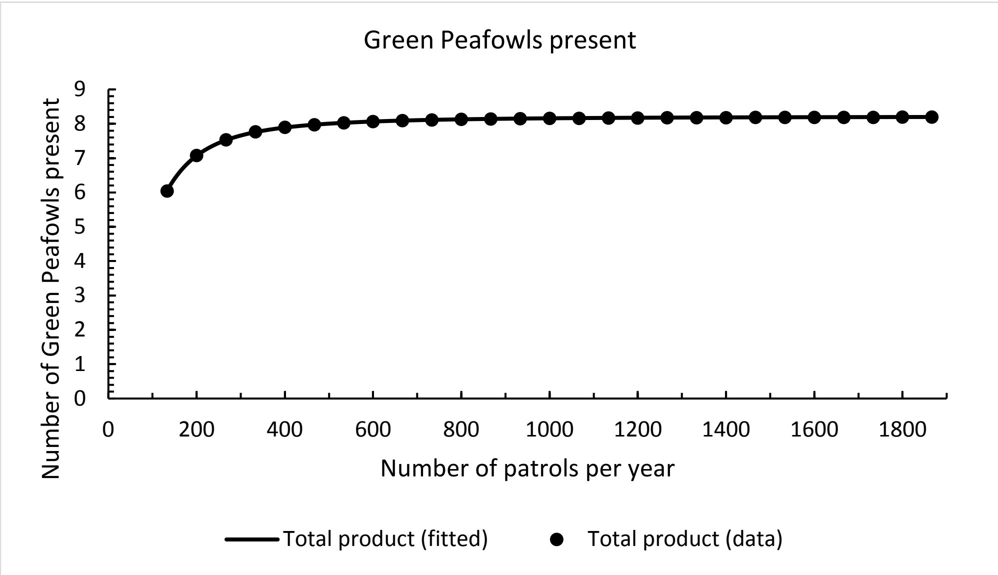


Figure 3: Total product of anti-poaching patrolling

Table 4: 'Market' demand and supply in 'input space'

Busy season		
Number of patrols per season	Marginal benefits	Marginal costs
42	$399	$298
124	$19	$108
252	$3	$113
354	$1	$133
435	$1	$157
506	$0	$182

Quiet season		
Number of patrols per season	Marginal benefits	Marginal costs
117	$399	$180
385	$19	$100
671	$3	$111
893	$1	$133
1099	$1	$157
1337	$0	$182

Supply meets demand at the efficient price p^e at the efficient quantity q^e between the first and second price level (Figure 4). As in PES-1, differences in marginal costs are exclusively embodied by season-specific efficient quantities and the number of patrols offered by teams at the efficient price outweighs the efficient number of patrols. The outcomes predicted per year associated with the first and second price levels are summarized in Table 5. As in PES-1, taking potential negative effects of high patrol densities in account might reduce the efficient price and quantity estimated in 'input space'.

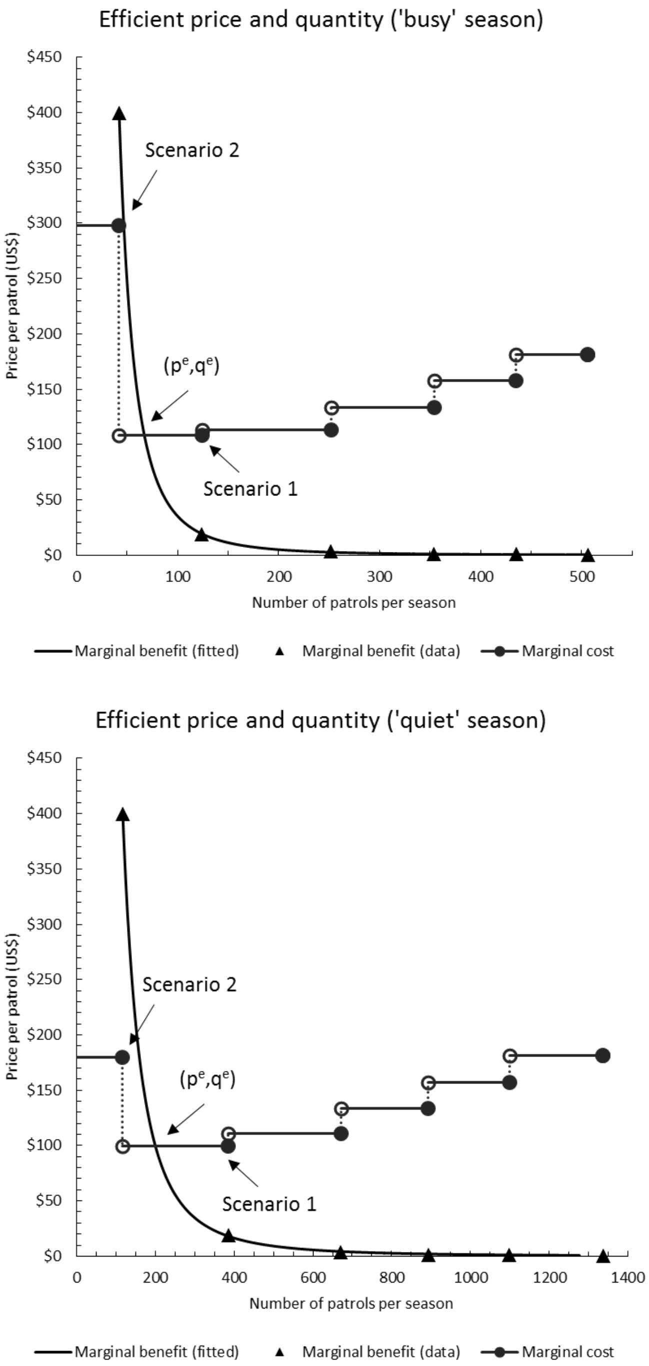


Figure 4: Efficient price and quantity in 'input space'

Table 5: PES scheme outcomes predicted per year (under Scenario 1 and Scenario 2)

	Scenario 1		**Scenario 2**
Number of villages with patrol teams	6		6
Number of patrol teams	28		17
Number of patrols	509		159
Average patrol frequency per km2 and month	4.8		1.5
Total benefits	$197,320		$161,354
Total costs	$69,210		$33,575
Total cost to teams	*$35,713*		*$8,749*
Total cost to agents	*$33,497*		*$24,826*
Total net benefits (total surplus)	$128,111		$127,779
Aggregate buyer payment	$51,864	($72,710)	$33,575
Aggregate payment from urban residents	*$6,011*	*($8,428)*	*$3,892*
Aggregate payment from international tourists	*$45,852*	*($64,282)*	*$29,684*
Aggregate supplier revenue	$51,864		$33,575
Aggregate supplier revenue to teams	*$39,213*		*$8,749*
Aggregate supplier revenue to agents	*$12,651*	*($33,497)*	*$24,826*
Consumer surplus	$145,457	($124,611)	$127,779
Producer surplus	-$17,346	($3,500)	$0
Producer surplus to teams	*$3,500*		*$0*
Producer surplus to agents	*-$20,846*	*($0)*	*$0*
Variable payments to village development funds	$4,797		$2,337

*Total cost to agents includes variable payments to village development funds

Suppliers were offered the number of patrols they each bid at the first price level (Scenario 2). In contrast to PES-1, none of the bids were withdrawn by the prospective suppliers once offers were made. In fact, three more teams joined the scheme, which increased the total number of patrols purchased by 16% compared to the number offered. Table 6 summarises the outcomes predicted to be generated by the purchased number of patrols.

Table 6: PES scheme outcomes predicted per year (purchased patrols)

	Purchased
Number of villages with patrol teams	6
Number of patrol teams	20
Number of patrols	184
Average patrol frequency per km2 and month	1.7
Total benefits	$169,730
Total costs	$36,796
Total cost to teams	*$10,125*
Total cost to agents	*$26,670*
Total net benefits (total surplus)	$132,934
Aggregate buyer payment	$36,796
Aggregate payment from urban residents	*$4,265*
Aggregate payment from international tourists	*$32,531*
Aggregate supplier revenue	$36,796
Aggregate supplier revenue to teams	*$10,125*
Aggregate supplier revenue to agents	*$26,670*
Consumer surplus	$132,934
Producer surplus	$0
Producer surplus to teams	*$0*
Producer surplus to agents	*$0*
Variable payments to village development funds	$2,656

*Total cost to agents includes variable payments to village development funds

6. Conclusions

In this report we have demonstrated how PES prices can be 'negotiated' by agents if the transaction costs cannot be lowered sufficiently to facilitate direct negotiations between buyers and suppliers. The pricing strategies used in both pilot PES schemes generated a net social benefit (surplus). The uniform pricing rule allowed suppliers to secure producer surpluses, while accounting for differences in opportunity costs of supply. Low cost suppliers were offered more patrols and as a consequence earn larger surpluses than high cost suppliers. The opportunity to earn surpluses provided suppliers with an incentive to participate in the conservation auctions and addressed equity concerns in a context of limited employment and income opportunities. Social exclusion and disruption was minimised through a supplier self-selection mechanism built into the conservation auctions.

Both schemes were designed to be adjustable to changing conditions. In a data-poor context, such as Lao PDR, the initial predictions of the dynamic population models that establish links between inputs and outputs are understood as a first approximation of reality. The model design enables periodic adjustments as more data are collected during the operation of the anti-poaching patrols. The accuracy of the model predictions is thus expected to increase over time. With the extent of the marginal benefits driven mainly by the number of buyers, accounting for potential negative effects associated with high patrol densities is expected to reduce the efficient price and quantity in 'input space'.

The design also allows agents to 'negotiate' different pricing for different locations and at different points in time. Agents have the opportunity to respond to changes in demand and supply after the completion of the supplier contracts. Repeating conservation auctions may reveal a change in the marginal costs of supply, with current suppliers leaving or new suppliers entering the 'market'. Innovation to generate cost savings is stimulated by the operation of a single price. Potential changes in demand can be captured by repeating the discrete choice experiments used to estimate the marginal benefits enjoyed by the buyers. Of course, any efficiency gains that might be achieved by adjusting the pricing to changes in demand and supply would be reduced by the transaction costs generated by these adjustments.

Designing and implementing the two schemes with the aim of mimicking market processes revealed some challenges. One challenge was presented by the format of the conservation auctions, which resulted in a discontinuous 'market' supply function. Its 'lumpiness' (represented by a step function), together with the promise that all teams would be offered the number of patrols they each bid at the determined price, resulted in allocative inefficiencies. Another challenge was 'matching' times frames. On the one hand, PES scheme sustainability requires ongoing supply with an associated ongoing benefit stream. On the other hand, ongoing supplier contracts would prohibit any adjustments to changing conditions described above. Consequently, contract periods of three years had to be matched with an ongoing supply.

The transaction costs of designing and implementing the two schemes are expected to decline significantly over the duration of the two pilot schemes. Start-up costs associated with developing the stochastic simulation models, the conservation auctions, and discrete choice experiments are 'sunk cost' and are irrelevant to the future operation of the two schemes. The auction design (including any manuals developed) can be used as a template if the auctions are repeated after the completion of the supplier contracts. The transaction costs are also expected to be lower for duplicate schemes introduced at other locations. The benefits estimated through choice experiments in the two pilot scheme locations may be applied at other locations through benefit transfer, a less costly method.

In this report, we have explored the extent to which market processes can be mimicked by PES schemes. Mimicking market processes requires the collection of data on demand and supply. The more data collected, the better is the mimicry. However, data collection is costly. Any efficiency gains generated through a higher degree of mimicry are reduced by the increased transaction costs associated with the additional data collection required. The marginal benefit of mimicry is diminishing. On the other hand, schemes designed with no regard to information on demand and supply bear the risk of making society worse-off. It remains unclear whether such schemes generate a social net benefit or loss.

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