PEAK DEMAND AND TIME-OF-USE PRICING IN A FIELD STUDY OF RESIDENTIAL ELECTRICITY DEMAND IN GERMANY

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Overview

According to the EU Energy Services Directive 2006/32/EC 2010 utilities need to offer final customers of electricity a tariff which provides incentives to save electricity. Such tariffs may vary by load or by time of use (TOU). Unlike flat rates, dynamic pricing (including time of use pricing), more adequately reflects the true marginal cost of electricity supply, sets financial incentives to shift demand from peak loads to off-peak loads, helps integrate fluctuating renewables (notably wind and solar) and plug-in electric vehicles into the electric grid, and - depending on its magnitude and geographical location, the shift in demand and improved load management may also save costs for building and running generation and transmission infrastructure (e.g. Borenstein 2005, Faruqui and Palmer 2011, Joskow 2012).

While various types of dynamic pricing schemes have been implemented in the US more than three decades ago (e.g. Faruqui and Malko 1983, Darby 2006, Ehrhart-Martinez et al. 2010, Faruqui and Sergici 2011), in most EU countries, these schemes have just started to diffuse, typically in response to the EU regulation, and primarily via pilot projects (e.g. Torriti et al. 2010, European Commission 2011, Gans et al. 2013, Di Cosmo et al. 2014).

In this paper, we econometrically analyse the effects of TOU pricing on the ratio of peak to off-peak demand. We also explore whether the effects of TOU pricing differ between weekdays and weekends, and whether they are persistent or fade over the time the TOU field study was conducted.

Methods

Eight municipalities located in five federal German states participated in the demand response field trial: Celle, Hassfurt, Kaiserslautern, Krefeld, Münster, Oelde, Schwerte and Ulm. In addition one municipality from Austria, Linz, also joined the field trial. Around 2000 participating households were randomly assigned to a pilot group and a control group of about equal sizes. Between May and November 2009 the pilot group households started receiving feedback on their electricity use and information on energy saving measures (either once a month by post or via access to an internet portal) (see Schleich et al. 2013). A subset of 100 pilot group households with web-based feedback in the German municipalities Kaiserslautern, Ulm and Schwerte also participated in a “TOU pilot”, which lasted for six months, from May to October 2010 (TOU period). Participation in the TOU-group was voluntary, and may thus not be totally random. For the households, which received a time varying tariff, the rate during peak times (10am to 6pm) was about 40% higher than during off-peak times. The peak price is about 21% higher and the off-peak price is almost 32% lower than the standard electricity price TOU group households had faced prior to the introduction of the TOU tariff

Data allows us to estimate a *difference-in-difference model*, using the difference in the ratio of peak to off-peak demand between the pre-treatment period and the treatment period as the dependent variable. Our regression analysis controls for socio-economic factors (income, education, age, household size, age composition, etc.) as well as information on household equipment (appliances, boilers, air conditioner etc.). Hence, these control variables may control for other factors (besides participation in the TOU group) which affect the change in peak or off-peak demand between periods (e.g. Angrist and Pischke 2009, p. 23). They may differ systematically between the TOU group and the control group, and may also be correlated with participation in the TOU group.

To explore whether the effects differ between weekdays and weekends, we also conduct the econometric analyses for weekdays in addition to all days during the week. Hence, four different dependent variables are considered in total. Likewise, to analyse whether the effects are persistent over the TOU period, we consider the first three months of the TOU period (May to July 2010) in addition to the full TOU period (May to October 2010) for all two types of dependent variables. More precisely, our dependent variable (*diff_peak_offpeak_ratio*) measures the difference in average daily peak demand in Wh in the TOU period compared to the pre-intervention period, i.e. the period before the TOU tariff was introduced.

Results

Results appear in Table 1. The parameter estimate associated with tariff is statistically significant (at $p<0.01$). Hence, the findings suggest that households respond to TOU pricing by lowering the peak ratio. Further, the parameter estimates of tariff hardly differ across columns. From a statistical point of view, they are indistinguishable. The point estimates for the effectiveness of TOU pricing correspond to a reduction of the peak ratio by 3 to 4 percentage points. For an average day, these figures correspond to a reduction in the peak ratio of around 4.5% to 5.5%. Since the peak ratio is higher on a weekend than on a workday, the percentage change for weekends is at the lower end of this range. Significant values for the covariates suggest that differences in the peak ratio between the pre-intervention period and the tariff period tend to vary with age composition, with the size of the apartment (potentially reflecting lighting needs), with electricity use in the pre-intervention period and with the number of appliances.

Table 1: Difference-in-difference regression estimates of the average effect of TOU pricing on the peak ratio

	diff_peak_offpeak_ratio			
	May to October		May to July	
	all days	workdays	all days	workdays
tariff	-0.0362 ***	-0.0306 **	-0.0372 ***	-0.0328 *
	(0.0122)	(0.0149)	(0.0143)	(0.0182)
ageto17	-0.0141 ***	-0.0136 ***	-0.0116 ***	-0.0099 **
	(0.0039)	(0.0040)	(0.0044)	(0.0046)
ageto60	-0.0046	-0.0032	-0.0080	-0.0070
	(0.0055)	(0.0056)	(0.0058)	(0.0060)
age60plus	-0.0055	-0.0042	-0.0059	-0.0050
	(0.0079)	(0.0083)	(0.0084)	(0.0085)
electricity	0.0001 ***	0.0001 ***	0.0001 ***	0.0001 ***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
floorsize	0.0002 **	0.0002 **	0.0003 ***	0.0003 ***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
appliances	0.0015	0.0016 *	0.0011	0.0012
	(0.0009)	(0.0010)	(0.0010)	(0.0011)
constant	-0.0325 ***	-0.0300 ***	-0.0352 ***	-0.0283 **
	(0.0110)	(0.0112)	(0.0119)	(0.0127)
F	7.43	7.73	10.25	10.13
Prob>F	0.00	0.00	0.00	0.00
R^2	0.035	0.033	0.038	0.036
Sample size	1538	1538	1538	1538

Conclusions

The results of our difference-in-difference estimations suggest that households respond to TOU tariffs, the point estimates correspond to average percentage reductions in the peak to off-peak ratio of 4.5% to 5.5%. Hence, our findings are well in line with the results from most TOU pricing experiments in other regions (but not for Ireland – see Cosmo et al. 2014), even though in our study the ratio of peak to off-peak prices is “only” 177%, and hence lower than in most other TOU pricing studies. On the other hand, since residential electricity prices in Germany are much higher than for example in the US, the economic incentives to clip (and possibly shift) demand are also higher in Germany for a given peak to off-peak price ratio. Further, our findings for the point estimates do not suggest difference in the effects of TOU pricing between workdays and weekends. Of course, from the perspective of the energy system, peak reductions are likely to create larger economic benefits on a weekday than on a weekend, since the load profile of the entire system is less pronounced on weekends, primarily because large parts of electricity demand from industry is missing. Likewise, our findings do not show differences in the effectiveness of TOU pricing over time. Since the experiment lasted for six months only, the change in demand patterns is likely to be the results of behavioural change, rather than investments in energy-saving (and possibly also smart) appliances. From this perspective, longer TOU periods would be expected to lead to stronger effects in the long run. On the other hand, the TOU effects may not sustain if households return to long-term habits after a certain time. Hence, future research could further explore the persistence of TOU effects. Future studies may also analyse whether TOU effects

interact with socio-economic variables, attitudes, or individual and social norms.

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