Distributional Impacts of dynamic pricing transitions for residential electricity consumers

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Overview

We investigate the distributional impacts of a transition to dynamic electricity pricing on residential energy users by applying hourly electricity load data for over 2,700 households in Hawaiʻi in the United States. Under dynamic pricing, the electricity rates reflect changes in the marginal costs across time of day as opposed to traditional rates that have no or few price changes within each day. In Hawaiʻi and most other electricity markets, the current (volumetric) retail rates cover not only the marginal costs but the fixed costs of electricity services. Thus a transition to marginal cost pricing requires the electric utilities to raise fixed electricity fees to cover the fixed costs. How such cost recovery is implemented affects the rate reform's distributional impacts on energy users with different characteristics.

Studying dynamic pricing impacts in Honolulu provides useful insights for pricing reforms in other parts of the world. The city has an exceptionally high share (30%) of households with rooftop solar PV, which tend to have much smaller electric bills than those without. This allows us to consider differential impacts on households with differences in multiple dimensions including PV ownership. While early PV adopters were subject to net energy metering, the households that adopted PV more recently face less favourable compensation rules on their excess electricity output. Early PV adopters, late adopters, and those without PV would experience different bill impacts depending on how the fixed fees are set for different households.

We consider how the electric bill profiles change under marginal cost pricing with alternative fixed fee allocation rules: uniform monthly fixed fees for all households and allocations based on the benefit taxation principle such that households with larger estimated benefits from electricity services pay higher fixed charges (Wolak 2018). As practical alternatives, we also consider fixed charge distribution tied to household property tax or income tax. We also simulate the billing impacts under future marginal cost scenarios with higher penetration of renewable energy.

Topics addressed: Electricity pricing and grid system; Regional energy issues; Energy access issues; Energy transition.

Methods

We apply 15-minute interval load data for a sample of residential electricity users in Honolulu, Hawaii, made available from Hawaiian Electric Company. This household-level data provides residential load profiles along with the PV ownership and the applicable rate schedule. Under the Net Energy Metering rate, for example, energy delivered from the utility to the household and energy delivered from household to the utility are cancelled out over every 12-month period. The sample is distributed over multiple census tracts with a diverse range of median household income levels. The anonymized data is linked to the property assessment data from the City and County of Hawaii, which allows us to observe the property tax assessment for each household. As an indicator of the marginal costs of electricity services, we use the hourly system lambda for Honolulu in Form 714 from the United States Federal Energy Regulatory Commission (FERC) with adjustments to account for line losses and for social costs of carbon emissions.

We compare the electricity payment of each household under the current rate structure and the payment under dynamic pricing, where the volumetric rate is set equal to the marginal costs for all households. We assume the total payment, including the volumetric payment and the fixed charge, equals the total costs of electricity services under each rate profile. The total volumetric payments of all households would be smaller under the marginal-cost pricing. The fixed charge covers the associated shortage. We consider several options to distribute the fixed charge over different households: uniform distribution, the benefit taxation formula as proposed by Wolak (2018), and those tied to the property tax.Borenstein (2007) studied wealth transfers among commercial and industrial customers under real-time pricing. Borenstein et al. (2021) apply the Consumer Expenditure Survey from the US Bureau of Labor Statistics to assess the distributional impacts under alternative marginal-cost pricing scenarios in California. They propose a system of fixed charges that are based on a sliding scale of income, so that lower-income households pay a lower monthly connection fee, which can be implemented with the state's tax authority. Our approach builds on these earlier studies by making use of household level hourly load profile observations. We also consider marginal cost scenarios under higher penetration of renewable energy to simulate the distributional impacts in the future, low-carbon energy system in the state. We also investigate a case in which the demand is not perfectly inelastic by applying a range of estimated (own) price elasticity and inter-hourly elasticity of electricity demand (Coffman, et al., 2018, Fripp, et al. 2018).

Results

As expected, the daytime load of the load profiles of average households with PV is negative. In our sample, however, the average peak load of those with PV exceed the peak load of those without. The aggregate residential profile is thus likely to change as more households adopt PV (Figure 1).

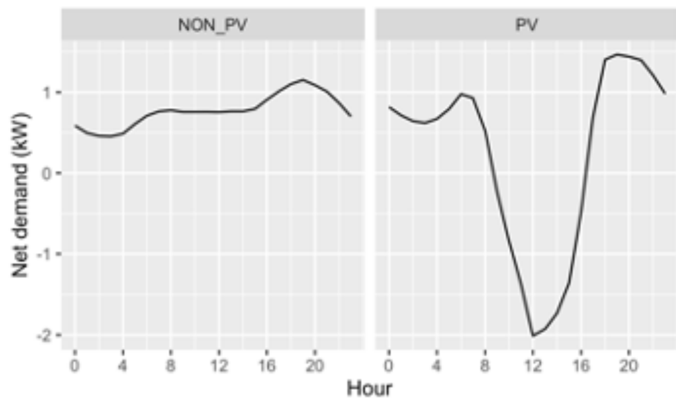

Figure 1: Average load profiles of households with and without PV.

If we assume the same fixed charge for all residential households, then the fixed charge would more than triple (to around $95 per month per household) under marginal-cost pricing. The uniform fixed charge leads to a highly regressive distributional impact because large energy users gain while small users lose (Figure 2). In contrast, alternative fixed charge allocations can lead to more progressive outcomes: the benefit taxation formula or the fixed charge tied to property taxes can minimize the rate impacts on low-energy users, or those PV non-adopters in low-income neighborhoods.

(a)

(b)

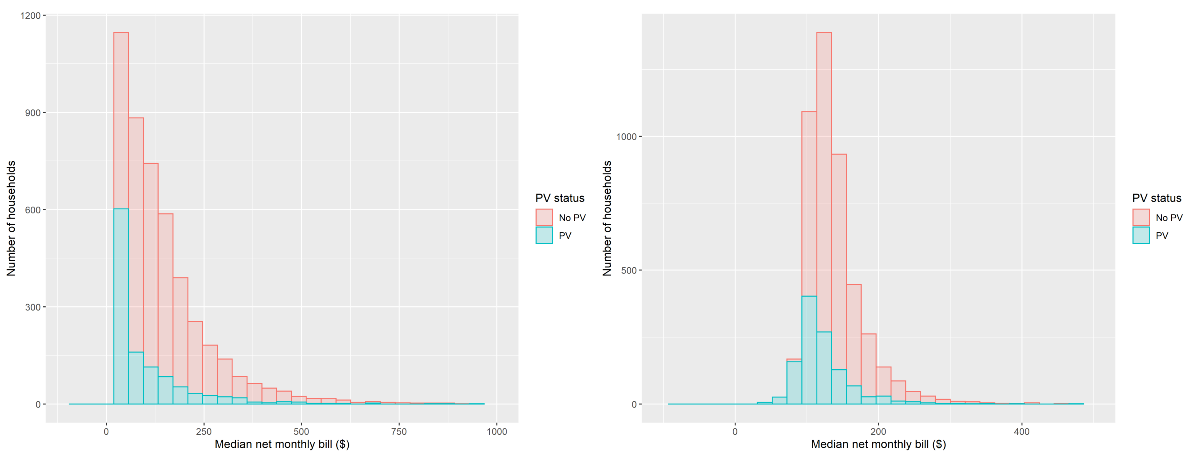

Figure 2. Distribution of electricity payments (a) under the current pricing and (b) under marginal cost pricing with uniform fixed charge. The horizontal axis measures the median net monthly bill; the number of households on the vertical axis.

Conclusions

The current energy systems across the world face both efficiency and equity concerns. Because various policies for decarbonization may disproportionately benefit households with higher income levels, equitable energy transition requires a progressive rate reform. This study confirms that, while marginal cost pricing can be made progressive with suitable and simple fixed charge distribution, the rate structure and the distributional impacts may differ depending on the degree of intermittent renewable energy integration.

References

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