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Risk preference and adverse selection for participation in time-of-use electricity pricing programs

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ABSTRACT

Time-invariant electricity pricing does not reflect daily variation in the cost of producing electricity and thus can cause economic inefficiency. Time-of-use pricing (TOU), which has higher electricity prices during peak hours and lower prices during non-peak hours, is a pricing scheme that can help achieve more efficient levels of electricity consumption. This study examines factors influencing consumers' participation in voluntary TOU programs with particular attention to individual-specific risk and time preferences elicited through multiple price-list experiments. Evidence from a study of 398 homeowners in Arizona and California, U.S., indicates that more risk averse consumers are less likely to enroll in TOU programs. The results suggest evidence of adverse selection, with households who consume less energy during peak hours being more likely to enroll in TOU programs. Time preferences are found to have a statistically significant and negative impact on consumers' adoption of programmable thermostats, a technology that can allow households to better respond to TOU pricing. However, we find no evidence that consumers' decisions to enroll in TOU programs and adopt programmable thermostats are correlated. Our results have important implications for policymakers and utility companies, which attempt to increase participation in voluntary TOU programs.

1. Introduction

Time-invariant retail electricity rates cause economic inefficiency when there is intraday variation in the demand for electricity and production costs vary by time of day (Williamson, 1966). If electricity load profiles were flat, then base load generating plants such as coal and nuclear power plants would meet all demand. However, with a rapid increase in the electricity demand in many markets during peak hours, only marginal facilities with greater marginal costs can ramp-up sufficiently fast (e.g., natural gas power plants). These marginal facilities are then employed for generating the supply to meet the increased demand. As a consequence of using a time-invariant pricing structure, there is a welfare loss estimated to be between 5% and 10% of wholesale energy costs (Borenstein and Holland, 2005).

One avenue for reducing this welfare loss is to adjust retail prices intraday based on the marginal cost of electricity provision. In a real time pricing (RTP) scheme, prices vary at high frequency (e.g., hourly) (Allcott, 2011; Wolak, 2011).

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Although conceptually RTP can reduce welfare losses, there are associated high fixed implementation costs and concerns over whether consumers would indeed exert the time and effort to respond to price changes on an hourly schedule (Wolak, 2011). A related but simpler approach implemented in many markets, is time-of-use pricing (TOU), which is third-degree price discrimination where customers are charged higher prices during peak hours and lower prices during non-peak hours. For utility companies, TOU pricing can help improve their load profile by shifting electricity usage from peak hours to non-peak hours. This improves economic efficiency by aligning prices more closely with marginal costs and reduces or delays capital investment in marginal facilities. Previous studies focusing on the effects of TOU pricing plans on energy consumption patterns (Caves and Christensen, 1984; Faruqui and Sergici, 2010; Newsham and Bowker, 2010; Jessoe et al., 2014) have found that residential TOU customers generally shift their peak-hour energy consumption to non-peak hours. However, related studies focusing on commercial sectors (Hirschberg and Aigner, 1983; Park and Acton, 1984; Aigner et al., 1994; Jessoe and Rapson, 2014; Faruqui et al., 2014; Qiu et al., 2016) have not reached a consensus on whether commercial customers respond to TOU pricing.

Despite the overall welfare gains and potential for retail (Faruqui and Sergici, 2010) and for commercial (Qiu et al., 2016) customers to reduce their electricity costs under TOU, there are two major issues that can confound the success of TOU: adverse selection and under-participation. Similar to many voluntary programs, there is the concern of adverse selection—i.e., voluntary TOU participants are households who consume relatively less energy during peak hours before switching to TOU pricing (Jessoe and Rapson, 2014). These households can take advantage of lower non-peak energy prices to reduce their energy bills even without changing their energy consumption behavior. Thus, the financial burden (less energy revenue) for a utility company will then be passed onto non-TOU customers. The second issue, under-participation in a potentially cost-reducing program, is similar to the well-known energy "efficiency paradox"—"cost-effective energy-efficient technologies based on simple net present value calculations at current prices enjoy only limited market success" (Brown, 2001; Jaffe and Stavins, 1994). Previous studies have found that behavioral factors (such as bounded rationality and high implied discount rates, Sanstad and Howarth, 1994), market failures (such as principal–agent problems, Jaffe and Stavins, 1994), as well as institutional and organizational factors (such as a trade-off with non-energy specific goals, Weber, 1997) can cause the efficiency paradox.

In this study, we present evidence on the presence of adverse selection and individual-specific factors that influence homeowners' decisions to enroll in TOU pricing programs. Critically, we move beyond previous studies that only consider sociodemographic of TOU participants (Baladi et al., 1998) and focus on two potentially critical individual-specific factors affecting enrollment: risk and time preferences. For a household, switching from familiar time-invariant electricity pricing to a novel TOU program under the expectation of reduced electricity bills is a decision that involves risks. Because of the inherent difficulties in projecting and managing future peak vs. non-peak energy usage, there is a risk for a household as to whether expected cost savings will actually be realized. Even if a household expects cost savings from enrollment, a sufficiently risk averse household may optimally choose not to participate. In addition to the element of risk, there is a time dimension that can potentially influence a household's decision to enroll in TOU programs. Households who are more impatient (i.e., who have higher individual-specific discount rates) can be more reluctant to enroll because of potential bill increases during the period of adjusting one's energy usage schedule to the new peak vs. non-peak pricing scheme. On the other hand, households who are more patient may be more willing to risk potentially incurring higher initial bills but with future savings over a longer-term horizon. However, because there is no up-front cost to enroll in TOU programs and for the markets considered in this study participants are not required to sign a long-term contract, it is likely that enrollment decisions are not affected by individual-specific discount rates. In contrast, time preferences could play a role in TOU participation indirectly by affecting a household's willingness to adopt[1] a programmable thermostat[2]. This home technology allows better response to time-variant electricity pricing (Faruqui and Sergici, 2010 and Faruqui et al., 2010) but involves up-front costs that are only potentially offset through a future stream of cost savings. As indicated in previous studies that have investigated the adoption of energy-efficient technologies (Hassett and Metcalf, 1993; Erdem et al., 2010; Qiu et al., 2014a), individuals with higher impatience are less likely to adopt.

To develop a better understanding of the influences and barriers to participation in TOU pricing, we proceed in two steps. In the next section, an illustrative model of the household decision in the presence of risk is developed. With this as a foundation, we present evidence from a survey of a representative sample of 398 homeowners in Arizona and California. We choose to analyze these two states because the former serves as a representative state with more conservative energy programs while the latter represents states that are more aggressive in this regard. In addition to background information on home and homeowner characteristics, energy usage, programmable thermostat adoption, and TOU participation, measures of homeowners' risk and time preferences were elicited using popular multiple price-list (MPL) techniques. Evidence from a set of econometric models indicates four key results: (1) risk averse consumers are less likely to enroll in voluntary TOU programs, (2) homeowners with lower peak-energy usage under time-invariant pricing are more likely to enroll (i.e., adverse selection), (3) time preferences influence investments in programmable thermostats but not TOU participation, and (4) there

[1] In this paper, adopting a programmable thermostat captures two situations: (1) a household installed such technology after purchasing a home; (2) a household purchased a home with such technology already installed.

[2] While programmable thermostats can facilitate easier management of household peak vs. non-peak energy usage, programmable thermostats are not a requirement for enrolling in TOU. This is in contrast to many direct load control programs where utilities can remotely adjust customer energy usage.