OPT-IN TOU TARIFF AND HOUSEHOLD ELECTRICITY CONSUMPTION: LESSONS FROM JEJU ISLAND, KOREA

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Overview

As global efforts to reduce greenhouse gas emissions strengthen, renewable electricity generation has expanded, leading to shifts in net electricity demand and growing importance in managing electricity consumption. Advances in metering infrastructure now enable time-varying tariffs, which reflect marginal costs and are recognized as critical for enhancing market efficiency. In South Korea, discussions on time-of-use (TOU) tariffs for residential electricity began in the late 2010s to provide households with more choices and accommodate renewable energy growth. Recently, an opt-in TOU tariff for residential electricity was introduced in Jeju Island in September 2021, allowing households to voluntarily switch from the standard tariff.

This paper evaluates the impact of the opt-in TOU tariff on household electricity consumption in Jeju using a difference-in-difference (DID) approaches, addressing challenges like self-selection and variations in enrollment timing. Results indicate a significant reduction in the share of electricity consumption during peak hours among TOU households but a notable increase in the share of consumption during off-peak hours. When it comes to the impact on daily electricity consumption, we observe somewhat mixed results. The traditional DID estimates suggest increased daily consumption, while the staggered DID estimates yield no significant overall changes. These findings emphasize the importance of rate structure design in ensuring the coexistence of TOU and standard tariffs, as program effectiveness depends heavily on how rates are structured and implemented.

Unlike earlier experimental studies[1, 2], recent research focuses on full-scale implementations, such as those in Canada [3], Australia [4], and Spain [5], where TOU tariffs were default or single options. This study contributes to the literature by examining an opt-in structure, addressing unique challenges like varitations in enrollment timing. This paper offers insights into how opt-in TOU programs can be designed to optimize electricity consumption patterns and informs future policy decisions.

Data and Methods

This paper utilizes data on hourly electricity consumption of households from September 1, 2020-August 31, 2022, covering one year before and one year after the introduction of the TOU tariff in Jeju Island. The pre-period is defined as the year preceding the introduction of the TOU tariff, from September 1, 2020 to August 31, 2021. Similarly, the post-period is defined as the year following its introduction, from September 1, 2021 to August 31, 2022. During the post-period, 1,460 households have enrolled the TOU tariff and they were considered as the treatment group. we constructed the control group by selecting households in Jeju Island that consumed over 450 kWh per month but chose to remain on the standard tariff. To construct the control group, we selected households with average monthly electricity consumption over 450 kWh, resulting in 11,526 households. The construction of the control group is based on our calculations indicate that households consuming over 450 kWh per month can reduce their electricity bills simply by switching from the standard tariff to the TOU tariff, without adjusting their consumption behavior.

Our empirical strategy to estimate the impact of the TOU tariff in Jeju Island relies on a DID estimator. By comparing the control and treatment groups across the pre- and post-periods, we identify the average treatment effect on treated (ATT). The empirical model used to detect changes in electricity consumption behavior induced by the TOU tariff for household i at day t can be expressed as:

$$\mathrm{y}_{\mathrm{i,t}} = \tau \cdot 1[TOU]_i \times 1[Post]_t + \beta \cdot 1[TOU]_i + \alpha \cdot 1[Post]_t + x_{i,t}\theta + \mu_i + \lambda_t + \varepsilon_{i,t}$$

where where μ_i denotes region-specific effects where household i is located, capturing all time-invariant region-specific characteristics associated with electricity consumption. λ_t indicates the year, month-specific effects, as well as day-of-the-week-specific effects. Lastly, $x_{i,t}$ is a set of potential explanatory variables and $\varepsilon_{i,t}$ is idiosyncratic error

terms. The outcome of variables, $y_{i,t}$, is the share of electricity consumption in the peak, mid-peak, and off-peak hours, $S_{i,t}^{k}$ where k ∈ (peak, mid-peak, off-peak), or natural log-transformed daily electricity consumption.

Results

Our results shown in Table 1 reveal three key findings. First, TOU-enrolled households shifted more electricity consumption to off-peak hours, reducing their peak-hour share as intended by the tariff design. Second, while the load-shifting effect reflects a change in consumption patterns, the TOU tariff also appeared to increase daily electricity demand. However, this was not supported by the staggered DID results. Before the TOU tariff, TOU-enrolled households consumed less electricity than the control group but surpassed their daily consumption in the post-period.

Table 1 Estimation results

	(1)	(2)	(3)	(4)
Dependent variable	Peak share	Mid-peak share	Off-peak share	Daily consumption
1[TOU]·1[Post]	-0.003***	-0.000	0.003**	0.030**
	(0.001)	(0.001)	(0.001)	(0.012)
1[Out]·1[Post]				
1[TOU]	0.004***	-0.003*	-0.001	-0.072***
	(0.001)	(0.002)	(0.002)	(0.012)
1[Out]				
1[Post]	0.002***	-0.010***	0.012***	-0.003
	(0.000)	(0.000)	(0.001)	(0.003)
Constant	0.418***	0.197	0.386**	2.775***
	(0.106)	(0.123)	(0.156)	(0.706)

Conclusions

This study confirms that the TOU tariff implemented on Jeju Island successfully encouraged households to adjust their electricity consumption patterns by reducing usage during peak hours and increasing it during off-peak periods. This demonstrates the potential for demand response in residential electricity. Additionally, the study notes that TOU-enrolled households increased their daily electricity consumption, potentially exploiting the tariff to reduce costs without changing usage behavior, especially households with higher baseline consumption. To ensure TOU tariffs promote optimal resource allocation and prevent revenue loss for KEPCO, adjustments are needed, such as reducing block-specific rate differences in the standard tariff and periodically updating TOU rates based on supply costs.

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