Do households respond to opportunity cost? Evidence from the electricity consumption of households with solar panels

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Anecdotal evidence suggests that households with solar photovoltaic panels treat solar-generated electricity as free, and hence tend to use more electricity when their panels are producing. But for some households the opportunity cost of using electricity is actually *higher*, not lower, during those times. In this paper I formulate a test of whether households with solar panels are responsive to the opportunity cost of their consumption. I then apply this test to a sample of half hourly electricity imports and exports for 530 solar households from Victoria, Australia.

In Victoria, as in much of the world, households with solar panels are paid a feed-in tariff for electricity they export to the grid (electricity produced and not immediately consumed). Although solar panels produce electricity at zero marginal cost the opportunity cost of consuming it is not zero. Instead, the shadow price of consuming electricity that would otherwise be exported is the feed-in tariff. In Victoria, feed-in tariffs can be above, below or equal to the cost of importing electricity. In general therefore the shadow price of consumption at times of export is different to the explicit price of consumption at times of import. I use this difference to present the first field evidence on whether households respond to opportunity costs.

Survey, laboratory and anecdotal evidence suggest that consumers (and academic economists) do not consider or are unable to calculate opportunity costs (Shavit et al., 2011; Phillips et al., 1991; Becker et al., 1974; Frederick et al., 2009; Ferraro and Taylor, 2005). A growing empirical literature has sought to identify whether similar behavioural anomalies observed in the lab are also present in field (see DellaVigna (2009) for an early survey). This literature has identified that consumers respond to average not marginal prices (Ito, 2014), have limited attention (Gilbert and Graff Zivin, 2014; Stango and Zinman, 2014), violate the fungibility of money (Hastings and Shapiro, 2013), and exhibit both loss aversion and reference dependence (Pope and Schweitzer,

2011; Crawford and Meng, 2011). To date however evidence from the field on attention to opportunity costs amongst households is lacking.

The nature of feed-in tariffs in Victoria and access to high frequency observations of electricity imports and exports from smart meters provide a unique opportunity to test whether households respond to opportunity costs. Solar penetration amongst households in Australia is now higher than one in six[1] suggesting that this setting is capable of providing general insights into household behaviour. For this group of households my test of opportunity cost compares two elasticities estimated for each hour of the day. The first elasticity measures household response to the cost of consumption when a household is importing (an explicit price). The second measures household response to the opportunity cost of consumption when a household is exporting (an implicit or shadow price). If households respond to opportunity costs then these two elasticities should be the same.

To identify the elasticities I match household exports and imports at the hourly level to satellite data on solar irradiance and temperature. I then exploit three sources of variation. First, variation in solar irradiance causes within-household variation in opportunity cost across and within days. Second, variation in feed-in tariffs and solar capacity causes opportunity cost to differ across households within the same hour. Third, spatial discontinuities in electricity distribution zones, price-plan discounts and historical meter allocations drive variation in import prices across and within households.

My identification strategy uses an estimate of solar production as an instrument for price. Controlling flexibly for the effect of temperature on consumption, I fail to reject that households are as responsive to the shadow price of consumption whilst exporting as they are to the explicit price of consumption whilst importing. Across hours of the day the estimated elasticities are negative, significant and statistically indistinguishable. I thus find that households are responsive to opportunity costs. I also find that household consumption is responsive to the income derived from solar generation. Holding price constant, an increase in income leads to an increase in consumption. I find that households respond both to expected income and shocks to solar income. Taken together, these results help to rationalise the observation that households may consume more when their panels are producing despite the higher opportunity cost of doing so. These conclusions hold across a number of fixed effects specifications and survive additional robustness

[1]Source: www.cleanenergycouncil.org.au/technologies/solar-pv.html accessed 21/10/2014

checks including alternative functional form assumptions and alternative instruments.

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