9-2017

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Energy Policy 108 (2017) 102–110

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Indigenous community preferences for electricity services: Evidence from a choice experiment in Sarawak, Malaysia

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ARTICLE INFO

Keywords:
Rural electrification
Indigenous communities
Choice experiments
Sarawak
Malaysia
South-East Asia

ABSTRACT

Providing indigenous communities with electricity services requires an understanding of preferences to ensure that electrification schemes are congruent with the communities' specific development pathways. We contribute to the literature by using a choice experiment to rank and quantify household preferences for electricity services in two indigenous villages in Sarawak, Malaysia. Specifically, we disaggregated electricity services into five attributes: private use for household appliances and lighting, public use for community facilities, productive use for income generation, the operator model and the monthly tariff. We found that the most value was placed on the operator-model underpinning the provision of electricity services and that there was a strong preference for a community-based model over a utility-based model. Interestingly, our results suggest that the preference for a community-based operator model may be related to the experience of using electricity for productive uses. We contend that our results demonstrate the importance of social and institutional challenges to providing electricity services to indigenous communities in Sarawak and highlight the need for the state utility to engage with indigenous communities to overcome these challenges.

1. Introduction

The vast majority of the rural electrification literature focuses on relatively homogenous ethnolinguistic communities based in rural areas. This literature has yielded important insights on what is required to provide universal access to electricity services in these areas (e.g. Barnes, 2007; Sovacool, 2012; Van Gevelt 2014). The same cannot be said for indigenous communities. Often located in extremely remote rural areas, many indigenous communities are among the most income and energy poor in the developed and developing world (Eversole, 2005). In an effort to address this poverty, indigenous communities are often the targets of modernization policies initiated by the government. These modernization policies often clash with the preference of indigenous communities to follow their own development pathways that harness and manage external influences while consolidating elements of their traditional organizational structures and culture (Curry, 2003; Altman, 2004; Anderson et al., 2006; McCaskill and Rutherford, 2005).

Providing access to electricity for all rural communities requires the matching of schemes to community preferences. For example, Sovacool (2012) details how a variety of community preferences, such as a social norm prohibiting the collection of tariffs for electricity, inhibited the deployment of electrification schemes in Bangladesh, Papua New Guinea, and Nepal. The literature further details a number of unintended consequences that may result due to rural electrification schemes. These include, for example, increasing gender and income inequality, changes to the social fabric of villages and increased vulnerability of customary land to encroachment by state and non-state actors (Zomers, 2003; Perera, 2009; Wong, 2009; Knight and Gunatilaka, 2011). Taken together, this strongly suggests that providing access to affordable and reliable electricity services to indigenous communities requires a detailed understanding of community preferences to both ensure that electrification schemes are designed and implemented appropriately, and to ensure that the community is able to balance both intended and unintended outcomes of electrification to fit their own development pathways.

We contribute to the literature by using a stated-preference choice experiment to understand, rank and quantify preferences for electricity services for two indigenous communities in Sarawak, Malaysia. Section 2 provides an overview of indigenous communities and electricity services in Sarawak, with a particular focus on small-scale efforts to improve rural electricity coverage. Section 3 contextualizes the data collection process, choice experiment design and selected econometric estimation strategy. Section 4 presents the results of econometric

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http://dx.doi.org/10.1016/j.enpol.2017.05.054
Received 18 November 2016; Received in revised form 23 May 2017; Accepted 27 May 2017
Available online 31 May 2017
0301-4215/

models and our estimations of the marginal willingness-to-pay for attribute changes. Section 5 provides a discussion of our findings. Section 6 concludes with a focus on policy implications for both providing rural electricity services to indigenous communities in Sarawak and globally.

2. Indigenous communities and electricity services in Sarawak

Located in Borneo, Sarawak has a population of approximately 2.6 million people. Almost 70% of the population is comprised of indigenous groups, collectively known as Orang Ulu or Dayak.[1] Collectively, the Dayak face common problems of encroachment of customary land for mega-infrastructure projects and logging, disenfranchisement from the political process, and comparatively low economic, education and health outcomes (Lasimbang, 2015).

Although there has been a steady stream of out-migration from Dayak communities in the Borneo interior, the majority continue to live in small rural communities along rivers and streams in the highlands (Lee and Bahrin, 1993; Amster, 2006). There are an estimated 6235 villages in Sarawak of which 2216 are underserved with respect to access to electricity services. These communities typically rely on small petrol and diesel generator sets which run for an average of 2–3 h a day. A minority of communities are also served by pico-hydro solutions, or mini-hydro or solar-diesel hybrid systems funded by development agencies or universities and non-governmental organizations (NGOs) (Sarawak Energy, 2014).

The government's approach to rural electrification in Sarawak is coupled with plans for economic growth at the state-level. The focus has largely been on mega-hydro projects, such as the Bakun Hydroelectricity project with an installed capacity of 2400 MW, in order to provide the conditions required to attract heavy industry to the state. As a result, electricity generated from Bakun does not reach the underserved Dayak communities despite being built largely on Dayak customary land (Sovacool and Valentine, 2011; Sovacool and Bulan, 2013).

In parallel to mega-projects, the state utility – Sarawak Energy – is tasked with promoting small-scale efforts to improve rural electricity coverage in Sarawak (Government of Malaysia 2006). For villages within 30 km of the existing electricity grid, the preferred approach is grid extension. For villages more than 30 km from the electricity grid, an off-grid approach is adopted with a preference for deploying hydro-diesel hybrid or solar-diesel hybrid mini-grids. As of 2015, there were 66 villages powered by 30 hydro-diesel hybrid or solar-diesel hybrid minigrids in Sarawak. Examples include the mini-hydro plant at Long Banga in Ulu Baram which consists of two 160 kW run-of-river turbines and an 80 kW diesel backup generator serving 132 households and the Solar-diesel hybrid at Rumah Dau in Betong which has a combined generation capacity of 147 kW and serves 26 households. Capital and operational funding for off-grid solutions is provided from the Federal government with Sarawak Energy being responsible for generation, transmission and distribution of electricity. With regards to the operator model for off-grid solutions, Sarawak Energy favours a utility-based model with the state utility fully-owning, operating and maintaining the systems (Sarawak Energy, 2014).

There are numerous cases of unsuccessful rural electrification schemes among indigenous communities in Sarawak. For example, Bario, an indigenous community in the Kelabit Highlands, has been the site of two mini hydro-electricity plants and a wind farm that have all encountered significant issues due to poor planning, design and implementation of the schemes. The unsuccessful outcomes of such projects has been largely attributed to an inadequate understanding of the electricity needs of indigenous community members and their lack of involvement in the conceptualization, design and implementation stages of the process (Koay, 2011; Kiew, 2012; Holmes, 2015). Additionally, there are cases where indigenous communities have rejected proposals to be connected to the electricity grid citing concerns over tariffs being raised unilaterally and implications surrounding their customary land ownership rights (Penan village elders, pers comm, 2016). This suggests that there is a need to better understand indigenous community preferences for electricity services in order to allow for electrification schemes to be designed and implemented appropriately.

3. Methods

3.1. Study sites

Our choice experiment was undertaken in two remote Penan villages in the upper Baram region of Sarawak: Long Lamai and Long Kerong (Fig. 1). The two communities are reachable from the nearest city, Miri, only through a combination of twin-otter aircraft, four-wheel drive over logging roads and a one-to-three-hour boat ride through river rapids. The communities of Long Lamai and Long Kerong consist of 116 and 40 households, respectively. Both communities were only permanently settled approximately 50 years ago, when many of Sarawak's Penan transitioned from a nomadic forest-dweller livelihood to a settled or semi-nomadic livelihood. All Penan settlements, however, continue to rely on the forest for a wide range of non-timber forest products that provide, among other uses, food, medicine and construction material (Donovan and Puri, 2004; Siew et al., 2013).

Both communities aim to balance outside influences with traditional and cultural organizational structures and express a desire to follow their own development pathways. The main livelihood strategies for both communities are hunting and gathering from the forest and agriculture. Several households in both Long Lamai and Long Kerong supplement this by offering homestay experiences for a small number of tourists every year. Recent years have seen the permeation of the cash economy into the social fabric of both communities. The Malaysian Ringgit is now the preferred medium for both inter- and intra-community exchange in both communities although its salience is more pronounced in Long Lamai than Long Kerong. Both communities face challenges to their traditional way of life as a result of settling. This has manifested itself most significantly in increased migration of the youth due to few economic opportunities and the allure of urban life (Brosius, 2006).

In terms of infrastructure, Long Lamai has limited access (during the wet season) to electricity through a 12 kW run-of-river mini-hydro plant built and operated with the assistance of the University of Malaysia, Sarawak and the Japan International Cooperation Agency. Long Lamai is also served by a primary school and a community hall. These facilities are not found in Long Kerong. The communities of Long Lamai and Long Kerong are both familiar with private, public and productive uses of electricity due to, among other factors, their frequent visits to trading communities served by the electricity grid. Additionally, school-aged children in both communities often move as far as the city of Miri to attend school and, when visiting home for school vacations, bring back a familiarity with electricity services that is communicated to adult household members.

3.2. Choice experiment

With its basis in welfare economics and random utility theory, choice experiments are a stated preference method for non-market valuation. The underlying assumption behind a choice experiment is that any good, service, programme or policy is describable in terms of its attributes and the various levels that these attributes may take. Experimental design theory can then be used to create different profiles

[1] Indigenous groups include the Berawan, Bidayuh, Bisayah, Kayan, Kedayan, Kelabit, Murut, Penan and Punan (Lasimbang, 2015).

Fig. 1. Study sites.

with varying attribute levels that can be compiled into choice sets. These resultant choice sets are enumerated to respondents who select their preferred alternative generating data on: which attributes are valued by respondents; the ranking of valued attributes among respondents; and the economic value of marginal changes to attribute levels (Bennett and Birol, 2010).

Choice experiments have increasingly been used to provide insights into a variety of energy policy issues. The vast majority of choice experiments have focused on renewable energy sources in developed countries (e.g. Bergmann et al., 2008; Dimitropoulos and Kontoloen, 2009) with only a handful of choice experiments undertaken in developing countries, such as Abdullah and Mariel's (2010) choice experiment investigating the willingness-to-pay of rural households in Kisumu, Kenya to avoid power outages or blackouts. To date, the authors are unaware of choice experiments in the area of energy policy undertaken with indigenous communities in a developing country.

We can assume that electricity services can be described in terms of its attributes. We selected five attributes and their attribute levels on the basis of a literature review, a scoping study to the communities of Long Lamai and Long Kerong, and a workshop held with academics, practitioners and village representatives at the bi-annual eBorneo Knowledge Fair in Ba'kelalan in November 2015. In particular, we used a participatory mapping approach (see Fig. 2) to understand daily routines and electricity service needs of indigenous communities to determine five relevant attributes and appropriate attribute levels. Our five attributes are the private use for household appliances and lighting, public use for community facilities, productive use for income generation, the operator model and the monthly tariff.

We use hours per day, specifically the number of hours per day that the household has access to reliable electricity for lighting and powering all household appliances, to proxy for private use of electricity. This attribute consists of four levels: 6 h; 12 h; 18 h; and 24 h. To capture the preference of public use of electricity for community facilities, we use street lighting. Our street lighting attribute consists of two-levels: no and yes. Our third attribute, income generation, represents the preference for using electricity for productive use and consists of two levels: no and yes.

For our fourth attribute, the operator model, the mini-grid literature suggests four types of operator models: community-based, private-based, utility-based and a hybrid model. In general, community-based models are owned, operated and maintained by the community for the community. This often requires external financial and technical assistance and that the community operates an effective tariff system allowing for the community to cover depreciation, operation and maintenance. The private-model sees a private entity build, manage and operate the mini-grid. This tends to require both the private entity to raise equity- and debt-finance and for public sector subsidization in order to make a sound business case. The utility-based model sees a government or state utility owning and managing all aspects of the mini-grid. Lastly, the hybrid model combines elements of community-, private- and utility-based models (Franz et al., 2014).

We only included community-based and utility-based operator models as levels in our operator model attribute. This decision was made after in-depth discussions with Sarawak Energy who ruled out private-based models as being a feasible option for electrifying indigenous communities in Sarawak due to the lack of a bankable business model and previous experiences. Inclusion of a hybrid model was similarly not included due to the confusion caused among respondents when piloting the choice experiment with community members.

Lastly, the monthly tariff was included as a quantitative attribute in order to derive estimations in willingness-to-pay space. We used the rural electricity tariff charged by Sarawak Energy as a benchmark to create four attribute levels. We included four attribute levels to ensure sufficient variation within the attribute. The decision to label the attributes RM5, RM10, RM15 and RM20 was based on feedback received during the previously mentioned eBorneo Knowledge Fair.

We adopted a main effects experimental design that included two attributes with four levels and three attributes with two levels for our choice experiment. This resulted in up to 384 choice profiles. We used an orthogonal fractional factorial design to reduce the number of profiles to a set of 16 optimal choice profiles which were duplicated and randomly combined to form 16 balanced and non-dominant choice sets (Louviere et al., 2000) (Table 1).

The choice experiment was enumerated in a three-part questionnaire based on O'Sullivan and Barnes (2007) and Scoones (2009). The three-parts of the questionnaire were: understanding current access and attitude to electricity services (see Table S1); socio-economic

Fig. 2. Attribute selection through participatory workshops.

information (see Table S2); and the choice sets. The choice sets part of the questionnaire consisted of 16 choice sets that were presented with each choice set consisting of two unlabeled alternatives and an 'opt-out' option. Our survey was translated into the local language and redesigned using appropriately interactive imagery to ensure that respondents understood the attributes and differing attribute levels (see Fig. 3). The survey was piloted with Penan elders known to the co-authors, and enumerated by a Penan research assistant at the University of Malaysia, Sarawak in June and July 2016.

Significant effort was made to ensure against systematic biases from respondents. This included discussions with the village leadership highlighting the benefits of the research project to the two communities. In particular, village leaders in both Long Lamai and Long Kerong saw a benefit in being able to identify the preferences of their communities with respect to electricity services using a rigorous methodology that could be used to help select the optimal development

Table 1
Choice attributes and attribute levels.

Attribute	Description	Number of levels	Levels
Hours per day	The number of hours per day that households receive reliable electricity for lighting and household appliances	4	6; 12; 18; 24
Street lighting	Provision of electricity for street lighting	2	No; Yes
Income generation	The ability to use electricity for income generation	2	No; Yes
Operator model	The organizational structure of electricity service provision	2	Utility; community
Monthly cost	The monthly cost of electricity services to the household (in RM)	4	5; 10; 15; 20

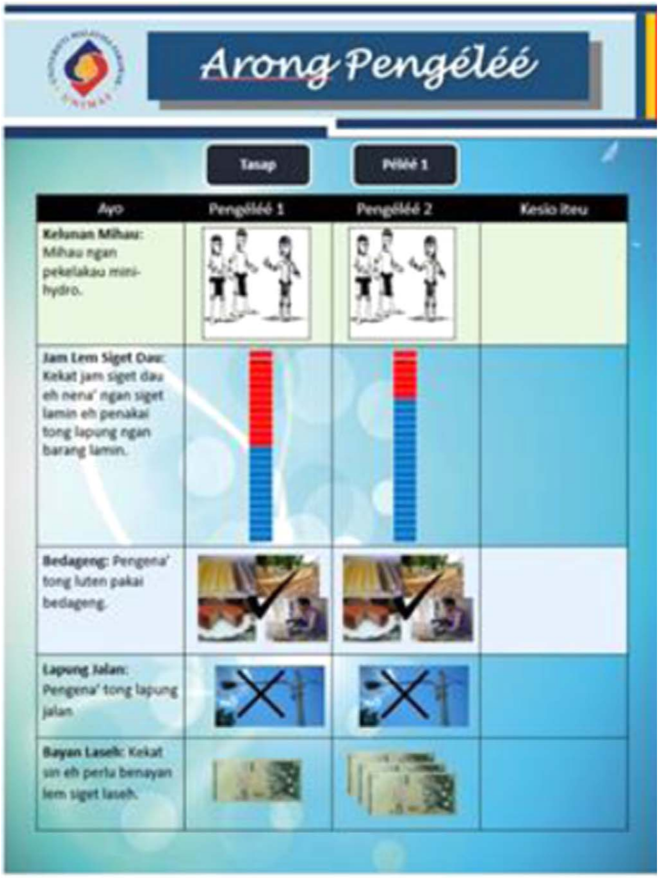

Fig. 3. An example of a choice set.

pathway for their communities. In addition, village leaders called community meetings to explain the research study and ensure the cooperation of households. Other measures taken included ensuring that each attribute and attribute-level was explained in-depth to each respondent during the enumeration process and sharing preliminary results with both communities in October 2016. There was general agreement with the preliminary results suggesting a high level of confidence in the initial respondents' responses in both communities.

In designing our sampling strategy, we sought to balance logistical limitations with statistical sample size requirements and enumerated our choice experiment to 100 households. We were, however, limited in our sampling approach by the fact that Long Kerong's total population consisted of only 40 households. We therefore sampled all 40 households in Long Kerong and randomly sampled 60 households in Long Lamai. Our survey achieved a 100% response rate and resulted in 100 usable questionnaires.

3.3. Econometric estimation strategy

We used a random parameter logit (RPL) model to analyze the data generated from our choice experiment. We selected the RPL model over the conditional logit (CL) model due to its ability to overcome the well-known limitations of the CL model.[2] By using the RPL model we are able to allow for preferences to vary across respondents as we are not restricted by the Independence of Irrelevant Alternatives (IIA) property (McFadden and Train, 2000). Following Dimitropoulos and Kontoleon (2009), our random utility function can be formally expressed as

$$U_{jtn} = \beta_{nk}' x_{jtnk} + \delta_k' z_n x_{jtnk} + \varepsilon_{jtn}, \tag{1}$$

where household n derives utility U from selecting alternative j in each of t choice sets available to the household. We assume that household utility consists of both a non-random observable contribution and a stochastic unobservable contribution. The observable contribution consists of a vector of k choice attributes, x_{jtnk}, and corresponding parameters, β_{nk}. Vector x_{jtnk} includes our five attributes: operator model, hours per day, income generation, street lighting and monthly cost. We do not include an alternative specific constant as our alternatives are generically labelled and there were an insufficient number of opt-outs to have non-zero within standard deviation (Abdullah and Mariel, 2010). Parameters vary across households according to a joint density function with a mean of $\beta_k$and a standard deviation of σ_k. ε_{jtn} is the unobservable contribution to household utility and takes into account specification error, measurement error and any unobservable attributes that may affect utility. We include household-specific characteristics, z_n, as determinants of some of the preference heterogeneity exhibited by households. Household-specific characteristics are interacted with choice attributes so that they do not drop out due to lack of variation across choices.

Household-specific characteristics include age, gender, education, household size, whether or not a household currently uses electricity for productive use, and a socio-economic asset index. Following Van Gevelt et al. (2016), the asset index is a composite variable consisting of individual household assets that are broadly representative of a household's socio-economic status. Selection of individual household assets was determined in consultation with academics familiar with Penan communities and community elders. A description of individual asset variables is presented in Table S3. The index was derived using principle component analysis. Formally, the asset index was defined as:

$$A_n = \sum_c f_c \frac{(a_{nc} - \bar{a}_c)}{s_c}, \tag{2}$$

where a_{nc} is the value of asset c for household n, a_c is the mean and s_c is the standard deviation. Uncorrelated linearly-weighted components were then derived from the initial variables and weighted by elements from the first eigenvector to create the composite variable.

Lastly, we exploit the compatibility of the choice experiment method with utility maximisation to calculate the marginal willingness-to-pay (WTP) for changes in attribute levels. The marginal WTP for each attribute can be calculated as:

$$WTP = -\frac{\beta_k}{\beta_m}, \tag{3}$$

where β_m represents the estimate of the monthly tariff attribute. To do this, we follow Train (2003) and Hole (2007) in using the maximum simulated likelihood method with 5000 random draws.

4. Results

4.1. Socio-economic characteristics

We present descriptive statistics for our six socio-economic variables in Table 2. As can be seen, the average household head in Long Lamai was 47 years old compared to an average age of 52 years in Long Kerong. Two household heads were female in Long Lamai compared with four female household heads in Long Kerong. The average number of years of education in Long Lamai was noticeably higher (7.33 years) than in Long Kerong (4.325 years). A total of 9 households used electricity for economic activities in Long Lamai compared with 2 households in Long Kerong. The average household size was remarkably similar for both Long Lamai (3.5 people) and Long Kerong (3.35 people). In terms of our asset index, the average household in Long

[2] The conditional logit model requires that the independence of irrelevant alternatives (IIA) property holds and that error terms are independent (McFadden and Train, 2000).

Table 2
Descriptive statistics.

Variable	N	N = 1	Mean	Std. Dev.	Min	Max
Age	100	–	48.89	14.091	22	81
Long Lamai	60	–	46.8	12.128	22	75
Long Kerong	40	–	52.025	16.271	25	81
Gender	100	6	–	–	–	–
Long Lamai	60	2	–	–	–	–
Long Kerong	40	4	–	–	–	–
Education	100	–	6.13	4.004	0	12
Long Lamai	60	–	7.333	3.433	0	12
Long Kerong	40	–	4.325	4.160	0	11
Productive use	100	11	–	–	–	–
Long Lamai	60	9	–	–	–	–
Long Kerong	40	2	–	–	–	–
Household size	100	–	3.44	1.553	1	8
Long Lamai	60	–	3.5	1.456	1	8
Long Kerong	40	–	3.35	1.703	1	8
Asset index	100	–	2.19e−09	1	−1.141	3.212
Long Lamai	60	–	0.319	1.095	−0.971	3.212
Long Kerong	40	–	−0.478	0.577	−1.141	1.280

*Note: Age refers to the age of the household head. Gender denotes a female household head. Education represents the number of years of education completed by the household head. Productive use refers to the use of electricity for economic activities. The variables used to calculate the asset index are described in the Supplementary information.

Lamai (0.319) can be considered to be more wealthy in terms of assets than the average household in Long Kerong (−0.478).[3]

4.2. Electricity services

In Long Lamai, all 60 surveyed households were connected to the mini-hydro plant. Households commented that there was not enough generation capacity for lighting and to power all their household appliances during the wet season. In the dry season, households reported that there was limited electricity due to drought and that electricity was conserved for public use, such as worship services at the Borneo Evangelical Mission Church. Electricity from the hydro mini-grid was provided free of charge to connected households, with a community-fund being used for operating and maintenance costs. A further 18 households operated petrol or diesel generators with 8 households relying on electricity generated from generators owned and operated by relatives. All 60 households used batteries, primarily to power torches for lighting when walking outdoors in the evening. Candles were used by 7 households and kerosene by a further 38 households. In Long Kerong, 15 households operated petrol or diesel generators and 13 households relied on electricity from generators owned and operated by relatives. All 40 households used batteries to light torches and 11 households used kerosene for lighting (see Table 3).

Electricity services used by households in both villages included lighting and household appliances, as well as tools. Household appliances included radio, mobile phones, television, electric fans, refrigerators, freezers, washing machines, rice cookers and electric kettles. Welders, drills, wood planers and chainsaws were also used by some households for economic activities. Households in Long Lamai did not pay a monthly tariff for electricity provided from the mini-hydro plant. Instead, a communal fund was used for its maintenance and operation. In total, households in Long Lamai paid an average of RM 41.04 per month for electricity services, with a minimum of RM 5, a maximum of RM 404.80 and a standard deviation of RM 69.33. Households in Long Kerong paid an average of RM 32.7 per month, with a minimum of RM 5, a maximum of RM 92, and a standard deviation of RM28.47. When asked about their perceived quality of electricity services, 50% of households in Long Lamai stated very poor and 50% of households stated poor. In Long Kerong, 58% of households stated very poor and 42% stated poor. Notably, no households selected adequate, good or very good.

[3] The asset index values presented in Table 2 refer to component scores. If the value is positive, then a higher score is associated with a higher component score. If the value is negative, then a higher score implies a lower component score.

Table 3
Electricity generation.

Generation technology	Pooled	Long Lamai	Long Kerong
Mini-hydro	60	60	0
Generator	33	18	15
Relative's generator	21	8	13
Batteries	100	60	40
Candles	7	7	0
Kerosene	49	38	11
N	100	60	40

4.3. Choice model estimations

Table 4 presents the results of our choice model estimations. These estimations highlight the goodness-of-fit for our model specifications, identify which attributes and interaction terms are statistically significant, and provide the basis for post-estimation calculations of the marginal willingness-to-pay, which allows for the ranking and quantifying of household preferences for electricity services.

Column (1) shows the results of a standard multinomial logit regression for our pooled sample that serves as our benchmark comparison. Columns (2–7) show the results of different specifications of our random parameter logit model detailed in Section 3.3. Starting with our multinomial logit specification, we find the coefficients of all five attributes to be statistically significant at the 1% or 5% significance levels. Our results suggest that households experience increasing utility when there is a community-based operator model, the more hours per day electricity is provided, the potential for income generation exists and there is street lighting. Households experience decreasing utility when the cost of the monthly tariff increases.

Column (2) shows results from our pooled random parameter logit model. An improved log-likelihood ratio[4] shows that this estimation is superior to the multinomial logit model estimated in column (1). In our estimation, we treat hours per day and monthly cost parameters as random with a logarithmic distribution. We find the standard deviations for both hours per day and monthly cost are statistically different than zero suggesting that these parameters vary across choice decisions and households. We find the coefficients for all five attributes to be statistically significant at the 1% level with the same signs as in our estimation in column (1). In column (3) we present the results from an augmented random parameter logit model for our pooled sample. In our augmented models, we include the interaction terms for age, gender, household size, asset index, and whether or not a household currently uses electricity for productive use with our five attributes. We only present statistically significant variables in Table 3. In addition to our five attribute levels being statistically significant at the 1% and 5% levels, we find that the interaction term of monthly cost and productive use is statistically significant at the 10% level with a positive coefficient. This suggests that households currently engaging in productive use of electricity experience increasing utility despite increases in the monthly tariff.

Columns (4–5) show the results from estimating the random parameter logit and the augmented random parameter logit models for the sub-sample of Long Lamai. We find that hours per day no longer benefits the model fit as a random variable. In column (4) we find all five attributes to be statistically significant at the 1% level. In our

[4] The log-likelihood ratio test is a statistical test that allows for a comparison of the goodness of fit between two models. A higher log-likelihood ratio indicates a better-fit.

Table 4
Choice model estimations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Attributes							
Hours per day	0.015***	0.084***	0.081**	0.069***	0.067***	0.120***	0.174**
	(0.005)	(0.011)	(0.034)	(0.012)	(0.213)	(0.022)	(0.073)
Street lighting	0.215***	0.859***	0.928**	0.617***	0.829***	1.237***	1.013
	(0.073)	(0.133)	(0.442)	(0.116)	(0.281)	(0.219)	(0.794)
Income generation	0.324***	0.985***	0.927***	0.662***	0.553***	1.601***	2.535***
	(0.073)	(0.098)	(0.295)	(0.116)	(0.175)	(0.188)	(0.661)
Operator model	0.162**	1.467***	1.365***	1.015***	1.144***	2.369***	2.671***
	(0.073)	(0.134)	(0.323)	(0.155)	(0.237)	(0.269)	(0.947)
Monthly cost	−0.069***	−2.048***	−1.641***	−1.765***	−1.649***	−2.349***	−1.739***
	(0.007)	(0.157)	(0.254)	(0.171)	(0.213)	(0.253)	(0.434)
Standard deviations							
Hours per day	–	0.047***	0.049***	–	–	0.082***	0.077***
		(0.013)	(0.013)			(0.019)	(0.020)
Monthly cost	–	1.139***	0.801***	1.028***	0.926***	0.908***	0.564***
		(0.161)	(0.185)	(0.193)	(0.226)	(0.218)	(0.213)
Interacted variables							
Operator model*productive use	–	–	–	–	−1.204**	–	–
					(0.564)		
Monthly cost*age	–	–	–	–	–	–	0.000*
							(0.000)
Monthly cost*gender	–	–	–	–	–	–	0.141*
							(0.076)
Monthly cost*productive use	–	–	0.122*	–	0.181**	–	–
			(0.067)		(0.078)		
Monthly cost*asset index	–	–	–	–	–	–	0.090*(0.053)
Observations	3150	3150	3150	1882	1882	1266	1266
Log-likelihood	−2141.880	−863.864	−851.635	−499.065	−488.252	−337.194	−318.541

Estimation (1): MNL. Estimation (2): Pooled RPL. Estimation (3): Pooled, augmented RPL. Estimation (4): Long Lamai RPL. Estimation (5): Long Lamai augmented RPL. Estimation (6): Long Kerong RPL. Estimation (7): Long Kerong augmented RPL.
Note: Only statistically significant coefficients are displayed in the augmented models.

augmented model (column 5), all five attributes remain statistically significant at the 1% level. The interaction tem between monthly cost and productive use of electricity is statistically significant at the 5% level suggesting that households engaging in productive use of electricity experience increasing utility despite increases in the monthly tariff. Additionally, the interaction term between operator model and productive use is statistically significant at the 5% level. This suggests that households currently engaging in productive use of electricity experience decreasing utility from a community-based operator model relative to a utility-based operator model.

Columns (6–7) show the results from estimating the random parameter logit and augmented parameter logit models for Long Kerong only. As in the pooled model, we find that the model fit benefits from including hours per day as a random variable. In column (6), we find all five attributes to be statistically significant at the 1% level. In column (7), street lighting is no longer statistically significant and hours per day is now only significant at the 5% level. The interaction terms of monthly cost and age, gender and the asset index are all statistically significant at the 10% level. This suggests that older household heads, female household heads and more asset wealthy households were more likely to experience increasing utility despite increases in the monthly tariff.

4.4. Marginal willingness to pay for attribute changes

In Table 5, we present our results for the marginal willingness-to-pay for each attribute. In all six specifications, coefficients for all four attributes are statistically significant at the 1% or 5% significance levels. For each attribute, a positive coefficient indicates that households are willing-to-pay more for a marginal change in attribute levels. In our augmented specification for our pooled sample (column 2), we find that households are willing-to-pay RM 4.859 more per month if the operator model is community rather than utility, RM 0.347 for more hours per day, RM 2.620 for the opportunity to generate income, and RM 4.614 for street lighting. For our Long Lamai sample (estimation 4), households are willing-to-pay RM 4.002 for a community operator model, RM 0.240 for more hours per day, RM 2.369 for the opportunity to generate income, and RM 1.741 for street lighting. For Long Kerong (estimation 6), we find that households are willing-to-pay RM 18.768 more for a community operator model, RM 1.158 for more hours per day, RM 11.723 for the opportunity to generate income and RM 9.529 for street lighting.

Table 5
Marginal willingness to pay for attribute changes.

	(1)	(2)	(3)	(4)	(5)	(6)
Hours per day	0.245***	0.347***	0.247***	0.240***	0.956***	1.158**
Street lighting	4.408***	4.614***	2.056**	1.741**	9.277***	9.529**
Income generation	3.364***	2.620***	2.517***	2.369***	12.338***	11.723***
Operator model	4.983***	4.859***	3.972***	4.002***	18.442***	18.768***

Estimation (1): Pooled RPL. Estimation (2): Pooled augmented RPL. Estimation (3): Long Lamai RPL. Estimation (4): Long Lamai augmented RPL. Estimation (5): Long Kerong RPL. Estimation (6): Long Kerong augmented RPL.
***, ** and * indicate statistical significance at the 1%, 5% and 10% levels.

5. Discussion

We found that households in our pooled sample derived increasing utility from private, public and productive use of electricity and a community-based operator model. Households derived negative utility from an increase in the monthly tariff. Interestingly, we found that households engaging in productive use of electricity experienced increasing utility despite an increase in monthly tariffs. When disaggregating the sample by community, we found that households in Long Lamai who engaged in productive use of electricity demonstrated decreasing utility under a community-based operator model relative to a utility-based operator model. We also found that households in long Lamai who engaged in productive use of electricity experienced increasing utility despite higher monthly tariffs. In Long Kerong we found that older household heads, female household heads and more asset wealthy households were more likely to experience increasing utility despite increases in the monthly tariff.

Our estimations further revealed that, for our pooled sample, households were willing-to-pay RM 4.859 per month more for electricity services provided through a community-based model compared to electricity services provided through a utility-based model. For our Long Lamai sample, households were willing-to-pay RM 4.002 per month for electricity services provided through a community-based model. For our Long Kerong sample, we found that households were willing-to-pay RM 18.768 per month more for electricity services provided through a community-based model. We attribute this preference to a desire for the two communities to follow their own development pathways and a general distrust of the government due to a history of contesting customary land ownership and the negative impacts of current mega-infrastructure projects, such as the Bakun Hydroelectric Project and the Murum Hydroelectric project (Sovacool and Valentine, 2011; Sibon, 2016).

The almost six-fold difference in willingness-to-pay for a community-based operator model between Long Lamai and Long Kerong can be attributed to two main factors. Firstly, Long Kerong is generally considered to be a more traditional and less progressive community than Long Lamai with less interaction with the wider world and less experience with the cash economy. Secondly, the existence of a mini hydro-plant in Long Lamai where households receive some electricity services for no monthly tariff may bias their willingness-to-pay for electricity services downwards.

Although we acknowledge the unique set of geographic, economic, political and social contexts that Long Lamai and Long Kerong are embedded within, we suggest that there are sufficient commonalities among many remote indigenous communities in Sarawak for our results to be of wider policy relevance within Sarawak (Eghenter and Jok, 2012). More specifically, our results suggest two important findings with policy implications for indigenous communities in Sarawak.

Firstly, our results quantitatively illustrate some of the social and institutional difficulties facing the state utility – Sarawak Energy – in providing electricity services to indigenous communities. This is a novel contribution as the overarching focus to date has been on technical and financial barriers. Specifically, we find that there is an overriding preference for electricity services to be provided through a community-based operator model due to a desire for both communities to follow their own development pathways and a general distrust of the government. This strong preference for a community-based operator model, however, is difficult to reconcile with ensuring sufficient generation capacity and reliability to provide electricity for private, public and productive uses. This is as community-based operator models tend to be limited to relatively small-scale and low technology systems due to, for example, a lack of capacity to maintain and repair more complex systems.

Secondly, our results suggest that the preference for a community-based operator model may be related to the experience of using electricity productively. For example, in Long Lamai we found that households who were using electricity for productive uses both preferred a utility-based operator model relative to a community-based operator model and were more willing to accept higher monthly tariffs. This suggests that households who associate direct economic benefits with electricity services are more likely to select options that guarantee access to reliable and adequate electricity services, even if this means a loss of community-ownership and a higher monthly cost. It is therefore possible that if more households were made aware of the economic benefits associated with the productive use of electricity there would be more of a willingness to accept a utility-based operator model that is better equipped to provide adequate and reliable electricity services for private, public and productive uses.

Our two main findings demonstrate the need for the state utility to invest time and resources in engaging with indigenous communities in order to overcome social and institutional challenges to providing access to electricity services. Using one such challenge - the strong preference for a community-based operator model - as an example, we suggest a two-fold approach for the state utility.

Firstly, we suggest that the state utility pilot a more flexible approach to operator models that cedes certain rights to the community to, for example, address concerns of 'land grabbing'. Such an approach would explicitly recognize the community preference for community-based operator models and the underlying reasons for this preference. This would then allow the state utility to work with communities to ensure that access to electricity services is congruent with the development trajectories of indigenous communities while being able to provide a superior level of electricity services than feasible through a community-based operator model. Secondly, we suggest that the state utility can reduce social and institutional barriers to electrification by engaging with indigenous communities to explore how electricity services can be used productively to generate direct economic benefits to communities. Such an approach, however, would likely require a targeted and coordinated effort to identify and enable the expansion of existing economic activities and the diversification into a new set of electricity-enabled economic activities.

6. Conclusions and policy implications

We used a stated-preference choice experiment to understand preferences for electricity services from households in the Penan communities of Long Lamai and Long Kerong. We found that households placed significant value on all five attributes of electricity services: private, public and productive use, operator model and the monthly tariff. We also found that households placed the most value on the operator-model underpinning the provision of electricity services and demonstrated a strong preference for a community-based model. Interestingly, our results suggest that the preference for a community-based operator model may be related to the experience of using electricity for productive uses. Taken together, our findings demonstrate the need for the state utility to invest time and resources in engaging with indigenous communities in Sarawak in an effort to overcome these social and institutional challenges to providing access to electricity services. Using the communities of Long Lamai and Long Kerong as an example, we suggest that the state utility consider piloting a more flexible approach to operator models and engage with communities to ensure that communities are able to generate direct economic benefits from the productive use of electricity.

Funding

Data collection for this article was funded by the Cambridge Malaysian Education and Development Trust (CMEDT) and through a grant from the Templeton World Charity Foundation (TWCF) (0096). The opinions expressed in this article are those of the authors and do not necessary reflect the views of CMEDT and TWCF.

Acknowledgements

We are thankful to Garen Jengan and participants at the eBorneo Knowledge Fair 2015 for their contributions during data collection. We would also like to thank Alvin Yeo Wee, Poline Bala, John Phoa, John Holmes, Bernie Jones, seminar participants at the Centre for Environment, Energy, and Natural Resource Governance, University of Cambridge and two anonymous reviewers for their helpful comments and guidance. We especially thank the communities of Long Lamai and Long Kerong for their hospitality and for their valuable time.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.enpol.2017.05.054.

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