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Exploring the behavioral and welfare implications of social-comparison messages in residential water and electricity

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HIGHLIGHTS

- Satiation determines how social-comparison messages impact water/energy use.
- Correcting internalities reduces water/energy use for activities at satiation.
- Increasing psychic costs reduces water/energy use for activities below satiation.
- Correcting internalities improves welfare whenever energy/water use is reduced.
- Increasing psychic costs improves welfare if price is below social marginal cost.

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ABSTRACT

Our model shows that how consumers adjust their water or electricity use in response to social-comparison messages (SCM), and the welfare impacts of SCM, depend on the behavioral mechanism driving conservation and whether consumers' water/energy use is at satiation.

1. Introduction

Several randomized controlled trials have established that social-comparison messages (SCM) that compare residential consumers' water or electricity use to that of a peer group lead to significant conservation (Allcott, 2011; Ferraro and Miranda, 2013; Brent et al., 2015). The literature, however, has only recently started to examine the behavioral mechanism(s) driving consumer conservation (Allcott and Kessler, 2015). This article presents a theoretical model of how consumers adjust their water/energy use in response to SCM. We use the model to make two points. First, the welfare impacts of SCM depend on the behavioral mechanism driving conservation. Second, if consumers' reach satiation for some of their water/energy use activities, the behavioral mechanism also determines how consumers adjust their water/energy use in response to SCM. We then discuss how future SCM can be implemented to have the greatest chance for achieving conservation goals and improving societal welfare.

The model considers the two predominant behavioral mechanisms for SCM emphasized in the previous literature (Levitt and List, 2007; Ferraro and Price, 2013). First, SCM can reduce water/energy use by increasing consumers' psychic (or moral) cost of use. SCM can increase consumers' psychic cost by increasing the salience of the public good aspects of water/energy use or by causing consumers to update their belief about the appropriate norm for water/energy use. We demonstrate that water/energy

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use reductions generated by an increase in psychic costs will only occur in activities where consumers' water/energy use is below satiation, and that the resulting conservation will only improve societal welfare if the retail price of water/energy is below social marginal cost.

Second, SCM provide consumers with otherwise unavailable information on how their water/energy use compares to that of their peers. This information may prompt some consumers to correct "internalities" in their water/energy use. Internalities are long-term benefits or costs that consumers do not consider in their decision-making and imply that consumers' water/energy use may not maximize their own utility (Allcott and Sunstein, 2015). Internalities can arise in water/energy due to dynamic inconsistencies in decision-making (Allcott et al., 2014); lack of salience due to infrequent or automatic billing (Sexton, 2015; Wichman, 2016); and confusion about non-linear price structures (Ito, 2014; Wichman, 2014). By prompting consumers to correct internalities, SCM can lead consumers to invest in and/or perform maintenance on their physical water/energy infrastructure (e.g., purchase new appliances, check sprinkler system for leaks) or adopt new water/energy use habits (e.g., shorten outdoor watering times, lower air conditioning). We demonstrate that correcting internalities will only lead to conservation for activities where consumers' water/energy use is at satiation, and unambiguously improve societal welfare if energy/water use is reduced.

There are at least three reasons why consumer satiation is relevant in residential water/energy. First, water/energy is an input into the production of final goods whose consumption is lumpy (e.g., cooking a meal, watching a movie), so that marginal conditions may not determine input use. Second, many water/energy use activities feature declining utility from over-use (e.g., heating/cooling, watering outdoor landscaping). Third, for many activities, the total cost of water/energy is small relative to the cost of other inputs, such as time, so that changes in marginal cost may lack salience (e.g., indoor lighting, showering). While previous studies have not discussed satiation when interpreting heterogeneity in consumer response to SCM, satiation has been put forward as an explanation for heterogeneity across income groups in the "rebound effect" in residential heating and cooling (Sorrell et al., 2009; Aydin et al., 2017).

2. The model

2.1. Basic set-up

We propose the following additively-separable utility function for consumer $i \in \Omega$:

$$V_i\left(y_i, w_i; K_i, H_i, S_i, N_i\right) = U_i^C\left(y_i\right) + \sum_{n=1}^{N_i} U_{i,n}^W\left(w_{i,n}; K_i, H_i\right) + U_i^P\left(w_i; S_i, N_i\right), \tag{1}$$

where $y_i \geq 0$ is consumer i's consumption of the numeraire good; $U_i^C\left(y_i\right) \geq 0$ is consumer i's utility from consuming y_i; $w_{i,n} \geq 0$ is consumer i's water/energy use in activity n, $n = 1, \ldots, N_i$; $U_{i,n}^C\left(w_{i,n}; K_i, H_i\right) \geq 0$ is consumer i's utility in activity n from consuming $w_{i,n}$; $w_i = \sum_{n=1}^{N_i} w_{i,n}$ is consumer i's total water/energy use; and $U_i^P\left(w_i; S_i, N_i\right)$ is consumer i's psychic cost of consuming w_i. $U_i^C\left(y_i\right)$ is increasing and concave in y_i and $U_i^P\left(w_i; S_i, N_i\right)$ is decreasing and concave in w_i.

Following Levitt and List (2007) and Ferraro and Price (2013), $U_i^P\left(w_i; S_i, N_i\right)$ depends on the extent that consumer i's actions are scrutinized, S_i, and her perceived social norm for acceptable water/energy use, N_i. Consumer i's psychic cost of consuming w_i is increasing in the extent that she believes her actions are scrutinized ($\frac{\partial^2 U_i^P(w_i;S_i,N_i)}{\partial w_i \partial S_i} < 0$) or deviate from her perceived social norm ($\frac{\partial^2 U_i^P(w_i;S_i,N_i)}{\partial w_i \partial N_i} > 0$).

Consumer i's satiation point for water/energy activity n is $\bar{w}_{i,n}\left(K_i, H_i\right)$. We define satiation as the level of water/energy use for an activity above which consumer i receives zero utility from additional consumption. This definition implies

$$U_{i,n}^W\left(w_{i,n}; K_i, H_i\right) = \begin{cases} u_{i,n}^W\left(w_{i,n}; K_i, H_i\right) & \text{for } w_{i,n} < \bar{w}_{i,n}\left(K_i, H_i\right) \\ u_{i,n}^W\left(\bar{w}_{i,n}\left(K_i, H_i\right); K_i, H_i\right) & \text{otherwise.} \end{cases}$$

$u_{i,n}^W\left(w_{i,n}; K_i, H_i\right)$ is increasing and concave in $w_{i,n}$ and depends on consumer i's physical water/energy infrastructure, $K_i > 0$, and her water/energy-use habits, $H_i > 0$. The marginal utility of $w_{i,n}$ is non-decreasing in K_i and H_i ($\frac{\partial^2 u_{i,n}^W(w_{i,n};K_i,H_i)}{\partial w_{i,n}\partial K_i} \geq 0$ and $\frac{\partial^2 u_{i,n}^W(w_{i,n};K_i,H_i)}{\partial w_{i,n}\partial H_i} \geq 0$), so that larger values of K_i and H_i correspond to more efficient infrastructure/habits. Further, $\bar{w}_{i,n}\left(K_i, H_i\right)$ is non-increasing in K_i and H_i.

Normalizing the price of y_i to one, consumer i's budget constraint is given by $m_i = y_i + C\left(w_i\right)$, where m_i is consumer i's wealth and $C\left(w_i\right)$ is consumer i's cost of w_i. Incorporating the budget constraints into (1), consumer i's optimal water/energy use for activity n is defined by

$$\frac{\partial u_{i,n}^W\left(w_{i,n}^*; K_i, H_i\right)}{\partial w_{i,n}} = \frac{\partial U_i^C\left(m_i - C^w\left(w_i^*\right)\right)}{\partial y_i}\frac{\partial C\left(w_i^*\right)}{\partial w_i} - \frac{\partial U_i^P\left(w_i^*; S_i, N_i\right)}{\partial w_i}. \tag{2}$$

(2) implies that consumer i will increase her water/energy use in activity n until its marginal utility equals its marginal cost, which includes both her marginal utility loss of foregone consumption and her marginal psychic cost, or until she reaches satiation, $w_{i,n}^* = \bar{w}_{i,n}\left(K_i, H_i\right)$.

In the remainder of this article, we assume that there is a flat volumetric charge for residential water/energy use, $\frac{dC(w_i)}{dw} = p$, that consumer i has a constant marginal utility of income, i.e., $U_i^C\left(y_i\right) = y_i$, and we use the subscript 0 to denote values of consumer i's variables prior to receiving an SCM and 1 to denotes values after receiving an SCM. Generalizing our model to consider non-linear pricing, such as a two-part tariff or an increasing block-rate volumetric charge, would not change our results if we assumed that residential consumers faced a flat volumetric charge within pricing tiers (which is reasonable given that most utilities in the United States employ rates of this form).

2.2. Conservation

Proposition 1. *1. If* $w_{i,n,0}^* < \bar{w}_{i,n}\left(K_{i,0}, H_{i,0}\right)$*, then* $\frac{dw_{i,n}}{dS_i} < 0$*; otherwise,* $\frac{dw_{i,n}}{dS_i} = 0$ *. 2. If* $w_{i,0}^* < \bar{w}\left(K_{i,0}, H_{i,0}\right)$*, then* $\frac{dw_i}{dN_i} > 0$*; otherwise,* $\frac{dw_i}{dN_i} = 0$.

Proof. See Appendix. ■

Proposition 1 implies that a marginal change in consumer i's psychic cost will only influence her water/energy use in activity n if her pre-SCM water/energy use is below satiation. When consumer i is at satiation for activity n, the marginal utility of the last unit of water/energy consumed will exceed its marginal cost, so that her water/energy use will not be influenced by a marginal change in her psychic cost. When consumer i is below satiation, the SCM will cause her to reduce her water/energy use if it increases the extent that she believes her actions are scrutinized, $S_{i,1} > S_{i,0}$, or causes her to updates her belief about the appropriate norm downwards,