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Nudging and other behavioral strategies to manage residential water demand: A review

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Abstract

Nudging has emerged as an alternative policy to manage water demand in the residential sector. Indeed, many field studies have been published recently to assess the impact of nudges on water consumption. In parallel, a large body of literature has been developed in the field of behavioral economics, including lab experiments to evaluate the impact of nudge-type treatments on individual behavior in public goods or common pool resources games. However, the corresponding results are too often neglected in field studies. In this context, focusing on the residential water sector, the aim of this survey paper is first, to focus on key issues in behavioral economics; second, to present the main results obtained in lab games; and third, to review field behavioral experiments. We conclude by discussing unexplored fields and some policy implications.

Keywords: nudging, water demand, experimental economics

JEL code: D01, D12, C91, C93, Q25.

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1 Introduction

Water-use management has been considered a key issue to address for a long period of time. According to the United Nations (UN, 2021), approximately 2,000 million people live in areas that suffer from water stress. Furthermore, droughts are increasingly affected by climate change (UN, 2021). Additionally, weak sanitation infrastructures and economic activities are causing strong deterioration in the quality of water bodies (UN, 2021; Reynaud, 2015). Moreover, there is still a high percentage of households with no access to basic water services (UN, 2021). Facing those challenges is an implicit objective in the 2030 UN Agenda for Sustainable Development, with Goal Number 6 aimed at providing clean water and sanitation for everybody and ensuring sustainable management of water resources. Despite not being the largest water use in volume, the residential water sector is clearly one of the key water sectors to be managed.

In this context, demand-side policies (DSP) have arisen as a significant tool for managing residential water use. In this respect, numerous authors have analyzed the impact of several DSPs in the domestic water sector. Traditionally, experiments have emerged naturally, i.e., changes in water tariffs (Olivier, 2010; Nataraj and Hanemann, 2011), rationing by means of water shortages (Roibás et al., 2019) or informational campaigns (Gaudin, 2006). However, since the work of Ferraro et al. (2011), *ad hoc* designed experiments have appeared as an alternative empirical approach to assessing water management public policies in the residential sector. Currently, researchers have the option to design their own experiments and conduct them either in the laboratory or in the field, then subsequently evaluating their impacts on water consumption or demand.

When managing residential water consumption, among other strategies, nudging (Thaler, 2018)emerges as a significant public policy. These kinds of policies are far from coercive[1]. Such policies are based on information that is intentionally provided to economic agents to motivate behavioral changes but without prohibiting any option (Congiu and Moscati, 2022). Information is crucial when making economic decisions; thus, it should be provided in such a way that it generates more rational behavior. Consequently, nudging could also be considered a significant tool to manage water resources. Moreover, other alternative behavioral strategies, such as boosting (Grune-Yanoff, 2018), are still emerging in the field of environmental economics.

The outline of the paper is as follows. The next section presents a discussion on some key points related to behavioral economics, setting nudges and other behavioral strategies in the experimental design. The third section captures the main findings of experiments in the laboratory as a platform that could complement field research. Then, a review of field behavioral experiments mainly in the residential water sector is presented, focusing on several key nudging issues. Finally, the last section concludes with a brief summary, discussing unexplored fields and some policy implications.

2 Behavioral economics

In this section, a discussion on some important issues linked to behavioral influencing strategies is introduced. Nudging, as a particular strategy, will be described, and some key items to consider in nudge design will be listed. Theoretical concepts will be illustrated with a few examples in the water field.

2.1 Behavioral Influencing Strategies

In regard to enhancing water conservation behaviors to reduce domestic water consumption, researchers have a wide range of *behavioral influencing strategies* (BIS) that could be employed. From the field of behavioral psychology, the *Theory of Planned Behavior* (TPB) (Ajzen, 1991) has been the basis of numerous interventions and experiments. The TPB considers that individuals behave according to careful rational decisions that are taken beforehand or planned.

However, according to Kahneman et al. (2011), there are two different ways in which people process decisions depending on the mode of thinking, namely, reflective and intuitive modes. The reflective mode of thinking is slower, effortful, and deliberative and requires conscious focus on the issue. This mode is habitually activated when the decision risks are high, when the decision is important or when deep reasoning is needed. In contrast, in the intuitive mode of thinking, impressions, associations, feelings, intentions and preparations for action flow naturally, allowing us to do things simultaneously without paying special attention to each action separately and without consciously focusing on how to do them. Most of the time, people use intuitive thinking in daily choices, using numerous heuristics to simplify decision-making. Following Kahneman et al. (2011), Koop et al. (2019) categorized the different BISs according to three different routes of information processing: (1) a reflective route, based on conscious rational arguments, experiences and knowledge, (2) a semireflective route, based on heuristics, and (3) an automatic route, based on automatic noncognitive responses[2].

In addition, as explained in Novak et al. (2018), there is empirical evidence of an intention-behavior gap when individuals have the intention to behave differently but fail to achieve this change in practice. As a consequence, it is crucial to focus not only on peoples willingness to change their water consumption behavior but also on the behavioral change process. This process includes multiple stages that have to be considered when designing a behavioral change, which Novak et al. (2018)[3] adapted to the area of water saving as follows:

- *Precontemplation*: People have no intention to change their water consumption behavior since they are unaware of this need. Habits mostly determine water consumption (Fielding et al., 2012; Jorgensen et al., 2009). To change these habits, it is key to get people to visualize the negative environmental consequences of wasting water, since ecological water beliefs encourage consumers to save (Corral-Verdugo et al., 2003). Additionally, clear social norms should be stated, such as social approval for saving water effective for water savings (Schultz et al., 2014).

- *Contemplation*: People are aware of the need and intend to change their behavior; thus, they now need to identify the appropriate actions to take. Factual knowledge about water should be provided, showing that water-saving actions can produce personal gains in exchange for a slight reduction in comfort, according to goal framing theory (Lindenberg and Steg, 2007).

- *Action*: People who have already started changing their behavior require continuous reinforcement. Users should be provided with actionable tips to save water (Randolph and Troy, 2008) to increase their perceived behavioral control along with positive reinforcements through social, virtual or physical rewards to keep engaged with water saving.

- *Monitoring*: Once people have changed their behavior, it is necessary for them to avoid slipping back to the old behavior. Thus, internalizing new habits that are intrinsically motivated to savings and helping individuals maintain a cycle of interest, curiosity, challenge, feedback and enjoyment are key strategies (He et al., 2010).

Therefore, researchers and policy-makers should acknowledge that the process of achieving lasting behavioral change is a long road. The strategy should first make people aware of the need to change their behavior, allowing them to visualize the negative impact of wasting water and then giving them tools to use and actions they could take to save water. Then, interventions should focus on positively reinforcing the new conserving behaviors that have been achieved so they can continue saving and maintaining these actions in the long run. Among the different BISs, nudges stand out as one way to achieve behavioral change in residential water consumption. This explains why some of the classical strategies to reduce consumption, such as increasing prices or setting tariffs penalizing consumption, could be unfair, as they affect the lowest income groups more negatively. Consequently, some of the recently designed experiments in the residential water management field include behavioral tools, such as *nudging*.

2.2 Nudging design: concept and key points

The term *nudge* was born from the economic theory of Richard H. Thaler, which was influenced by the psychologist Daniel Kahneman. The idea hinges on the architecture of decisions and behavioral sciences, i.e., the analysis of the processes that lead human beings to decide and act in one way or another, given our limited rationality and that we are emotional and influenced by others and by the environment in which we make decisions. *Nudges*, according to Thaler and Sunstein (2008) (pp.6-8), are "any aspect of the choice architecture that alters people's behavior (...) without forbidding any options or significantly changing their economic incentives (...)", significantly altering "the behavior of Humans even though it would be ignored by Econs". Recently, in an excellent review, Congiu and Moscati (2022) discussed the main components of this definition, the paternalism implicit in the nudge concept and its effectiveness in changing behaviors.

According to these authors, the Thaler and Shunstein definition has been revised in recent years, thereby improving the characterization of this strategy. For instance, Sunstein (2018), in a more recent approach, has reinforced the idea of libertarian paternalism, thus preserving individuals' freedom of choice.

There is an important stream of literature that analyzes nudges aiming to promote environmentally desirable behavior[4]. In nudges' design, there are some particular items that one should consider to increase the probability of achieving the desired results. In the following paragraphs, some of the most important aspects in this regard are briefly presented.

- *Visualization* refers to the creation of images, diagrams, or animations to communicate a message is an important item to consider in nudging. Novak et al. (2018) summarized the guidelines for water consumption visualization to support behavioral change according to the study of Micheel et al. (2015). Actually, Novak et al. (2018) found positive user feedback on both consumption visualizations and tips, leading people to think about water conservation more often and learn about their own consumption (thus being better informed). Drawing and the use of different colors is also another issue to consider when designing nudging strategies (Otaki et al., 2019).

- *Framing* refers to the way (cost vs. saving, present vs. future, loss vs. gains...) the nudge is presented to the public. For example, Lambert and Lee (2018) found that framing graywater reuse as a cost saving or water conservation measure generates the highest acceptance compared to environmental conservation.

- *Persistence* studies the frequency of sending messages, which is also a significant attribute to consider when designing nudges. As mentioned later, we distinguish between one-time interventions and more frequent interventions.

- *Gamification* consists of presenting the nudge as a game; it has been used to reinforce[5] desired behaviors by competition with neighbors and by distributing virtual rewards for water saving, water efficiency education, profiling and participating in social networks, as seen in Novak et al. (2018).

- *Goal setting* refers to defining particular goals to reach and has shown promising results in energy consumption (Abrahamse et al., 2005) since it increases one's commitment toward savings, provides a sense of achievement when goals are reached, and strengthens user's hedonic, normative and gain goals, according to Novak et al. (2018). Conservation goals can also be considered when designing nudges to manage water consumption (Brent et al., 2020).

- *Technology acceptance* is a crucial issue to consider, especially when smart technologies are used as an information tool. Sometimes the levels of acceptance are not high, which can have a negative impact on the effectiveness of nudging strategies (Schultz et al., 2014).

- *Boomerang effect* refers to the outcome in which some of the low-use consumers change their behavior in the opposite direction as that of the desired behavior. Trying to avoid this countereffect, for example, Chabé-Ferret et al. (2019) sent positive messages to those consuming water below average (based on Schultz et al. (2007)).

- *Hawthorne effect* refers participants behaving differently because they know they are being observed (Schwartz et al., 2013). To avoid the *Hawthorne effect*, Chabé-Ferret et al. (2019) also sent messages to the control group.

Previous features should be considered when designing nudging strategies. Some of them will be deeply discussed in Section 4, mentioning some examples in the residential water field. However, there are other behavioral alternatives to nudges that are briefly described in the next section.

2.3 Nudges versus boosts: new research perspectives for water conservation

Boosts have the same objective as nudges, i.e., correcting behavioral biases and helping individuals overcome their limitations. However, boosts are presented in the literature as an alternative to nudges. Boosts generally take the form of basic and very general training that allows the development of a set of skills that can be used to solve many different choice problems. Recent papers have discussed the relevance of boosts and the conditions for using them instead of nudges (Grune-Yanoff and Hertwig, 2016; Hertwig, 2017; Grune-Yanoff et al., 2018; Grune-Yanoff, 2018).

One can distinguish different sets of boosts, i.e., risk literacy from uncertainty management and motivational boosts (Krawiec et al., 2021; Huang, 2018). Risk literacy provides training in basic statistical skills, such as frequency calculation and interpretation. Boosts of this type are, for example, used to better understand the statistics of disease survival, as seen in Gigerenzer et al. (2008). Uncertainty management boosts proposes to breakdown complex decisions into several simple tasks (or step-by-step rules, (Krawiec et al., 2021)). For instance, Milkman et al. (2014) combined effort (gym use) with a reward (downloading and listening to music at the same time). Next, Drexler et al. (2014) taught entrepreneurs to separate family and business accounts to better manage their business. Finally, motivational boosts aim to develop individuals' skills, such as their own motivation, effort or attention (Tang and Posner, 2019). These are boosts that are often used to increase school performance (Alan et al., 2019; Aronson and Good, 2002; Blackwell and Dweck, 2007; Good and Inzlicht, 2003). Other types of boosts exist, such as those proposed by Kozyreva and Hertwig (2020) or Krawiec et al. (2021) called inoculation strategies, which consist of teaching individuals to identify relevant information or misinformation in a complex framework.

Boosts and nudges do not affect individual behavior in the same way. Grune-Yanoff and Hertwig (2016) have identified situations where the use of boosts is recommended. First, unlike nudges, boosts are effective in the presence of heterogeneous preferences, either time-varying preferences or contracting individual objectives (Hertwig, 2017). Indeed, boosts provide new skills to individuals but leave them free to make their own decisions and promote their autonomy, leading to the acquisition of new or improved individual skills and allowing individuals to exercise personal agency (Hertwig, 2017). Boosts thus have potentially more lasting or persistent effects than nudges. Second, according to Grune-Yanoff (2018), nudges and boosts differ in their ethical implications. Indeed, boosts may have less negative welfare effects as they develop autonomy and are less intrusive compared to nudges, which sometimes generate the feeling of being manipulated or loss of autonomy. Conversely, boosts require the participation of individuals and are therefore more transparent than nudges. Boosts thus protect more against manipulation or malevolent governments than nudges (Hertwig, 2017). However, boosts are not always operational when faced with skills that are difficult to develop through basic training or to teach or when faced with individuals who are not motivated.

To our knowledge, there are few experiments that have examined boosts as they relate to ecological issues. DellaValle and Sareen (2020) discussed the relevance of boosts to address fuel poverty. According to these authors, boosts in the form of basic education can enable individuals to identify fuel poverty situations and to find relevant solutions. In a recent paper, Lazaric and Toumi (2022) proposed to assess the implementation of boosts associated with electricity consumption reduction targets on 77 households in the Monaco principality. These boosts consisted of very specific technical tips (such as unplugging electrical outlets at night). The final results showed the efficiency of the boosts combined with a low ambitious consumption reduction target (15% consumption reduction) and thus found that the boosts alone did not have a significant effect on energy consumption. However, water consumption is also a privileged field of application for boosts and nudges but remains unexplored to the best of our knowledge.

3 Lab experiment and nudges for residential water users

In this section, we discuss previous literature that has conducted laboratory experiments connected to this field, with special attention given to those that developed nudges. These examination of these studies allows us to propose experiments in a controlled environment that are able to test the effect of treatments in a simplified setting, different from the real world. Indeed, laboratory experiments are complementary to field studies, but most of them are decontextualized. However, there are few papers based on laboratory experiments in the field of water (i.e., mentioned as a key word). There is, however, a very large body of literature that analyzes the impact of social norms on individual behavior in lab games and addresses the conditions that are favorable to the emergence of new norms. Some of these papers are based on normative and descriptive individual beliefs, which have not been used in field studies analyzing water consumption.

3.1 Interest and limitations of laboratory experiments to analyze the impact of nudges on consumer behavior

Laboratory experiments have several advantages compared to field studies. First, they allow the testing of the impact of treatments in a controlled environment. Lab experiments can also include monetary incentives that help participants change their behavior almost instantly and allow the researchers to ask the participants about their beliefs and even modify them. Such experiments are therefore a useful and low-cost first step before a field study, where behaviors are influenced by multiple factors and often characterized by inertia. Many lab experiments are built on induced values (Smith, 1976; Lusk and Shogren, 2007). In such a setting, we are able to define the individual optimal consumption derived from the induced utility function and budgetary constraints and thus measure the individual's deviation from her optimum, which is impossible to define in practice. Contrary to field studies, laboratory experiments are therefore perfectly suited to evaluate the impact of nudges on consumption choice and to distinguish deviation below from above the optimum, thus addressing overconsumption and rebound effects. Another interest of lab experiments lies in the absence of evocative framing for the choice framework. As noted by Alekseev et al. (2017), evocative framing, which relies on a real-life situation but can also evoke strong emotions, should be used carefully since it can interact with the participants' observable characteristics.

However, according to Levitt and List (2007), there are limitations to the interpretation and generalization of the lab results. Indeed, the literature has shown that being observed exaggerates the importance of prosocial behaviors compared to unsupervised environments. Extant studies also indicate that participants in lab experiments, who are often students, are unrepresentative of the general population because they are younger, more educated, and more empowered to understand the tasks they are given. Finally, the range of choices that an economic agent faces is very limited in the laboratory setting compared to the field. Indeed, participants often face only one dimension, which does not allow for the simulation of all the choices that an individual faces in the real world. For example, an individual may devote a large part of her time to helping others but never make donations in monetary form. In the laboratory, however, she may only be allowed to make monetary donations but not help people.

Before showing the main results in lab experiments dealing with social norms, we present recent papers making the complex pricing of water more salient to encourage rational consumption choice.

3.2 Complex tariff scheme and consumption

Some recent papers are devoted to water tariff schemes and focus on the effects of their complexity on individual behaviors in lab experiments. Indeed, utilities often choose price-incentive-based policies to manage water consumption and generally adopt an increasing block rate (IBR) pricing scheme. In its conventional form, this pricing scheme breaks down the metered volume of water during the billing period by the use of ordered blocks with increasing unit prices.

IBR tariff schemes can achieve the goals of environmental protection and social equity and are currently implemented in the United States, as well as in many European and developing countries. Water preservation can be promoted if high tariffs are used for nonbasic water uses. However, the IBR is complex compared to the constant rate (CBR), where the unit price level is constant regardless of the consumption level. However, the proper use of an IBR water schedule implies first that consumers be first perfectly informed about the tariff scheme and second that they be perfectly rational, thereby making them able to assess the impact of changes in consumption on water bill. If information is not perfect or if consumers are boundedly rational, then price incentives may be inefficient, therefore challenging conservation goals being sought through this peculiar tariff scheme. Two recent papers have implemented lab experiments to help people deal with such complex tariff schemes.

Mayol and Staropoli (2021) designed a lab experiment that aimed to compare three tariff schemes, namely, CBR only, CBR plus fixed part (two-part tariff) and IBR. First, participants were asked to complete a questionnaire to assess their own consumption given their equipment and habits. Second, they were asked to spontaneously choose the tariff scheme they preferred. In a last step, participants were informed about the incentives of the IBR tariff and its ability to reduce consumption and were asked to again choose one tariff scheme. Based on their actual consumption, participants in the lab experiment initially chose the simplest CBR alone. However, when the tariff schemes were explained to them and monetary incentives were introduced, they chose IBR more when it allowed them to reduce their bill, thus reducing their aversion to complexity.

In another recent paper, Binet et al. (2022) designed a laboratory experiment in which participants chose either a water consumption level under CBR or a simplified IBR tariff scheme, where the unit price of the last unit consumed is applied to all the quantities chosen. The aim of Binet et al. (2022) was first to provide experimental evidence for a water consumption bias (difference between consumption and the optimal value) when households are faced with a complex tariff scheme. To obtain an objective measure of this bias, the authors calibrated optimal consumption values using a Stone-Geary utility function. Second, they analyzed the effects of an informational nudge based on a marginal price recall on individual consumption (called IR treatment). Indeed, in each session, a participant of a certain type should choose a consumption level between 1 and 20 and do so repeatedly during 20 periods under no information recall and then again during another 20 periods under information recall (IR), with the tariff scheme being the same for the whole session (within-subject design). Ultimately, the results first show that individual consumption bias is positive, indicating an average consumption level above the optimal level, which can be interpreted as ironing where the consumer makes his or her decision upon an average price and thus leads to overconsumption. A second important result is that the consumption bias is significantly reduced by providing information recall about marginal prices to participants; but this is true under the simplified IBR tariff scheme only.

3.3 Impact and emergence of social norms

The impact of social norms can be studied in laboratory games such as common pool resources, public goods or dictator games. Generally, lab experiments include more than 200 participants (often students) in groups of 4 or 8 people, making it possible to identify the impact of the choice of other participants on individual behavior from one period to another. Compared to field experiments, lab experiments also ask participants about their beliefs regarding descriptive and normative norms and measure the influence of their beliefs about social norm in the society on the observed behavior. Lab experiments thus analyze the process of the emergence and evolution of social norms. This stream of literature thus allows improving the field papers that generally do not deal with beleifs and expectations in term of social norms (see next section including social comparison tools).

3.3.1 Lab games and social norms

Water is a common good. Therefore, common pool resources (CPR) games are a natural framework used to analyze the impact of social norms on water consumption[6].

In CPR games, participants receive a fixed endowment and are asked to make an investment choice or similarly to decide on a level of extraction x_i. More precisely, the fixed endowment is allocated between a private and a collective account. The return of the private account is fixed. Increasing individual extraction level x_i not only increases individual payoff but also decreases the total resource availability, which captures the social dilemma issue. Indeed, many studies such as (Walker et al., 1990) have obtained allocations predicted by self-interest, which corresponds to over-exploitation issues.

In this context, the literature has shown the importance of social interactions among the participants of the group in the laboratory to get closer to the optimum and thus reduce overconsumption. Indeed, the studies by (Ostrom et al., 1994) or (Poteete et al., 2009) showed the importance of communication among participants to reach the optimal level of extraction in a repeated CPR game. Communication helps decrease the level of extraction and converge toward the cooperative optimal solution.

Public goods (PG) games, in which participants are asked to contribute to a collective account and have incentives to free ride, are also relevant to analyzing the impact of social norms on water overconsumption. PG and CPR games are often considered equivalent when analyzing social dilemma issues, i.e., situations where individuals do not consider the impact of their choices on others. The studies by Apesteguia and Maier-Rigaud (2006) and Kingsleya and Liu (2014) showed that cooperation divergence observed between the two games is only explained by variation in experimental parameters.

A PG game is also a good setting to test the impact of social norms on public good contribution[7]. PG games are generally carried out over several periods. During the first period, participants individually choose the amount of their contribution to the public good. In the second period, the contributions of other participants are revealed. The results support compliance with social norms. Indeed, there is a tendency to increase one's contribution when one realizes that it was below the average of the others in the same group. However, compliance with social norms is not universal. Indeed, Fischbacher and Gächter (2000) showed that there are several participant' profiles. In their lab experiment, approximately 50% of the subjects were conditional cooperators, i.e., people who are willing to contribute more to a public good the more others contribute. But, one-third of the participants remained free riders and did not conform to the descriptive norm. More recently, Kandul and Lanz (2021) also proposed analyzing the impact of out-group behavior on individual choices in a public good game. The authors showed that participants adjust their contribution depending on the out-group information transmitted. For example, participants in one group do not change their contribution if they realize that participants in other groups contributed less on average than they did. Finally, Fehr and Gächter (2000) showed that the contributions are increased due to sanctions.

These laboratory experiments are in the same vein as the field experiments conducted by Ferraro (2009) and Ferraro et al. (2011), for example. But, the results of these studies can additionally enrich field studies. For example, the in-group versus out-group distinction should lead to distinguishing several social groups in the field, i.e., one close and one more distant. Field studies should also identify conditional cooperators from others. One other crucial contribution of lab games is to analyze the determinants of social norm adoption and to highlight the role of normative and descriptive beliefs and expectations in terms of social norms that may influence conditional cooperators' behaviors.

Indeed, the set of publications by Bicchieri (2017), Bicchieri and Xiao (2009) and Bicchieri (2006) allows us to better understand the mechanisms of the adoption or rejection of a social norm by measuring the beliefs of individuals in lab experiments. Laboratory experiments carried out in this field consist of observing the participants' behaviors and asking them about their normative and descriptive beliefs. According to Bicchieri (2017), a descriptive belief or expectation is 'what we expect others to do'. Thus, individuals who think that others are going to save water will tend to conform with such behavior. A personal normative belief is what 'I think should be done'. Normative social expectation is 'what we believe others think we ought to do' or what other people approve of (Bicchieri and Xiao, 2009). If one is convinced that society expects one to save water, such a belief will increase your compliance with this standard. These papers show that conditional norm followers, who represent the majority of individuals, conform to social norms if their normative and descriptive expectations are in the same direction. Bicchieri and Xiao (2009) also focused on the case of divergence among normative and descriptive expectations and revealed that participants follow descriptive but not normative beliefs in that case. They concluded that norm compliance is therefore dominated by descriptive beliefs.

Definitively, the findings of the abovementioned lab experiments should be taken into account to enrich field studies. The next section will describe the main contributions of analyzing nudges in the residential water field. Several dimensions will be analyzed, such as nudging strategies, the temporal extension of consumption impacts or some design issues.

4 Field experiments and nudges for residential water users: lessons and main results

The empirical literature on behavioral economics in the residential water sector has increased since the seminal work by Ferraro et al. (2011). At that point in time, several studies have been developed to assess the impacts of nudging in managing residential water consumption. In this section, some controversial issues will be discussed, such as some alternatives in the nudging framework, communication channels and design, methods to assess nudging impacts and temporal issues regarding the length of the treatments or the extension of the effects. Table A1 in the Appendix displays a summary of the main contributions in this field.

4.1 Nudging strategies

In recent decades, a wide range of information-based programs have been put into practice to motivate people to use water efficiently. These programs include actions and policies in line with water-saving campaigns, as seen in Russell and Fielding (2010) or Stewart et al. (2010). When designing nudges in this field, the first decision that should be made is the kind of information that we would like to provide. In this respect, several approaches have been identified, ranging from simple technical advice to more sophisticated informational strategies. On the one hand, water-saving tips are frequent in both natural and field experiments (Schultz et al., 2014; Strong and Goemans, 2015; Novak et al., 2018; Brent and Wichman, 2020). On the other hand, social or self-comparisons are a common tool (Ferraro et al., 2011; Fielding et al., 2013; Schultz et al., 2014; Seyranian et al., 2015; Strong and Goemans, 2015; Novak et al., 2018; Otaki et al., 2019; Brent et al., 2020). Moreover, other options, such as moral suasion and/or social/personal identity treatments, are used in some of these experiments (Ferraro and Price, 2013; Seyranian et al., 2015; Rajapaksa et al., 2019).

Providing *tips* about how to save water is an easy and inexpensive measure to implement but sometimes has no effect on saving water (Ferraro et al., 2011; Schultz et al., 2014; Seyranian et al., 2015); such provision can even have the opposite effect (Liu et al., 2016; Fielding et al., 2013). Tom et al. (2011) analyzed two experiments in which water conservation programs provided useful information to behavioral change to conserve water and found that the program with greater detail in regard to measurement and feedback was more effective. In Brent et al. (2020), households were messaged with information on their consumption and tips to save water, which resulted in savings of approximately 4%.

In addition, by comparing different interventions for impulse water conservation in households, Seyranian et al. (2015) found that giving information alone (i.e., water-saving tips) was the least effective approach. Similarly, Ferraro et al. (2011) found technical advice to have a negligible effect, while including normative messages and social comparisons significantly reduced water consumption, with the social comparison intervention being the only intervention to have a lasting impact. The usefulness of providing tips is often questioned and criticized, and the disadvantages of such tips range from the fact that they might be helpful only in places with water shortages (Inman and Jeffrey, 2006; March et al., 2015) or be effective only for short periods (Saurí, 2013; Katz et al., 2016).

A very simple but also useful method to influence behavior is to give *feedback* (FB) about the user's water consumption. Just by informing the household about its detailed levels of water use, water savings have been achieved, as seen in Liu et al. (2017) or Chung (2021). Nevertheless, this strategy has often been used as a complement to more sophisticated nudging strategies, as seen in Agarwal et al. (2021), Jessoe et al. (2021), Otaki et al. (2022) or Torres and Carlsson (2018a), for example.

Social comparison tools (SCT) have also been another interesting strategy used to induce water savings in the residential sector. An excellent review can be found in Nauges and Whittington (2019). As Seyranian et al. (2015) explained, two normative feedback messages can be applied, namely, descriptive social norms, which are descriptions of people's behavior, and injunctive norms, which are prescriptions of desirable household behavior, indicating social approval or disapproval. Nauges and Whittington (2019) also captured that distinction with descriptive norms by showing a statement or a graph where authors display their own household's water consumption and the water consumption of other households versus injunctive norms, thereby providing households with feedback on that comparison.

SCT is usually implemented with respect to the average or median water consumption in the household's neighborhood (Ferraro and Price, 2013; Ferraro and Miranda, 2013; Seyranian et al., 2015; Miranda et al., 2019), but it is also possible to find comparisons with respect to the average consumption in the city (Miranda et al., 2019). However, the latest benchmark indicator is less effective than the neighborhood reference (Miranda et al., 2019), meaning that closer comparisons tend to work better. Brent et al. (2017) used households with similar characteristics in terms of family members and the size of irrigable land as benchmarks. Nevertheless, it is worth noting that this information is not frequently available for water suppliers. Fielding et al. (2013) made a comparison based on the percentage of households showing some water-saving habits, with this strategy being quite effective for water conservation. It is crucial to set the more adequate framework identity as a benchmark indicator (Miranda et al., 2019).

Additionally, comparisons could be made in either absolute terms (showing information on total consumption) or relative terms. In this respect, Brent et al. (2020) assessed both strategies, and developed a social comparison framed as performance toward a conservation goal in contrast to the traditional comparison (in gallons or cubic meters). They found that the treatment using social comparisons in relative terms generated conservation among several types of households, including low-use customers[8].

In general, SCT generates positive effects in terms of water conservation (Ferraro et al., 2011; Seyranian et al., 2015; Brent et al., 2017; Jaime Torres and Carlsson, 2016; Brick et al., 2017; Otaki et al., 2017; Miranda et al., 2019; Brent et al., 2020). Nauges and Whittington (2019), in a review of SCT on water consumption, found water savings ranging from 0.6% to 5.6%. In particular, Brent and Ward (2019), who compared the effectiveness of different nudges, found social comparison nudges to be particularly strong, especially when household consumption was above average, compared to the monetary savings related to increasing the marginal price structure. Similarly, Brent et al. (2020) found that implementing SCT in a conservation goal framework reduced water consumption by 38%.

As Chabé-Ferret et al. (2019) explained, one advantage of social comparison approaches is being cost-effective, since they can be applied to a large population with small costs. Nonetheless, Nauges and Whittington (2019) showed that a main disadvantage of this type of strategy, among others, is a *moral tax* induced by social comparison. Likewise,Chabé-Ferret et al. (2019) analyzed the disadvantage of the *boomerang effect*, in which some of the low-use consumers change their behavior in the opposite direction as the targeted direction. Moreover, as Chabé-Ferret et al. (2019) explained, the effect of social comparison relies, on the one hand, on the fear of receiving a social sanction (Sunstein, 1996) or on conforming to what is seen as effective behavior (Thøgersen, 2014). On the other hand, SCT increases the visibility of others' actions and thus influences behavior through automatic heuristics, which raise interest and show better response in customers (Liu et al., 2015); however, their effect is sometimes difficult to isolate (Sønderlund et al., 2014).

Another option is performing *historical self-comparisons* (SFCs). This option avoids the moral tax or similar costs related to social comparisons since attention is exclusively focused on the household's historical behavior. Recently, Otaki et al. (2019), who studied how different communicating methods in historical self-comparisons of water consumption, found SFCs to be effective in water savings even regardless of the level of water consumption.

Moral suasion (MS) is another alternative used in this field. In general, this tool involves different alternatives to making households feel responsible for the goal of water conservation. Rajapaksa et al. (2019) showed that this kind of message can strongly promote water conservation behaviors. In this respect, Seyranian et al. (2015) distinguished between personal and social identity, with the difference being the type of language used. These authors suggest inclusive language as the preferred language in communications, emphasizing the normative component of 'who we are' and 'how we act' as a community.

Less frequent is the strategy based on providing feedback on water tariffs and prices in the so-called *financial nudges* (FN). For instance, in Brent and Ward (2019), households were first surveyed to check the degree of information that they have on water consumption and bills; afterward, they were provided with extended and customized information on water bills, prices, and consumption. The authors discovered that low-water-use households increased their water consumption, since they learned that water was cheaper than what they declared in the survey.

Finally, and aimed at achieving significant behavioral changes, more sophisticated techniques could be implemented that combine different alternatives at the same time. In this respect, Novak et al. (2018) designed an app/web supported system to stimulate water savings that combines smart-meter based consumption visualization, water-saving tips and gamified incentives, showing the high potential of combining different procedures to get better results than each measure isolated[9]. The effect of the visualizations and tips in (Novak et al., 2018) resulted in reductions in water consumption of 27.5% for the intervention group, while the average reduction was 8% for the control group in a trial of three months. Technological issues are closely linked to the information channels detailed in the section below.

4.2 Tools to send information: the role of new technologies

Typically, normative feedback is given via pamphlets or flyers (Schultz et al., 2007). Most field experiments developing nudges include some treatment where information is sent by e-mail (Ferraro and Price, 2013; Brent et al., 2020), even along with water bills (Rajapaksa et al., 2019; Miranda et al., 2019). However, some of these studies use other types of tools, such as e-mail or mobile phone messaging. These alternatives make it easier to send messages at any time. For instance, Otaki et al. (2019) implemented a field experiment in Tokyo in which water droplets with illustrations were sent every two weeks by e-mail. Similarly, Chabé-Ferret et al. (2019) used SMS-based communications to nudge farmers into water saving in Southwest France.

Another popular alternative is the use of smart meters in combination with new technologies. The willingness to reduce consumption is a prerequisite; however, as Davies et al. (2014) pointed out, smart metering has the potential to provide knowledge and awareness about consumption to households. This technology is able to give feedback to customers that will empower them to better understand their water consumption and to adapt it according to monetary or environmental benefits. This technology delivers water users near real-time information in much more sophisticated ways (Schultz et al., 2014). According to Strong and Goemans (2015), water smart readers are monitoring devices that provide households with real-time information on their consumption[10] Some governments have raised the potential benefits of smart metering (NERA, 2007; PCE, 2009) since they assume that consumers can better manage their resources by making informed decisions.

In metering water consumption, according to Cominola et al. (2015), two classes of data can be distinguished: low-resolution and high-resolution. On the one hand, low-resolution data are recorded in frequencies as quarters of year, and this type of data is useful to measure seasonality and is analyzed with time series model procedures. On the other hand, high-resolution data are delivered by high-resolution sensors with the ability to measure water consumption on a subdaily basis. This can be done through intrusive metering, directly estimating water end uses by installing sensors on water-consuming appliances, or through nonintrusive metering, which registers the total water flow in the whole household.

As Sønderlund et al. (2014) point out, a smart meter can record consumption in real time or near real time and communicate this information to the utility and the consumer, but it is important to examine the effect of such feedback about water consumption to change household behavior[11]. One advantage of such information is providing households with a clearer (compared to tips) sense of which activities consume more water and, therefore, they can save water more effectively (Fielding et al., 2013). In any case, as Strong and Goemans (2015) pointed out, smart meters by themselves do not give households information on water prices or tariff structures unless they are accompanied by some additional communications (Novak et al., 2018), since households are in general highly uninformed about water tariffs (Carter and Milon, 2005; Binet et al., 2014; Garcia-Valiñas et al., 2021). One suitable communication channel for such information is in-home displays. In-home displays (IHDs) or mobile media apps could be powerful tools to reduce water consumption, reinforcing conservation and saving behaviors (Strengers, 2011; Harou et al., 2014).

Fielding et al. (2013) used smart water metering as a tool for behavioral change and as a resource to test the effectiveness of water use management interventions. They demonstrated that demand management strategies can promote significant water savings. In this line, Strong and Goemans (2015) used smart metering to assess the effect of providing real-time information on households' water consumption, finding households better informed about pricing systems and consumption more price sensitive. Additionally, when giving feedback on average daily water consumption, possible boomerang effects could occur, as seen in Schultz et al. (2007), where feedback messages had the undesirable effect of increasing consumption on low consumers, as Seyranian et al. (2015) explains. Either way, real-time quantity information affected water consumption, as consumers became aware of prices and reacted more rationally to them (Strong and Goemans, 2014, 2015; Roseta-Palma et al., 2020).

In any case, and as mentioned before, technology acceptance is crucial. Schultz et al. (2014) conducted a nudging field experiment in San Diego (US); to do so, the authors used a web-based interface and postal mail as communicating channels, and they observed that the former was less effective in reducing water consumption, since only 18% of households checked the website. Therefore, policy design should also be aimed at reinforcing technology acceptance since it is a prerequisite to making technological nudging effective.

4.3 Visualization: drawing and design

As previously mentioned, visualization is a significant issue in this field. An adequate design could make a nudge more effective. Thus, the use of colors, symbols or images/pictures could help to reinforce the power of nudges as a tool to manage residential water demand. In this respect, there are several studies that have used some interesting design features that are worth discussing.

Inserting different colors in a nudging design is a technique quite frequently used to give behavioral feedback. Traditionally, green or blue colors are associated with 'good' behavior, while red is linked to water waste or overconsumption (Miranda et al., 2019). Otaki et al. (2019) showed that the use of graphical water droplet illustrations in different colors led to an increase in the proportion of households showing a slight water decrease with respect to households in the control group.

A few papers have also included some emoticons when providing feedback to households related to their water consumption. Smiling/sad faces/emojis have been used in water-nudging messages, with heterogeneous results. Otaki et al. (2017) found that high-use consumers decreased their water consumption when they received such emoticons, whereas in low-use consumers, water use decreased when they saw that their water consumption had already decreased. Similarly, Novak et al. (2018) included some 'like' and 'dislike' icons to provide customized feedback in their visualization tool[12] found that this tool generated significant water conservation behaviors.

Furthermore, the use of drawings or pictures showing water as a scarce resource is also important. For instance, Tiefenbeck et al. (2018) installed a device in the household's shower to display the water and energy consumption, providing households with information on their real-time consumption. The visualization strategy displayed a polar bear animation with an iceberg that progressively shrunk as the quantity of resources consumed increased. This strategy led to a 22% reduction in energy and water consumption for showering.

4.4 Methods to analyze nudging impacts

Most papers in this field have used average treatment effects (ATE) (Ferraro et al., 2011; Ferraro and Price, 2013; Schultz et al., 2014; Brent et al., 2020; Joo et al., 2018) as the main technique to assess the effect of the nudge. The ATE procedures evaluate the difference in means between the results obtained from the units in the treated group (a population that is enrolled in some program) and the units assigned to the control group (a population that is not enrolled). An extension of ATE is the conditional average treatment effects (CATE) procedure, which has been used in (Brent et al., 2020). The difference between these two approaches is the fact that the CATE assesses the effect of the treatment in a subgroup of the population, while the ATE is the effect of the treatment in the whole population (see, for example, (Aakvika et al., 2005) or (MaCurdy et al., 2011))

Several studies have also applied difference-in-differences (DID) (Hoyos and Artabe, 2017; Miranda et al., 2019), which measures the effect of a program by calculating the effect of the treatment (independent variable) on an outcome (dependent variable). This method is based on comparing the average change over time in the outcome variable for the treatment group to the average change over time for the control group. Additionally, simple tests comparing means of water consumption are usually performed (Willis et al., 2010; Otaki et al., 2017; Novak et al., 2018).

However, one important issue that has been neglected by previous literature is that most of these studies have focused on comparing water use before and after the nudge but have not assessed the effect of the treatments in a water demand framework, thereby not providing price elasticity estimates. Two significant exceptions are Strong and Goemans (2015) and Brent and Wichman (2020). We describe the details of these two studies below.

For example, in the study by Strong and Goemans (2015), households were subsidized to purchase a smart meter that gave users real-time information on their flow rate and their water consumption over the billing period. Strong and Goemans (2015) split the sample of households to identify the effect of water smart reader (WSR) ownership on households before and after receiving the device[13]. Strong and Goemans (2015) found that owning a smart reader device increased water consumption almost 9% through the estimation of the water demand with a DCC model in which they included a dummy variable for owning a device. Afterward, the authors conducted different estimates for those with and without water readers, with the differences between the parameter estimates across the different samples being the effect of the treatment on the treated. Interestingly, they found that having a water device makes households more responsive to price changes and less responsive to changes in income.

Another example is the study of Brent and Wichman (2020), in which households received a WSR and, afterward, they were messaged with information on their own water consumption and some tips on how to save water; this approach resulted in savings of approximately 4%. To assess the price sensitivity effect of the nudge, the authors employed the difference in discontinuity. Surprisingly, they found households' response to the nudge to be quite similar regardless of the economic incentive given to the family to boost water conservation. Then, Brent and Wichman (2020) measured the extent to which the nudge affected price sensitivity and found limited evidence of an economically meaningful relationship between prices and nudges.

4.5 Nudging and temporal issues

When looking at experimental design, some differences in terms of nudging length have been observed. Some studies have designed experimental frameworks based on a one-time intervention (Ferraro et al., 2011; Ferraro and Price, 2013; Ferraro and Miranda, 2013; Bernedo et al., 2014; Miranda et al., 2019), while others have extended the interventions over a longer period of time (Fielding et al., 2013; Strong and Goemans, 2015; Novak et al., 2018; Otaki et al., 2019; Brent and Wichman, 2020). In this respect, no clear conclusions have been observed.

Moreover, a very interesting research question is the temporal duration of nudging effects. Most studies have found impacts in the short run, particularly when social nudges are implemented (Nauges and Whittington, 2019). However, the long-term effects are not clear. In this regard, Beal et al. (2013) showed that tools oriented toward the curtailment of water consumption would generate more reliable water conservation patterns over the longer term.

Seyranian et al. (2015) detected that information given alone (i.e., water-saving tips) are the least effective approach; in contrast, consumers exposed to social norms, social identity or personal identity, reduce their consumption in both the short and long term. In Davies et al. (2014), the long-term effects of giving information through smart metering were assessed; the authors found that the group of participants in their study consumed more than 6% less water, while households in the control group consumed 1% more than before the experiment, even three years after the experiment.

In contrast, Fielding et al. (2013), who conducted a similar experiment to that of Ferraro (2009) or Ferraro et al. (2011), found that the effects of interventions dissipated in the long term in all cases. Similarly, Bernedo et al. (2014), who developed a nudge that combined several strategies (technical information, moral suasion, and social comparisons), observed declining effects on water consumption over time and registered reductions in their effects by almost 50% 12 months later. Miranda et al. (2019) noticed that some effects of nudging could last up to four months, beyond which they decreased. Otaki et al. (2019), who analyzed the impact of a historical self-comparison nudge, did not find any impact on water consumption in the long run. Strong and Goemans (2015), in regard to their technological nudging, observed that water consumption tends to return to previous levels in the long term, similar to the findings of Fraternali et al. (2019).

5 Conclusions and future research

Nudging and other behavioral strategies have emerged as alternative policy tools for managing water demand in the residential sector. However, policy-makers should consider several information processing pathways to be more successful. First, the starting point could be developing informational campaigns to provide customers with the knowledge to understand the importance of water and to increase their ability to achieve water savings. The messages could be designed as social norms and presented in a manner that would favor people acting in an attempt to conform to these norms. Likewise, the information should be properly framed, highlighting the best option in the present, in a suggestive and intrinsically motivating way; it should preferably be personalized rather than in the form of general messages. Last, campaigns could evoke emotions and use priming by showing images or videos so that the desired behavior appears to the consumers almost automatically and without effort. Taking all these aspects into account, behavioral strategies could perform efficiently in achieving water conservation behaviors.

Both laboratory and field experiments have provided plenty of information to optimally design these behavioral strategies. However, there are still some gaps to be developed in future research. For instance, lab experiments show that individual beliefs and expectations influence the probability of adopting a norm. However, these issues have been neglected in field studies. Thus, field research could build on these laboratory findings by identifying conditional cooperators and studying the degree of their social norm compliance based on their empirical and normative beliefs. Field studies could, after such identification, try to change the beliefs of those who think that others do not save water as a priority and show them that this belief is not true.

Most studies have found that nudging leads to significant water consumption reductions in the residential sector. Congiu and Moscati (2022) pointed out that in principle, nudges may work in the long run, with their positive effect persisting over time. However, the current literature review has shown that some papers have found that positive effects dissipate over time. No clear profiles have been detected; thus, this is still an interesting topic that needs to be extended. In our opinion, this issue is clearly connected with boosting, which is a relatively unexplored issue in the residential water sector.

In this respect, the training framework could be oriented toward how to estimate the level of one's approximate daily water consumption. This would allow one to evaluate the amount of the water bill and to trigger more virtuous consumption behaviors to reduce consumption when the threshold of the highest bracket reached by the household is almost reached. Ferraro and Price (2013) proposed the use of small technical instructions that explain small water-saving actions. This treatment was not found to be significant, probably because it was not sufficient enough to train individuals in water-saving actions. Full training sessions could be provided at home to teach basic water-saving actions (e.g., turning off the water during certain stages of showering or dishwashing or not watering the garden when it has rained during the week). Moreover, boosts could be used to improve financial information leading to a better understanding of the complex pricing of tap water (tariff literacy) to make small everyday actions that reduce water waste more operational (uncertainty management) and to increase the motivation of agents by boosting their ecological concern, particularly in relation to the issues of water resource scarcity (motivational boost). The literature on water demand estimation has shown that part of the overconsumption of water is due to a lack of knowledge of increasing block rate tariff schemes, leading many households to underestimate the price of water (Binet et al., 2014). In that context, small training sessions dedicated to improving one's knowledge of the current pricing scheme could thus help to reduce excessive consumption.

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Notes

[1]Actually, they are considered "soft" policies, as opposed to mandatory or "hard" policies, such as pricing, taxation or quotas, since nudging does not impose any change in economic incentives.

[2]The *reflective route* includes knowledge transfer and increasing self-efficacy. Knowledge transfer has been proven to be useful in achieving water savings (Kneebone et al., 2018; Fielding et al., 2013), although it is itself insufficient, as discussed later. The *semireflective route* emphasizes social norms. People tend to adjust their behavior toward the most appropriate conduct when their actions are confronted with desirable behavior (Landon et al., 2018; Bernedo et al., 2014; Ferraro et al., 2011); that is, people try to conform to social norms. In this respect, framing and tailoring are key issues to consider. Finally, the *automatic route* evokes emotions to influence behavior. Moreover, it proposes the use of unconsciously processed cues in the environment to reinforce desirable behavior (Papies, 2016).

[3]This model for behavioral change is based on the trans-theoretical model of Prochaska and DiClemente (1992); Prochaska et al. (2008).

[4]See Schubert (2017) for a review on green nudges and their ethical implications.

[5]Once reinforcements are removed, the desired behavior tends to extinguish (Richter et al., 2015).

[6]Standard CPR games in the lab have been developed by Walker et al. (2000); see Anderies et al. (2011) or Ostrom et al. (1994) for a review of the literature

[7]See Chaudhuri (2011) for a review of the literature

[8]Note that traditionally, richer households and high water-use customers have been more reactive toward SCT (Seyranian et al., 2015; Nauges and Whittington, 2019).

[9]A demo can be seen at this link: https://www.youtube.com/watch?v=YLrTW9MVUjk

[10]Water smart-metering enables the gathering of detailed data registered through real or near to real-time monitoring, high resolution interval metering, automated water meter reading and access to data from the internet, as explained in Makki et al. (2015). Check Makki et al. (2015) for a review on different smart meters.

[11]Check Sønderlund et al. (2014) for a discussion on water consumption feedback using smart meters.

[12]Note that the web/app-based visualization tool is more complex and was developed by Novak et al. (2018), including further information (consumption, tips, other drawings, etc.).

[13]An important issue to consider, as the authors mention, is that households were self-selected into the program, which is a source of potential endogeneity of participation.

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Table 1: Nudging strategies review (I)

Authors	**Experimental setting**	**Intervention mode**	**HHs and treatments**	**Methods**	**Behavioral strategies**	**Consumption reductions**	**Long-run analysis**
Willis et al. (2010)	Australia, Gold Coast; Winter 2009	IHD	151 HHs; Continuous	Sample t-tests	FB / other	3%	-
Tom et al. (2011)	United States, California; WWHC March 2000 - 2008 DLS January 2001	Postal mail / phone	200 HHs; One-time	Descriptive statistics	FB / tips	-	-
Ferraro and Price (2013)	Atlanta, Georgia; May 2007 - April 2007	Postal mail	106,668 HHs; Two-times	ANOVA / ATE	tips / SCT	4.8%	Dissipated
Ferraro and Miranda (2013)	Atlanta, Georgia; May 2007 - April 2007	Postal mail	106,668 HHs; Two-times	CATE / Quantile TE	tips / SCT / MS	-	-
Fielding et al. (2013)	Australia, South East Queensland; September 2010 - January 2011	Postal mail	221 HHs; Four-times	Random intercept model	FB / tips / SCT	11.3 LPD	Dissipated
Bernedo et al. (2014)	Atlanta; May 2007	Postal mail	83,300 HHs; One-time	ATE	tips / SCT / SFC / MS	2.7-4.8%	Persistent
Smith and Visser (2014)	South-Africa, Cape Town; November 2012 - December 2012	Postal mail	398,423 HHs; One-time	OLS / ATE	FB / tips / SCT / SFC	1%	-
Schultz et al. (2014)	United States, San Diego; July 2009 - August 2010	Postal mail / web	301 HHs; One-time	ANOVA	FB / SCT / SFC	16-26%	-
Datta et al. (2015)	Costa Rica, Belen; July 2014	Postal mail	5,626 HHs; One-time	Descriptive statistics / DID	SCT / GS	3.4-5.6%	-
Brent et al. (2015)	United States, California; September 2011 - ongoing	Postal mail / email	7,361 HHs; One-time	ATE / DID	tips / SCT	4.9-5.1%	-
Seyranian et al. (2015)	United States, Los Angeles; July - August	Postal mail	374 HHs; One-time	OLS / ANOVA	tips / SCT / SFC / other	Boomerang effect	Dissipated
Liu et al. (2016)	Australia, New South Wales; May 2013 - September 2013	Postal mail	68 HHs; Two-times	ANOVA	FB	8%	-
Jaime Torres and Carlsson (2016)	Colombia, Antioquia; January 2013 - December 2013	Postal mail	1,857 HHs; Twelve-times	ATE	FB / tips / SCT	6.8%	Persistent

Abbreviations: HHs = households, LPD = liters per day, IHD = In home display or mobile media apps, ANOVA = Analysis Of Variance, ATE = Average Treatment Effects, CATE = Conditional Average Treatment Effects, DID = Differences in Differences, OLS = Ordinary Least Squares, SEM = Structural Equation Model, GLMM = Generalized Linear Mixed Models, SCT = Social Comparison Tools, SFC = Self-Comparison, PG = Public Good, GT = Goal Setting, MS = Moral Suasion, FB = Feedback.

Table 2: Nudging strategies review (II)

Authors	Experimental setting	Intervention mode	HHs and treatments	Methods	Behavioral strategies	Consumption reductions	Long-run analysis
Nayar and Kanaka (2017)	India, Chennai; -	Postal mail / phone	74 HHs; One-time	Descriptive statistics	tips / SCT	5.0%	-
Brick et al. (2017)	Cape Town; November 2015 - April 2016	Postal mail	366,048 HHs; Six-times	ATE	tips / SCT / FB / PG	0.6%-1.3%	-
Quesnel and Ajami (2017)	United States, California; 2005 - 2015	Media coverage	1,200 HHs; Continuous	Regression	other	11-18%	-
Liu et al. (2017)	Australia, New South Wales; May 2013 - September 2013	Postal mail / web	188 HHs; Two-times / continuous	Descriptive statistics	FB	4.2-8.0%	-
Otaki et al. (2017)	Japan, Tokyo; September 2017 - February 2018	Fax	246 HHs; Twelve-times	Variability rate	FB / SCT	Reduced	-
Wichman (2017)	United States, North Carolina; February 2009 - June 2014	Postal mail	59,000 bills; One-time / continuous	ATE	other	Increase +3.55%	-
Bhanot (2017)	United States, California; November 2012, January 2013, March 2013 and May 2013	Postal mail / email	3,896 HHs; Four-times	ATE	SCT / other	Increase +8.22-17.85 GPD	Persistent
Katz et al. (2018)	Israel; May 2013 - June 2013	Postal mail	1,399 HHs; Three-times	DID	SCT	6.1-7.6%	-
Torres and Carlsson (2018b)	Colombia, Antioquia; January 2013 - January 2014	Postal mail	1,311 HHs; One-time	ATE	FB / SCT	6.8%	Persistent
Novak et al. (2018)	Switzerland; July 2015 - February 2016	IND / web	35 HHs; Continuous	Descriptive statistics	FB / tips / SCT / GT / other	27.5%	-
Miranda et al. (2019)	Costa Rica, Beln; July 2014	Postal mail	5,626 HHs; One-time	DID	tips / SCT / GS	4.8-4.9%	-
Rajapaksa et al. (2019)	Australia, Brisbane; 2010 and 2011	Postal mail	753 HHs; One-time	SEM	tips / MS	Reduced	-
Otaki et al. (2019)	Japan, Tokyo; September 2017 - February 2018	Email	479 HHs; Twelve-times	Sample t-tests	FB / SCT / SFC	Reduced	Dissipated
Goette et al. (2019)	Singapore; December 2016 - January 2017	Leaflets	899 HHs; Six-times	ATE	tips / SCT / MS / FN	3.9-4.1 LPD	-

Abbreviations: HHs = households, LPD = liters per day, IHD = In home display or mobile media apps, ANOVA = Analysis Of Variance, ATE = Average Treatment Effects, CATE = Conditional Average Treatment Effects, DID = Differences in Differences, OLS = Ordinary Least Squares, SEM = Structural Equation Model, GLMM = Generalized Linear Mixed Models, SCT = Social Comparison Tools, SFC = Self-Comparison, PG = Public Good, GT = Goal Setting, MS = Moral Suasion, FB = Feedback.

Table 3: Nudging strategies review (III)

Authors	Experimental setting	Intervention mode	HHs and treatments	Methods	Behavioral strategies	Consumption reductions	Long-run analysis
Brent et al. (2020)	United States, Nevada; July 2015 - August 2015	Postal mail	43,052 HHs; Two-times	ATE	FB / tips / SCT	1.5%	-
Brent and Wichman (2020)	United States, California; November - December 2014, March - April 2015	IHD / web	45,223 HHs; One-time	DID	FB / tips / SCT	3.5-4.5%	-
Jessoe et al. (2021)	United States, California; March 2015 - May 2016	Postal mail / email	18,500 HHs; Six-times	ATE	FB / tips / SCT	4-5%	Dissipated
Agarwal et al. (2021)	Singapore; August 2016 - December 2016	Postal mail	1.5 million HHs; One-time	DID	FB / SCT / other	0%	Persistent
Bhanot (2021)	United States, San Francisco; December 2014 - January 2015	Email	45,866 HHs; Six/seven-times	ATE	FB / SCT	2.5-3.5%	-
Chung (2021)	United States, Minnesota; 2015 - 2018	Web	6,332 HHs; Continuous	DID / ATE	FB	2.1-4.4%	-
Daminato et al. (2021)	Spain, Tenerife; 2010 - 2019	Web	51,674 HHs; Continuous	Regression / DID	FB / other	2%	-
Kazukauskas et al. (2021)	Sweden; March 2016 - March 2017	IHD	525 HHs; Continuous	ATE	FB / SCT	0%	-
Otaki et al. (2022)	Japan, Tokyo; March 2019 - September 2019	Email	783 HHs; Fifteen-times	GLMM / ANOVA	FB / SCT / PG	4.6%	Persistent

Abbreviations: HHs = households, LPD = liters per day, IHD = In home display or mobile media apps, ANOVA = Analysis Of Variance, ATE = Average Treatment Effects, CATE = Conditional Average Treatment Effects, DID = Differences in Differences, OLS = Ordinary Least Squares, SEM = Structural Equation Model, GLMM = Generalized Linear Mixed Models, SCT = Social Comparison Tools, SFC = Self-Comparison, PG = Public Good, GS = Goal Setting, MS = Moral Suasion, FB = Feedback.