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How to Tell if Time is on Our Side: Measuring Whether Time-of-Use Rates Cause Economic Hardship

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ABSTRACT

Utilities have demonstrated concern that Time-of-Use (TOU) rates may cause undue economic hardship for customers, particularly senior and low-income customers who may have difficulty reducing or shifting their usage to off-peak hours, and therefore may experience hardship from paying higher bills. One of the primary challenges to determining whether TOU rates cause economic hardship is measuring such a complex concept. Analyses of electricity bills can measure bill impacts after switching to a TOU rate, but not whether these impacts caused economic hardship.

This paper presents a methodology for measuring economic hardship, drawing from a randomized controlled trial (RCT) study of over 55,000 California households that were assigned to either a TOU or standard rate. To measure economic hardship, the research team designed survey questions to measure specific aspects of economic well-being. A mixed-mode approach (mail, phone, web), combined with bill credit incentives, resulted in impressive response rates (82%) and representativeness (including non-English speaking households, seniors, and other traditionally hard-to-reach segments) in this dual-wave multi-language survey. Factor analysis identified survey questions that collectively measured economic hardship, forming the construction of an economic hardship index. The researchers then statistically compared hardship between customer segments on a TOU rate and those on the standard rate. This dual-wave RCT approach provides a valid and reliable means for assessing the extent to which TOU rates caused economic hardship and whether hardship changed throughout the course of the pilot. The paper details the methodological approach, key findings, and some benefits and challenges of the approach.

Introduction

In Decision 15-07-001, the California Public Utilities Commission (CPUC) ordered California's three largest investor owned electric utilities (IOUs) to conduct pilot programs and studies of residential TOU electric rate designs, beginning in the summer of 2016. California's three largest electric IOUs are: Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas and Electric (SDG&E). The IOUs had to file applications proposing default TOU rates for residential electric customers no later than January 1, 2018. In accordance with this Decision, all three IOUs piloted up to three unique TOU rates from Summer 2016 through December 2017.

Further, Public Utility Code Section 745 required the IOUs to ensure that any default TOU rate schedule does not cause unreasonable hardship for senior and economically vulnerable households in hot climate regions. Research Into Action, Inc. conducted primary research on behalf of the IOUs to investigate

whether any of the piloted TOU rates resulted in increased economic hardship for vulnerable households in hot climate regions.[1]

Some prior research found both load reduction (Potter, George, and Jimenez 2014) and bill reduction (Simmons and Rowlands 2007) for low-income customers on TOU rates. Conversely, accompanying research for this study found that on average all customers – including low-income customers – had higher electricity bills under TOU rates in summer months (George et al. 2017). However, (to the authors' knowledge) prior TOU bill or load impact research has not explored whether these impacts caused significant economic hardship for vulnerable populations. Thus, the underlying purpose of this research is to answer the following question: *if vulnerable populations experience higher electricity bills under TOU rates, does this bill increase significantly worsen their economic well-being, or does the increased bill have no substantial effect on their economic livelihood?*

Methods

One of the key objectives for the TOU pilots was to investigate whether any bill impacts stemming from TOU rates negatively impacted the economic well-being of low-income customers residing in hot climates. Since bill impacts alone cannot expose the more sociological issue of whether TOU rates cause economic hardship, we relied on customer surveys to answer this research question. An integral part of pilot design was to conduct two surveys, one at the end of the first summer and the other at the end of the first full year on the TOU rates. A substantial portion of the "pay-to-play" incentives used to recruit customers into the study were tied to completion of the surveys to obtain high response rates for all customer segments (including non-English households, seniors, and other traditionally hard-to-reach segments). Achieving high response rates (and thus representativeness) is essential to obtaining valid insights regarding some of the key research issues of interest. The remainder of this section provides an overview of the survey design, implementation, and analytical methods that were applied to obtain key research findings, and other implementation and methodological issues useful for understanding and interpreting key survey findings.

RCT Pilot Approach

A key objective of any pilot or experiment is to establish a causal link between the experimental treatments (e.g., TOU rates) and the outcomes of interest (e.g., economic hardship). The most effective way to do this is through a RCT research design. With this approach, participants are offered a treatment and, after they agree to accept it, they are randomly assigned to either the treatment or control condition. This ensures that treatment and control customers are identical in every way except for exposure to the treatment. As such, any observed difference in economic hardship between treatment and control customers results from either the treatment of interest (e.g., TOU pricing) or random chance. The research team used an RCT design in these pilots.

A key challenge in designing the pilots was deciding how to gain insights from residential opt-in TOU pilots that might help inform policy decisions for residential default TOU pricing, since default TOU pricing was not allowed at the time of the pilots. To better represent the mix of customers that are likely to be enrolled under default conditions, the pilot implementation team used what came to be called a "pay-to-play" (PTP) recruitment strategy. Under this approach, rather than recruit customers onto a specific rate by educating them about the features and potential benefits associated with the rate, as a typical opt-in pilot or program might, the pilot implementation team offered prospective participants an

[1] This paper represents just a small portion of the California Opt-in TOU Pilot research. To learn more about the pilot activities and the research results (including bill and load impacts), readers are encouraged to consult George et al. 2017.

economic incentive for agreeing to participate in the pilot and then randomly assigned participants to one of the TOU rate options or to the control condition.

Another important aspect of the pilot design – and the focus of this paper – involved assessing whether TOU rates may cause unreasonable hardship for selected customer segments. Public Utility Code Section 745 requires that the CPUC ensure that any default TOU rate schedule does not cause unreasonable hardship for senior citizens or economically vulnerable customers in hot climate regions. To provide insights on this important issue, the research team developed a stratified sampling and recruitment plan. The team also divided each IOU service territory into three climate regions (designated as hot, moderate, and cool). Within the hot regions, the pilot implementation team oversampled senior households and low-income customers enrolled in the CARE/FERA programs.[2,3]

Survey Design and Implementation

The research team developed a 20-minute mixed-mode survey to answer several key research questions, including whether studied TOU rates increased economic hardship. The research team designed the survey for online, mailed paper, and phone modes. Following Dillman's Tailored Design Method (Dillman, Smyth, and Christian 2014), survey implementation involved a mixed-mode approach to achieve a high response rate from pilot participants and minimize non-response bias. The researchers attempted to reach a complete census of all 55,269 pilot participants, recruiting them to the survey about four months after the pilot began. To encourage survey participation, respondents were offered bill credit incentives; on average, respondents received a $55 bill credit for responding. Pilot participants with email addresses on file received an invitation letter with a web link via the U.S. mail, then two email invitations. Non-responders received a mailed questionnaire and a phone call. Pilot participants without email addresses received a mail invitation letter with web link, followed by an additional mailed reminder letter. Non-responders received a mailed questionnaire, a follow-up postcard reminder, and, finally, a phone call (Figure 1). All participants who did not respond via email or mail received between one and five phone calls.

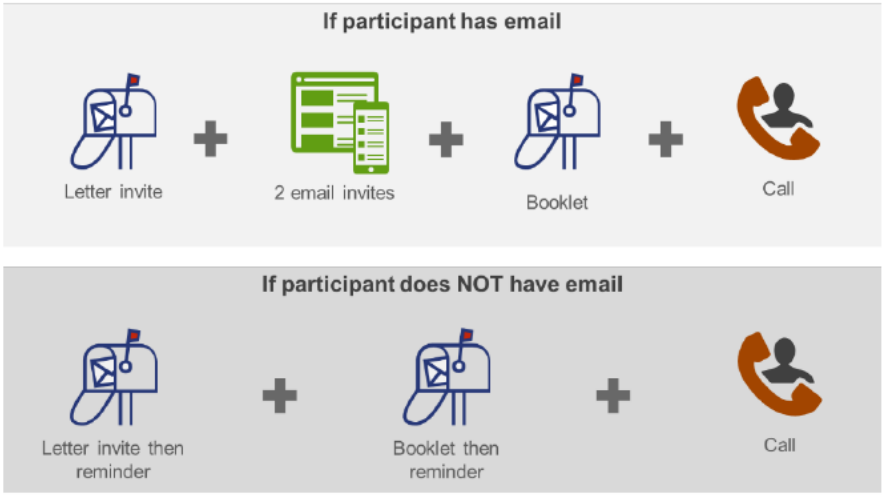

Figure 1. Survey implementation process.

Ultimately, this method achieved a response rate of 82% for both surveys. Lower-income, hard-to-reach populations had lower response rates; however, all response rates were sufficiently high to

[2] Senior households are defined as households with one or more household members with an age of 65 or older.
[3] California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA).

minimize non-response bias. Response rates were very similar between control and treatment groups, which ensures the internal validity of key findings based on comparisons across groups.

Analysis: Developing an Economic Hardship Metric

One of the primary purposes of this study was to assess whether TOU rates cause unreasonable economic hardship for particularly vulnerable households, such as seniors or low-income customers living in hot climate regions. To do this, the research team needed to create a valid, reliable economic index metric using rigorous methods. Table 1 summarizes the process for developing the economic hardship metric.[4]

Table 1: Economic Hardship Metric Development Process

Metric Development Step	Methods Used
Step 1: Generate Items and Gather Data	Mix of new and established items in mixed-mode survey
Step 2: Reduce Data to a Model	Exploratory factor analysis
Step 3: Confirm Model	Cronbach's alpha and Composite Reliability (CR)
Step 4: Generate Metric	Index computation of items loading in factor analysis

Step 1: Generate Items and Gather Data. To ensure comparisons of economic hardship, the research team designed survey questions to assess multiple aspects of economic difficulty, such as a person's self-rated concern for being able to pay their bills, the means used to pay bills (such as household income, loans from friends/family, forgoing paying rent, etc.), and the difficulty customers had paying their bills during the pilot period. The researchers also included questions from previously validated metrics of financial health, such as the Consumer Financial Protection Bureau's (CFPB) Financial Well-Being Scale (CFPB 2015).[5] For the first three CFPB items, the survey asked respondents how well each of the three statements described their financial situation using a scale of "not at all," "very little," "somewhat," "very well," and "completely." For the last two items, the survey asked respondents how often each applies to them using a scale of "never," "rarely," "sometimes," "often," and "always." The CFPB items are:

- Because of my money situation, I feel like I will never get the things I want in life
- I am just getting by financially
- I am concerned that the money I have won't last
- I have money left over at the end of the month
- My finances control my life

Using newly-developed questions in concert with previously validated ones ensured that the survey included both traditional views on financial health as well as elements of financial hardship specific to electricity rate design.

Step 2: Reduce Data to a Model. To prepare the data for Step 2, the researchers identified all survey questions related to economic status and created interval-level indices out of ordinal or categorical survey items as described below:

[4] Table 1 outlines the process used for the first survey. The researchers followed the same process for the second survey, except the factor analysis of the second survey data was confirmatory – as opposed to exploratory – as it served to confirm that the underlying items from the original economic hardship metric continued to load onto a factor together (and thus continued to collectively operationalize the latent concept of economic hardship).

[5] The Researchers used The CFPB's methods for the abbreviated version of their "Financial Well-Being Scale."

- Summed the response values for three 0 to 10 Likert scale items related to how the respondent's rate plan works for them.[6] Scores ranged from 0 to 30, with 30 interpreted as high agreement that the rate works well for the respondent.
- Summed the response values for the number of times respondents had trouble paying both their electricity bill and other important household bills since the beginning of the pilot.[7] Scores ranged from 0 to 6, with a score of 6 corresponding to six or more times the respondent had trouble paying their important household bills.
- Summed the number of different methods a respondent used to pay their household bills outside of using their current monthly income. Scores ranged from 0 to 10, with a score of 10 interpreted as the respondent using ten alternative methods (e.g., borrowing money from a friend) to pay their bills.
- Calculated the CFPB financial well-being index using five Likert scale items, as dictated by the CFPB's published methods for the index. Scores ranged from 19 to 90, with a score of 90 corresponding to a very financially secure respondent.
- Used a 0 to 10 Likert scale item indicating concern about paying bills, with a 10 meaning a respondent was very concerned about paying their bills.

Next, the research team analyzed the transformed data using exploratory factor analysis (EFA). EFA methods serve two purposes: 1) as a data reduction method to identify items that are not useful, and 2) as a tool to reveal underlying, or "latent," patterns in the survey data. EFAs are ideal for exploring potential metrics because the method groups (or "loads") statistically-related items together into "factors." Thus, the end result of EFA defines a set (or sets) of variables that collectively measure one or more larger constructs. These resulting factors expose amalgamations of individual metrics that - when combined - more effectively measure a complex concept (such as "economic hardship") than any of the factor's underlying survey items can in isolation.

Because the range of possible values on the items used in the EFAs varied considerably, respondent values for these variables were standardized into z-scores, in which a score of zero reflects the sample mean and a score of one is one standard deviation away from the mean. Standardizing responses eases comparisons across items with dissimilar scales and improves factor analysis compatibility, without sacrificing variability.

Because EFA is an exploratory method, the initial models included potentially relevant survey items that were not included in the final model. Ultimately, the researchers chose a factor that included loadings from four of the five variables initially tested. The first bullet from the list above denotes the item that did not load on this factor. Table 2 exhibits the items, as well as their rotated factor loadings, from the final model that guided construction of the economic hardship index. As seen in Table 3, the final model passed all diagnostic tests and explained a considerable amount of variance.

Table 2: EFA Results (After Excluding Item One)

Item	Rotated Factor Loading
Concern for bill payment	0.869
Problems paying bills	0.847
CFPB financial well-being index	-0.669
Number of alt. ways used to pay bills	0.569

[6] Cronbach's alpha = 0.91. Cronbach's alpha measures the internal consistency of the source variables included in the index. Scores of 0.7 and higher demonstrate satisfactory internal consistency.

[7] Cronbach's alpha = 0.84.

Table 3: Additional EFA Information

Extraction method	Principal Axis
Rotation method	Oblimin with Kaiser Normalization
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.800
Bartlett's Test of Sphericity	0.000
Eigenvalue	2.681
Variance explained	67%

Step 3: Confirm Model. To assess convergent validity, the research team calculated the Average Variance Extracted (AVE) by averaging the squared factor loadings. The final model resulted in an AVE score of 0.56. A value above 0.5 is acceptable (Fornell and Larcker 1981). To assess reliability of the items in the model, the researchers calculated Cronbach's alpha and Composite Reliability (CR) scores. The resulting Cronbach's alpha of 0.84 and CR of 0.84 indicate a good measure of internal consistency between the four items the EFA identified as potential inputs to the economic index metric.

Step 4: Generate Metric. To calculate the final economic index scores, the research team combined the four items into one metric. For this multi-step process, the research team inverted the z-scored values from the financial well-being index to match the direction of the other three variables to be included in the index (where higher scores mean higher economic difficulty). The researchers then summed the values from these four items into an initial score. To make the metric easier to interpret, the researchers normalized the metric such that a score of zero means the absence of economic difficulty and 10 means complete economic difficulty as measured by the survey. The research team used the following formula for normalizing the economic index metric:

$$Economic\ Hardship\ Score = \frac{(Initial\ Index\ Score + Min\ Observed\ Score)}{(Max\ Observed\ Score + Min\ Observed\ Score)} * 10$$

Most (84%) respondents provided responses to all questions necessary to calculate the economic index. Non-CARE/FERA customers had higher response rates than CARE/FERA or other targeted segments, but overall the question-level response rates were very high across all segments. Figure 2 shows the distribution of economic index scores for first wave survey respondents.

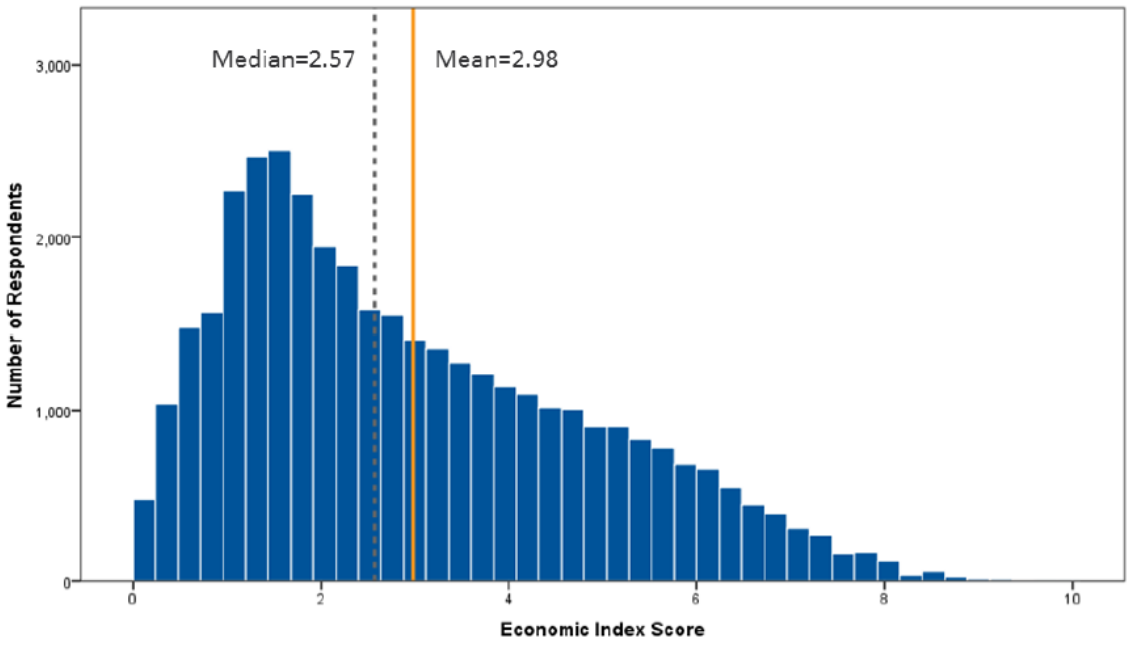

Figure 2: Histogram of Economic Index Scores

As seen in Figure 3, CARE/FERA households tended to have higher economic index scores than the non-CARE/FERA segment.[8] Conversely, the distribution of economic index scores for seniors was similar to non-senior households.

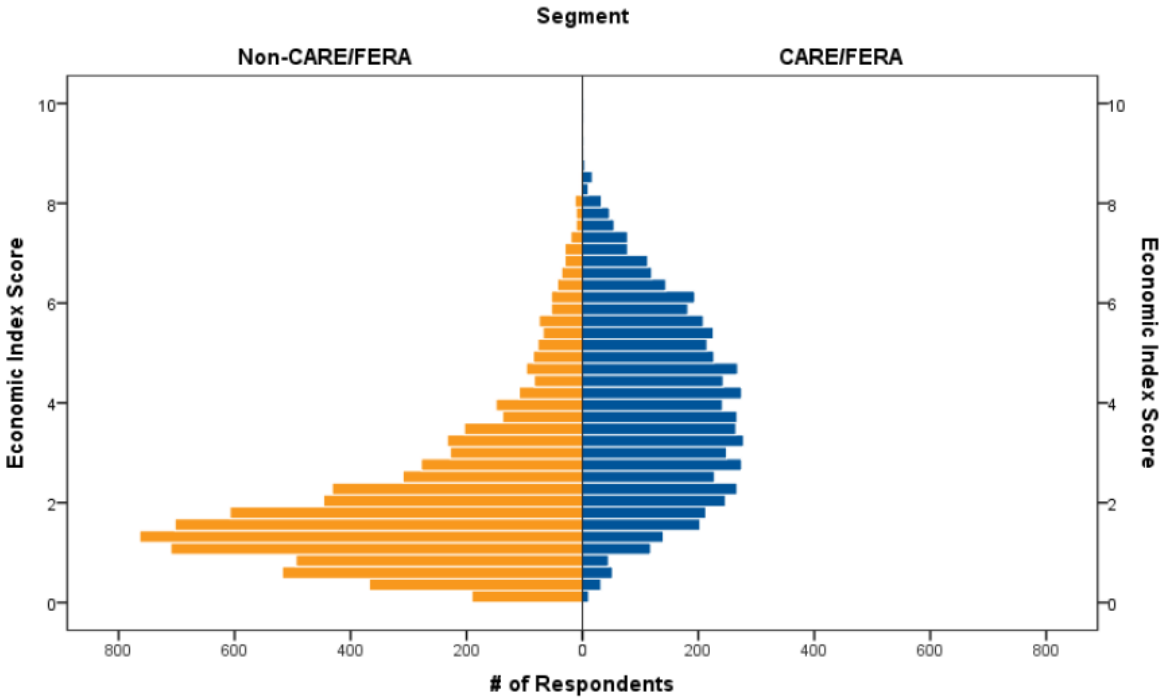

Figure 3: Histogram of Economic Index Scores For CARE/FERA And Non-CARE/FERA Segments

[8] Note that the distributions of economic index scores reflect the entire pilot survey sample, including customers from standard rates and all piloted TOU rates. Thus, differences in distributions are not a function of rate assignment.

Analysis: Testing Whether TOU Rates Cause Economic Hardship

To assess whether any of the pilot TOU rates caused economic hardship for certain groups, the research team used t-tests to compare the difference in average economic index scores between the rate treatment and control groups for the segments shown in Table 4.[9] The researchers performed these tests separately for each IOU; Table 4 indicates the IOUs for which we performed a given rate group analysis. Sample sizes were sufficiently large to detect small effect sizes. For example, first wave sample sizes for the compared groups shown in Table 4 ranged from n=93 to n=1,673, with an average sample size of n=536. Given the RCT design, any statistically significant differences between control and treatment customers can be attributed to the TOU rates (or random chance).

Table 4: Segments Tested by Rate

Climate	Segment	Control vs. TOU Rate 1	Control vs. TOU Rate 2	Control vs. TOU Rate 3
Hot	Non-CARE/FERA	PG&E, SCE	PG&E, SCE	PG&E, SCE
	CARE/FERA participants	PG&E, SCE	PG&E, SCE	PG&E, SCE
	CARE/FERA - participants and eligible nonparticipants	PG&E	PG&E, SCE	PG&E, SCE
	Below 100% of Federal Poverty Guideline (FPG)	PG&E	SCE	Not tested
	100%-200% of Federal Poverty Guideline (FPG)	PG&E	SCE	Not tested
	Seniors	PG&E	SCE	Not tested
Moderate	Non-CARE/FERA	All IOUs	All IOUs	PG&E, SCE
	CARE/FERA participants	All IOUs	All IOUs	PG&E, SCE
	CARE/FERA - participants and eligible nonparticipants	All IOUs	All IOUs	PG&E, SCE
Cool	Non-CARE/FERA	All IOUs	All IOUs	PG&E, SCE
	CARE/FERA participants	All IOUs	All IOUs	PG&E, SCE
	CARE/FERA - participants and eligible nonparticipants	All IOUs	All IOUs	PG&E, SCE

Key Findings

Although billing analysis demonstrated that households on a TOU rate paid an average of $5 to $40 more a month during the summer than what they would have paid on a standard rate,[10] analysis of the first wave of survey data revealed that those on a TOU rate did not tend to experience increased economic hardship compared to members of corresponding control groups on a standard rate.[11] Table 5 exhibits all statistically significant ($p<.05$) segment differences in economic hardship by rate and IOU. As seen in the table, none of PG&E's pilot TOU rates resulted in increased economic hardship. Conversely, of the 30 segments treated in SCE's territory, only three of SCE's segments experienced increased economic hardship following the first summer of the pilot, all of which were low-income segments in hot climate zones. Interestingly, both of SDG&E's TOU rates demonstrated decreased economic hardship for some

[9] Control groups remained on their standard "flat" rate tier. For a complete description of the rates tested, see George et al. 2017.

[10] See George et al. 2017 for a complete compilation of summer bill impact results.

[11] As of press time, results of the second wave survey were still under review. Second wave survey results are forthcoming.

non-low-income groups.[12] As seen in the table, senior segments did not significantly vary in economic hardship regardless of assigned rate plan.

Table 5: Observed Differences in Economic Hardship Following First Summer in Pilot*

IOU	TOU Rate 1	TOU Rate 2	TOU Rate 3
PG&E	No effect	No effect	No effect
SCE	No effect	↑ Hot Climate 100-200% FPG	↑ Hot Climate CARE/FERA ↑ Hot Climate CARE/FERA - on or eligible
SDG&E**	↓ Moderate Climate Non-CARE/FERA ↓ Cool Climate Non-CARE/FERA	↓ Moderate Climate Non-CARE/FERA	-

*↑ denotes higher economic index scores and ↓ denotes lower economic index scores for the listed TOU segment compared to the analogous control group.

** SDG&E did not pilot a third TOU rate and did not sample hot climate customers due to their extremely low incidence rate in the SDG&E service territory.

Despite observing some significant differences in economic hardship, the effect was minimal: significant t-test results reflected up to a 0.4 difference in mean economic index scores. Thus, any significant difference in economic hardship reflected no more than a 4% increase in measured hardship. Additional analysis revealed that the magnitude of this difference is the approximate equivalent of an increase in one answer choice in any one of the indices underlying the hardship metric (for example, the 4% difference in hardship is equivalent to TOU Rate customers having difficulty paying one more bill or using one more additional non-income payment method than Control customers).

Conclusions

Benefits and Challenges of the Methodological Approach

The dual-wave RCT approach described in this paper provides a valid and reliable means for assessing the extent to which TOU rates caused economic hardship and whether hardship changed throughout the course of the pilot. The employed methodology has a variety of benefits:

- The RCT approach allows for observing an effect and attributing causality
- The mixed-mode survey approach, coupled with generous incentives, resulted in impressive response rates (82%) and representativeness (including non-English households, seniors, and other traditionally hard-to-reach segments)
- The economic hardship metric is based on established questions related to general financial well-being as well as original items specific to electricity use
- Factor analysis proved to be an effective means for measuring the complex latent concept of economic hardship, but researchers must first ask the right questions

However, this methodological approach is not without its downsides. Namely, it was expensive, required sample sizes that may be prohibitively large for some researchers, and required considerable

[12] SDG&E's control rate was seasonally adjusted, such that the control's summer rate price was more similar to the TOU rates. Seasonal adjustment of the control rate was not as significant for the other two IOUs.

time (in terms of staff hours spent and calendar days elapsed). Further, the opt-in nature – as well as the financial incentives for participating – limit the extrapolation of the results to TOU implementation strategies outside of those employed in this study. Nonetheless, these results provide valuable insight to utilities, particularly those seeking to use opt-in formats and financial incentives for signing up for TOU rate plans.

TOU Rates Had Minimal Impact on Economic Hardship

Even though tested TOU rates slightly increased residential customer electricity bills in the summer, they did not cause widespread economic hardship for vulnerable populations.[13] Two of SCE's three TOU rates caused minor (up to 4%) increases in economic hardship for some low-income groups in hot climate zones. None of PG&E's TOU rates influenced economic hardship, and SDG&E's TOU rates demonstrated decreased economic hardship for some non-low-income customers. Increased economic hardship for vulnerable populations was limited to hot climate zones, and seniors did not experience increased economic hardship via TOU rates.

Discussion: Policy Implications

The results suggest that TOU rates do not increase economic hardship for most customers, even if their bills increase after transitioning to a TOU rate plan. However, the study demonstrates a clear interaction between climate and income: TOU rates only exacerbated economic hardship for customer segments that were both low-income and located in hot climate zones. This finding highlights how the results from this study reflect California's climate and technological backdrop*:* electricity use associated with harsh weather in California is mostly customers using air conditioning during times of moderate to extreme heat. Nonetheless, it is possible that the study's results may also replicate in extremely cold climate zones where electric heat is common in residential applications. The interaction of rate structure, income, climate, and HVAC fuel-type reveals an important policy implication for those planning to transition residential customers to TOU rates: consider implementing preventative measures that ensure low-income customers with electric HVAC systems in extreme climates are not overly economically burdened by the transition. Below, the authors offer some strategies for policy makers to consider.

Opt-in Instead of Default

Despite the minor and inconsistent effect of TOU rates on economic hardship, the CPUC interpreted the results from this study as evidence that TOU rates could potentially increase economic hardship for low-income customers in hot climates, and therefore IOUs will exempt CARE/FERA participants in hot climate regions from defaulting onto the TOU rates. Instead, CARE/FERA participants can still voluntarily opt-in to a TOU rate plan if they so desire (meanwhile, all other customers will be automatically defaulted onto a TOU rate and must manually opt-out in order to revert to a flat rate tier). This strategy could strike a good balance between system-wide load reduction and equity goals.

Baseline Allowance

If utilities or policy makers wish to default all residential customers onto TOU rates, baseline allowances for low-income customers using electric HVAC systems in extreme climates can help offset the

[13] The IOUs seasonally adjusted their TOU rates, lowering both peak and off-peak rates in the winter months (compared to the summer months). As a result, the IOUs predict that TOU customers will pay less than customers on standard rate plans in the winter months. Initial analysis of winter billing data suggests this may be the case.

increased electric bills that vulnerable customer segments may experience as a result of the transition. Baseline allowances provide an allotment of energy use at a lower price, thereby subsidizing the electricity bill the customer receives at the end of the month. Utilities and policy makers may wish to seasonally adjust baseline allowances to correspond with seasonal system peaks. At least one California IOU will use a baseline allowance for their TOU default pilot, basing the allowance on where the customer lives, their heating source, and the season.

Bill Protection

Another strategy that can alleviate the economic burden faced by low-income customers on TOU rates is a bill protection program, where customers receive bill credits for the difference they paid over their first year on a TOU rate (that is, they receive a bill credit for the difference between what they paid on the TOU rate compared to what it would have been on their previous flat rate tier). This "try before you buy" approach gives customers time to adapt their lifestyles to TOU rates and can subsequently opt-out and recoup the money lost to higher bills if they are unable to effectively respond to a TOU rate structure via shifting or reducing their electricity usage.

Multiple TOU Rate Plans

Critics of TOU rates may argue that low-income customers (particularly, the working poor) do not always have the luxury of reducing their electricity usage or changing the time they use it. Even though the first wave's impact evaluation found that low-income customers assigned to a TOU rate had modest load reductions, the aforementioned criticism is a valid argument from an equity perspective. To alleviate this concern, the authors recommend that utilities offer multiple TOU rate plans for customers to choose from. This strategy allows customers to choose a rate plan that works for their schedule, which could mitigate the aforementioned concern and may even give low-income customers the opportunity to better actively manage their electricity bills and therefore save money compared to a flat rate tier.

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