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研究課題名（和文）Electricity Pricing and Subsidy for Energy Conservation in Developing Country: Evidence from Natural Experiment

研究課題名（英文）Electricity Pricing and Subsidy for Energy Conservation in Developing Country: Evidence from Natural Experiment

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交付決定額（研究期間全体）：（直接経費）　　3,200,000円

研究成果の概要（和文）：私は研究プロジェクトで収集したデータを使用して2本の論文を書きました。
1. "Short-run Impact of Electricity on Social Capital: Evidence from a Rural Electricity Program." 著名なジャーナル「Empirical Economics」から条件付き採択を受けています。
2. "Designing Nonlinear Electricity Pricing with Misperceptions: Evidence from Free Electricity Policy."（進行中）

研究成果の学術的意義や社会的意義
Access to electricity in developing countries is increasing. Effective pricing mechanisms are crucial to achieving environmental and developmental goals. This study examines the welfare effects of nonlinear pricing and the impact of electricity on social engagement and interactions.

研究成果の概要（英文）：I wrote two papers using data collected for the research project:
1. "Short-run Impact of Electricity on Social Capital: Evidence from a Rural Electricity Program". This paper has received conditional acceptance from the prestigious journal Empirical Economics, and I hope it will be published soon.
2. "Designing Nonlinear Electricity Pricing with Misperceptions: Evidence from Free Electricity Policy". This paper is still a work in progress. We plan to complete it this year and submit it to a top economics journal.

研究分野：Energy, Environment and Development

キーワード：electricity　nonlinear price　welfare　social engagement　social interactions

１．研究開始当初の背景

Access to electricity in developing countries is increasing, with the majority of electricity being generated from fossil fuels. Household electricity demand constitutes a significant portion of the total demand and is likely to rise with increasing income. This is expected to result in higher emissions from electricity generation under the current scenario. To address this, policymakers have implemented various pricing mechanisms to promote conservation while providing subsidies to low-income households. One popular mechanism is increasing block pricing, which subsidizes low-income households and encourages conservation among higher-income households through higher marginal prices.

Moreover, electricity is a primary target for policymakers aiming to achieve environmental goals. Consequently, carbon taxes are becoming a common policy instrument in developing countries. However, for such economic instruments to be effective, households must respond to nonlinear electricity prices. In this study, we examines whether consumers are responding to nonlinear electricity price and subsequent welfare effect. Further, in the electricity literature, the impact of electricity on economic outcomes has garnered significant attention. However, it remains unclear whether electricity also affects noneconomic outcomes such as social interactions and community engagements. This study also examines the effect of electricity on social engagement and interactions.

We use monthly administrative electricity consumption data from 2012 to 2018 in Bhutan. In Bhutan, increasing block pricing was adopted in the early 2000s. During our study period, the first tier ranged from 0 to 100 kWh, the second tier from 101 to 300 kWh, and the third tier for consumption exceeding 300 kWh. In October 2013, the government introduced a subsidy providing 100 kWh of free electricity per month to rural households, while urban households were not eligible. This subsidy program created differences in pricing schedule, which we leverage to identify whether households are responding to nonlinear electricity price in this study.

２．研究の目的

Nonlinear pricing, particularly increasing block pricing, is widespread in utility services such as electricity and water. With the introduction of environmental taxes, including carbon taxes, the electricity price will directly be affected. Therefore, this study aims to

examine whether households are responding to nonlinear electricity pricing. Additionally, during our study period in Bhutan, a subsidy program providing free electricity was introduced. Another objective of this study is to examine the welfare effects of such subsidy programs. Furthermore, using additional data collected during the study, we also investigate the impact of electricity provision on noneconomic outcomes such as social interactions and social engagement.

３．研究の方法

To examine whether households are responding to nonlinear electricity prices, we first apply bunching estimator following the methods of Saez (2010), Chetty et al. (2011), and Kleven and Waseem (2013). We estimate the counterfactual observations just below and above the subsidy threshold, where the marginal price increases, using the following polynomial regression:

$$c_j = \sum_{\{n=0\}}^{q} \beta_n \left(k_j\right)^n + \sum_{\{i \in K^L, K^U\}} \gamma_i \cdot \{k_j = i\} + u_j$$

where c_j is the number of observations in bin j, k_j is the mid-consumption of bin j, and q is the polynomial order. $K^L \; and \; K^U$ are k_j just below and above the subsidy threshold 100 kWh. In our study, the excluded bins are (95, 100] and (100, 105]. Furthermore, we assume that the subsidy would incentivize lower consumers to increase consumption, while high consumers may be incentivized to reduce consumption. Therefore, we also account for this assumption when counting the number of observations in bin j.

To estimate the effect of the subsidy on consumption, we use matching differences-in-differences following the approach of Deryugina, MacKay, and Reif (2020). Using nearest neighbor matching, we identify three similar urban households with a similar consumption pattern before the introduction of the subsidy (using consumption before the subsidy as a matching variable).

We also examine whether households are responding to marginal or average prices following Ito (2014). Specifically, we estimate the following regression model:

$$\Delta \ln kWh_{it} = \beta_1 \Delta \ln MP_{it} + \beta_2 \Delta AP_{it} + f_t(kWh_{it_m}) + \gamma_d + \delta_{bt} + u_{it}$$

Where $\Delta \ln kWh_{it}$ is the consumption difference between month t of current year and month t of the previous year. $\Delta \ln MP_{it}$ and $\Delta \ln AP_{it}$ are the marginal and average prices, respectively and $f_t\left(kWh_{it_m}\right)$ is the percentile of kWh_{it_m} where $t_m = t - 6$ which is expected absorb the correlation between the error term and prices. To address endogeneity of prices, we use instrumental variables regression using a simulated instrument approach. In particular, we project past consumption onto the current price schedule and use it as an instrument for the prices. Furthermore, we undertake a model-based approach to examine

the welfare effects by constructing a model for electricity demand. This approach is currently a work in progress.

４．研究成果

Bunching: Our raw data indicate significant bunching at the 100 kWh consumption threshold by rural consumers following the introduction of the subsidy. However, as shown in Figure 1, we do not observe similar excess bunching for rural consumers before the subsidy. To quantify the excess bunching, we estimate the bunching ratio, which is the ratio between the number of observation in the sample and the counterfactual in the excluded regions. Our results show that after the introduction of the subsidy, the number of observations has increased by about two times compared to the counterfactual observations.

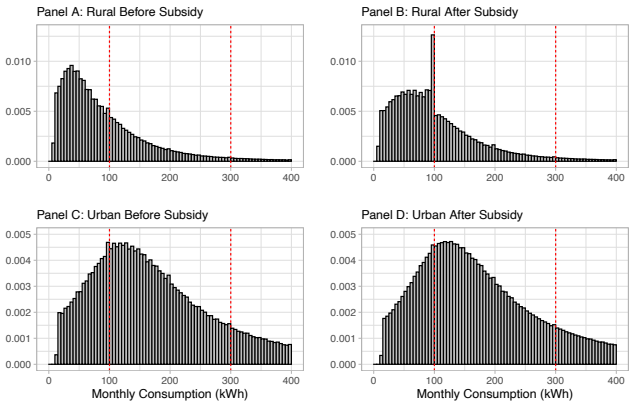

Figure 1: Distribution of consumption before and after subsidy by rural and urban consumers

IV Results: The regression results on whether consumers are responding to marginal or average prices indicate that households in Bhutan are responding to the marginal price, not the average price. The regression results are reported in Table 1. Although the coefficients for both average and marginal prices are negative, the coefficient for the average price is not significantly different from zero. This result is likely capturing the household response to marginal price after the introduction of the subsidy, specifically for rural households. Alternatively, the findings suggest that households respond to the marginal price when the change in the marginal price is substantial.

	(1)	(2)	(3)
MP	-0.187***		-0.183***
	(0.007)		(0.024)
AP		-0.147***	-0.003
		(0.005)	(0.019)
Bill-cycle FE	Yes	Yes	Yes
District FE	Yes	Yes	Yes
N	6484489	6484489	6484489

Note: Outcome variable is the difference of log(kWh) of same month in the previous year. Sample period starts from January 2012 to December 2018. Standard errors are clustered at household level. Above model is estimated without controlling for rural fixed effect because the electricity price schedule differs between rural and urban and rural fixed effect is likely to capture the differences of the prices schedule between urban and rural.

Matching Difference in Difference results:

The results of the matching difference-in-difference analysis, which examines the effect of the subsidy on electricity consumption, are reported in Figure 2. The matching period refers to the time frame used to match rural households with urban households that had similar consumption patterns before the subsidy was introduced. The placebo period is the period before the subsidy introduction.

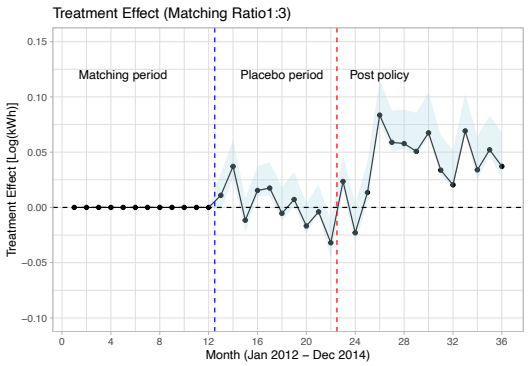

Figure 2: Effect of subsidy on consumption

Figure 2 shows the point estimates after the policy implementation along with the corresponding standard errors obtained from the subsample methods. On average, our results suggest that the subsidy increased electricity consumption in rural areas.

Effect of Electricity on noneconomic outcomes: Using the subset of data collected for this study, we also examine the effect of electricity provision on noneconomic outcomes such as social engagement and social interactions. Since electricity provision is an endogenous variable, we use land gradient as an instrument and estimate bivariate probit models. Additionally, we employ matching methods to estimate the effect of electricity on various measures of social engagement and interactions. The results are summarized in Figure 3. Overall, our findings indicate that in the short run, the effect of electricity on noneconomic outcomes is not distinguishable from zero. This paper is submitted to the journal Empirical Economics and has received conditional acceptance.

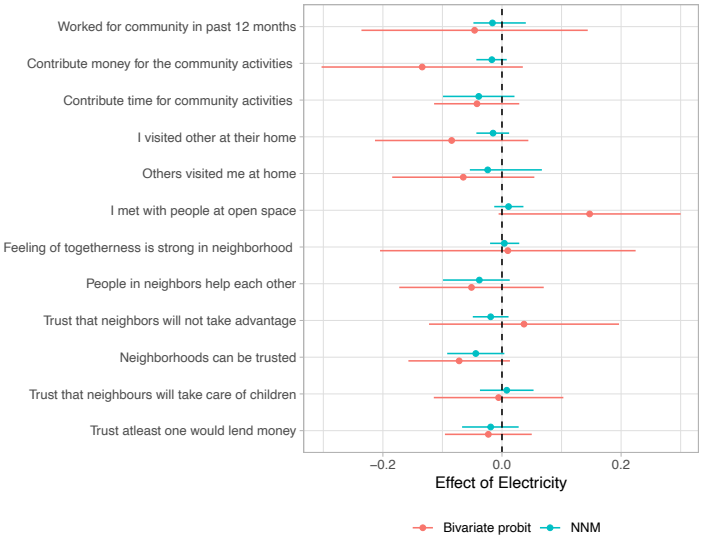

Figure 3: Effect of electricity on social engagement and interactions

５．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　1件／うちオープンアクセス　0件）

１．著者名 Ngawang Dendup, Dil Rahut and Yayue Xiao	４．巻 -
２．論文標題 Short-run Impact of Electricity on Social Capital: Evidence from a Rural Electricity Program	５．発行年 2024年
３．雑誌名 Empirical Economics (Conditional Accpetance)	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計2件（うち招待講演　0件／うち国際学会　2件）

１．発表者名 Ngawang Dendup
２．発表標題 Designing Nonlinear Electricity Pricing with Misperceptions: Evidence from Free Electricity Policy
３．学会等名 2023 Australian Conference of Economist（国際学会）
４．発表年 2023年～2024年

１．発表者名 Ngawang Dendup
２．発表標題 Designing Nonlinear Electricity Pricing with Misperceptions: Evidence from Free Electricity Policy
３．学会等名 2023 Asian Economic Development Conference（国際学会）
４．発表年 2023年～2024年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

In September, we will travel to Bhutan and present our findings to utility company Bhutan Power Corporation and Bhutan Electricity Authority.

6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考
研究協力者	遠山 (Toyama Yuta)		
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研究協力者	ヤユエ (Xiao Yayue)		

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関