THE INCIDENCE OF COMPLEX TARIFF SCHEMES AND INFORMATION ON WATER CONSUMPTION: A LABORATORY ECONOMIC EXPERIMENT

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Abstract.

The aim of this paper is to provide experimental evidence for a water consumption bias when households face a complex tariff scheme. To obtain an objective measure of this bias, we design an incentivized laboratory experiment where participants choose a water consumption level under different tariffs schemes, namely, a Constant Block Rate (CBR) and an Increasing Block Rate (IBR). Our first result is that, as expected, the individual consumption bias is positive, indicating an average consumption level above the optimal level. Second, under a progressive tariff scheme, the consumption bias is lower than that under the CBR, which demonstrates the efficiency of price incentives in terms of water conservation. A third important result is that the consumption bias is significantly reduced by providing information recall about marginal prices to participants under the IBR tariff scheme.

Key-words: Laboratory economic experiment, water consumption, cognitive bias, price information, tariff structure.

1. INTRODUCTION

According to the World Bank (2016), 1.6 billion people suffer from water scarcity. Projections to 2050 underline that demand for water will increase due to population growth, urbanization and agricultural uses. At the same time, climate change will affect rainfall, with increased variability. All in all, water availability could be reduced by two thirds compared to 2015 levels. Indeed, in 2050, 4 billion people could live in water-stressed areas, including in both developing and developed countries (OECD, 2016). Finally, ensuring sufficient water availability is essential to reducing poverty, maintaining economic growth, avoiding water conflicts and guaranteeing food security (World Bank, 2016).

The OECD (2016) has made policy recommendations to deal with the current and future challenges concerning water scarcity, and the European Union provided the water framework directive (Artell and Huhtala (2016)). Indeed, European laws and policies intend to favor a « dehydrate » economy. For this purpose, most of the water utilities have developed policies based on price incentives. Utilities 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 ordered blocks with increasing unit prices. Such a tariff scheme, which can achieve the goals of environmental protection and social equity, is 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 non-basic water uses. However, the proper use of an IBR water schedule implies that the consumer is perfectly informed about the tariff scheme, making him able to assess the impact of changes in water consumption on his invoice. If information to the consumer is not perfect, there may be insufficient behavioral changes, which could challenge the conservation goals being sought through this peculiar tariff scheme. Indeed, following Shin (1985) and using data from a household survey carried out in the Reunion Island, Binet et al. (2014) and Cabral et al. (2017) showed that the price perceived by consumers subject to an IBR tariff scheme is lower than the price perceived by a perfectly informed consumer (the marginal price, i.e., the price of the last unit consumed). Therefore, water consumption tends to be far greater than the optimal level for the consumer. In this paper, we conjecture that such deviation may come from individual cognitive biases arising from the relative complexity of this tariff schedule. Following the recommendations of the World Bank (2016) and OECD (2016), we implement a simple behavioral nudge – a salient information recall about the marginal price – to enhance the efficiency of individual responses to water price incentives. We conjecture that relevant information could help consumers make better choices for themselves.

The traditional increasing block rate (IBR) tariff scheme incorporates two dimensions that are mixed together: on one hand, the effect of increasing the marginal price when the consumption level rises and, on the other hand, the effect of blocks consisting of various thresholds that set different marginal prices. In our experiment, we focus on marginal price misperception by individuals and how this misperception can be reduced with real-time information recall about the marginal price to be paid under a particular consumption level.

To disentangle the effect of the pricing scheme from that arising from information and to provide a precise measure of the individual consumption bias --- defined as the difference between the optimal consumption level and actual consumption level -- we designed a laboratory economic experiment where participants faced various pricing schemes and were exposed to a different degree of information regarding the marginal price. Some papers based on field experiments are close to our paper with respect to the issue of nudging. Ferraro and Price (2013) and Bernedo et al. (2014) found a significant and persistent impact of nudging compared to a social norm on water consumption. However, we depart from these studies as they do not address the issue of possible combined effects of price information under different tariffs schemes. To this end, we compare behavioral consumption choices under the tariff schemes of a simplified Increasing Block Rate (IBR) and a Constant Block Rate (CBR). The price schedule was fully described in a document that was distributed to all participants and for each schedule. The document was publicly read at the beginning of the experiment. After, participants were told to make repeated consumption choices under the corresponding price schedule. Then, in some periods, each participant's personal computer provided a marginal price recall, and, in other periods, no recall was provided. We thus test for the efficiency of a behavioral nudge, as we provided individuals with information about a choice they faced (Coffman et al., 2015). To disentangle the effect of learning from the effect of information properly, participants repeated the consumption choices under a constant environment 20 times.

Many papers in the field of environmental economics have used laboratory economic experiments; see for example García-Gallego et al. (2012). However, seldom is a laboratory experiment used to study the effect of complex pricing on consumption. To our knowledge, the sole paper that investigates such a question with a laboratory experiment is Huck and Wallace (2015), who compare the consumption level of a homogeneous good chosen by participants within a laboratory compared to the optimal level under different pricing schemes[1]. Using a laboratory economic experiment in the case of individual drinking water consumption is unprecedented.

[1] In particular, Huck and Wallace (2015) observe that, under a complex pricing scheme (3 units for the price of 2), participants tend to consume more than 30% compared to the optimal level. We also observe this overconsumption but under a different design. Moreover, as in our experiment, they also have a baseline treatment where the unit price is constant.

Following Harrison and List (2004), we argue that a laboratory experiment is the most efficient method of creating counterfactual scenarios, but this method also has other strengths regarding the issue we want to tackle. First, it allows us to have a precise control of the choice framework for individual consumption, thereby disentangling the impact of information and the impact of the tariff scheme. Second, as we induced heterogeneous preferences within the lab (induced values experiment, see Lusk and Shogren, 2007; Murphy et al., 2010), we are able to have a clear theoretical prediction about the optimal consumption choice for each type of participant, which could not be observed in the field. As a consequence, the difference between actual and optimal choices is a direct measure of the consumption bias, which can be unambiguously tied to our experimental conditions. We first observe that the consumption bias consists in overconsumption for a vast majority of our subjects. A second result is that permanent information recall about marginal price helps participants to reduce overconsumption, even if consumption decreases less as participants become more experienced through choice repetition. Providing information recall about the marginal price generates the same mechanism as in Levitt and List (2007), with households re-optimizing their water consumption. A last result is that the progressivity of the IBR tariff helps in reducing overconsumption compared to the Constant Block Rate tariff. Therefore, the IBR tariff structure, together with information recall about the marginal price, may be an efficient ecological policy to manage residential water consumption.

The remainder of the paper is organized as follows. In Section 2, we provide details about our experimental design. In Section 3, experimental results are presented. Finally, Section 4 concludes our paper.

2. EXPERIMENTAL DESIGN

Our experimental design consists in an induced-value setting (Murphy et al., 2010; Huck and Wallace, 2015) where exogenous preferences for water consumption are given for each participant by relying on a utility function. We also set exogenously individual constraints for water consumption, in particular the tariff scheme, endowment and consumption for other goods. The following subsections explain our particular microeconomic calibration (2.1) and the experimental conditions that we implemented in the laboratory (2.2.). The last subsection (2.3) derives the experimental predictions.

2.1 Microeconomic specification and experimental calibration

To tackle possible heterogeneity in individual consumption choices, we use the Stone-Geary approach (Stone (1954)) to model residential water demand as in Gaudin et al. (2001), Martinez-Espineria and Nauges (2004). This specification for individual demand enables us to differentiate a captive component for consumption that is independent from prices and income in the short run from a variable that is price and income dependent. The corresponding demand function of the good priced through a fixed charge F and a block rate tariff p is the result of the maximization of the following utility function (1):

$$U_i(q, X) = \beta \ln(q - c) + (1 - \beta) \ln(X - \gamma) \tag{1}$$

where water consumption level is $q > c$, $X > \gamma$ denotes the composite good level, and $0 < \beta < 1$ and $c > 0$ stand for parameters that can be respectively interpreted as the marginal budget share and a committed quantity for good priced with block rates and $\gamma > 0$ a committed quantity for the aggregate of other consumption goods.

Assuming a unitary price for the composite good, the budget constraint can be written as follows:

$$Y_i + D + F = pq + X \tag{2}$$

where Y_i is the household income and p is the marginal price of water. If we consider the traditional IBR tariff schedule, D *is* the variable for Nordin's difference, expressing the refunding to which the consumer would be entitled if she paid her entire water consumption at the marginal price. The corresponding expenditure function for the block rate priced good, the solution of this optimization problem, is written as follows:

$$pq = pc + \beta(Y - F + D - pc - \gamma) \tag{3}$$

Price elasticity of demand increases with β. As shown in equation (2), the corresponding budget constraint of the consumer is obtained by multiplying the consumption level by the marginal price. The thresholds appear through an income effect adding Nordin's D to the consumer's income. However, as the contribution of our paper focuses on marginal price misperception, we retain a simplified IBR, with Nordin's D and the fixed part equal to zero. We thus ignore the income effects of the tariff scheme to focus on the impact of increasing the marginal price on consumption choice.

We therefore calibrate optimal consumption choices by assuming two possible levels of individual endowment (High H or Low L) and two classes of utility functions. As a consequence, there will be four types of consumers in our experimental sessions, as shown in the following Table:

Table 1. Characteristics of the utility function and endowments for each participant type

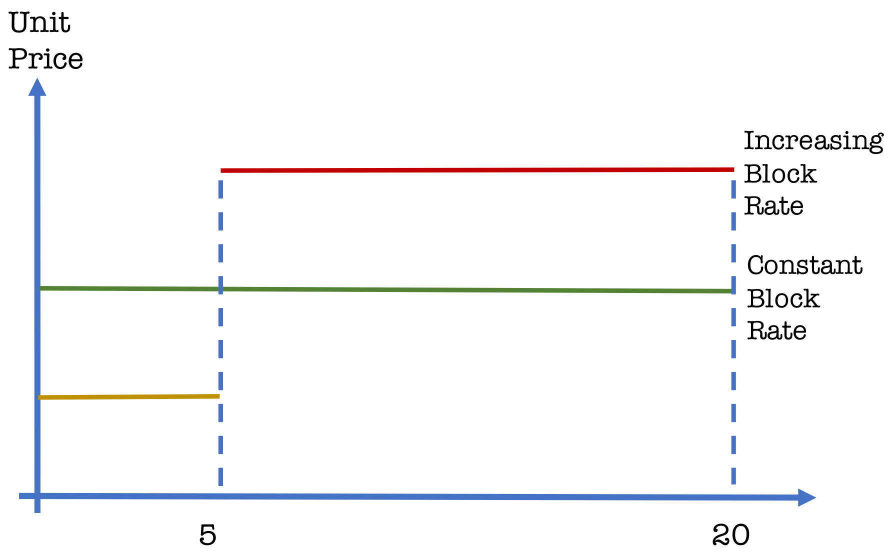
Minimum Consumption Budget share for water Endowment	$c_1 = 1$ $\beta_1 = 0.1$	$c_2 = 6$ $\beta_2 = 0.01$
$Y_L = 50$	Type 1 (U_{1L})	Type 3 (U_{2L})
$Y_H = 200$	Type 2 (U_{1H})	Type 4 (U_{2H})

Values for the parameters c and β define two extreme individual profiles, to create heterogeneity in preferences in our experimental design.

2.2 Experimental treatments and conditions

Our experiment consists in a 2x2 design, where 2 pricing structures are combined --- a CBR scheme and an IBR scheme --- with 2 levels of price information recall obtained during the choice period – no information recall versus information recall. CBR corresponds to a marginal price of water that remains the same, whatever the consumption level chosen by a participant. An IBR scheme consists in our experiment of setting a threshold where the marginal price is *p=1* if consumption is below or equal to the threshold of 5 and *p=3* if the consumption level is higher than the threshold. The following figure explains the possible tariff structures that households face:

Figure 1. IBR and CBR standard tariff schemes

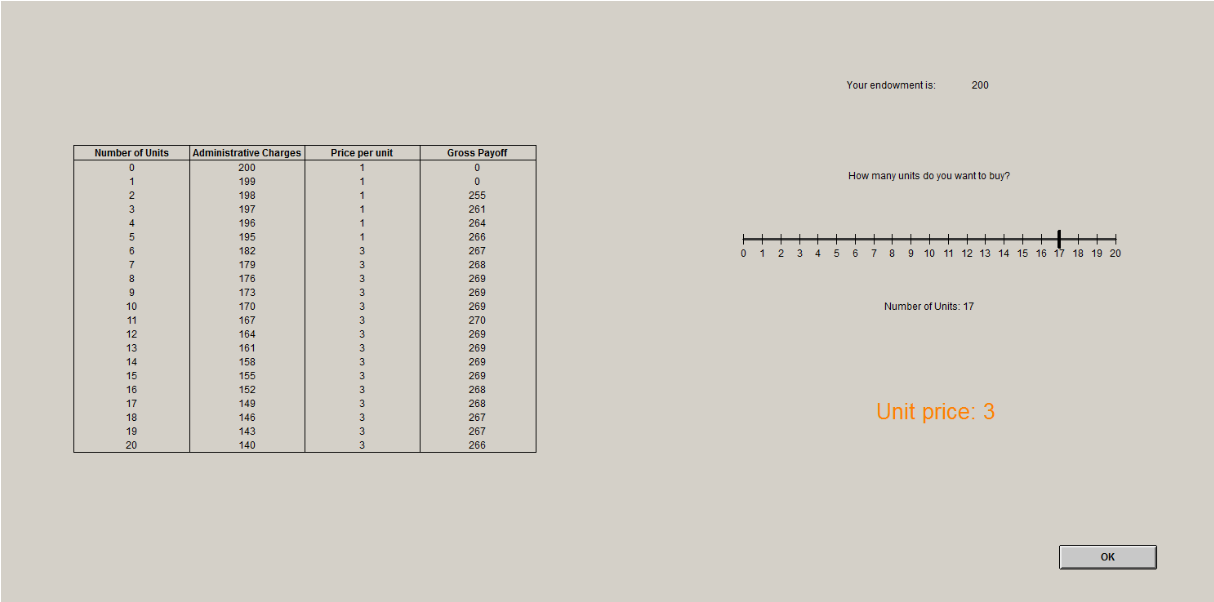


Therefore, if we consider a quantity equal to 7, the standard bill would be equal to 5 p_1 + 2 p_2+*F*. However, we add in the lab a modified version of this traditional IBR. Unlike the usual IBR scheme, when consumption exceeds the threshold, the unit price p=3 is applied to all the quantities chosen. This methodological choice is retained as it simplifies the bill computation by the participants during the experiment and allows us to concentrate on the cognitive biases that mainly arise from the misperception of the marginal price values.

In each session, a participant of a certain type should choose repeatedly during 20 periods under "No Information Recall, NIR" and then another 20 periods under "Information Recall, IR", the tariff scheme being the same for the whole session (within-subject design).

Before making choices, participants were carefully told what the situation choice was. The payoff each participant received depended on her consumption choice level, given the tariff scheme and exogenous gains arising from the underlying net utility (see details on the instructions in the appendix). The following capture of our computerized interface displays the kind of information recall we provided:

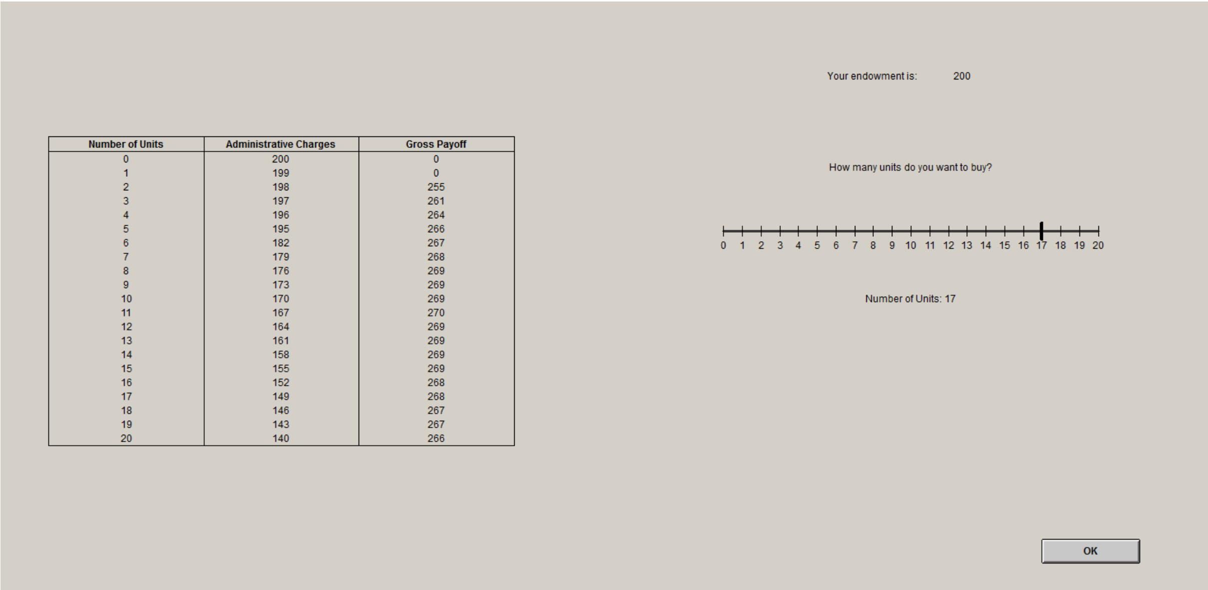
Figure 2. Screen capture of Z-Tree for a participant of Type 2 under IBR + price information recall (translated from French)



Number of Units	Administrative Charges	Price per unit	Gross Payoff
0	200	1	0
1	199	1	0
2	198	1	255
3	197	1	261
4	196	1	264
5	195	1	266
6	182	3	267
7	179	3	268
8	176	3	269
9	173	3	269
10	170	3	269
11	167	3	270
12	164	3	269
13	161	3	269
14	158	3	269
15	155	3	269
16	152	3	268
17	149	3	268
18	146	3	267
19	143	3	267
20	140	3	266

Simply said, the information we provided was minimal. Being perfectly aware about the pricing scheme to which he was exposed, each participant changed the cursor position from 0 to 20 and was able to see information recall about the unit price for the particular position of the cursor. For example, (see figure above), if the participant set the cursor to a consumption level of 17, they saw a recall that the unit price was 3 (in orange color). If the cursor was moved below 5 units, the message indicated that the unit price was 1 (under a green color). We call this condition "Information Recall" (IR). Under the other condition, labeled "No Information Recall" (NIR), the situation choice was exactly the same with exception to information recall, as the following screen capture shows in figure 3:

Figure 3. Screen capture of Z-Tree for a participant of Type 2 under non-linear tariff + no information recall (translated from French)



Number of Units	Administrative Charges	Gross Payoff
0	200	0
1	199	0
2	198	255
3	197	261
4	196	264
5	195	266
6	182	267
7	179	268
8	176	269
9	173	269
10	170	269
11	167	270
12	164	269
13	161	269
14	158	269
15	155	269
16	152	268
17	149	268
18	146	267
19	143	267
20	140	266

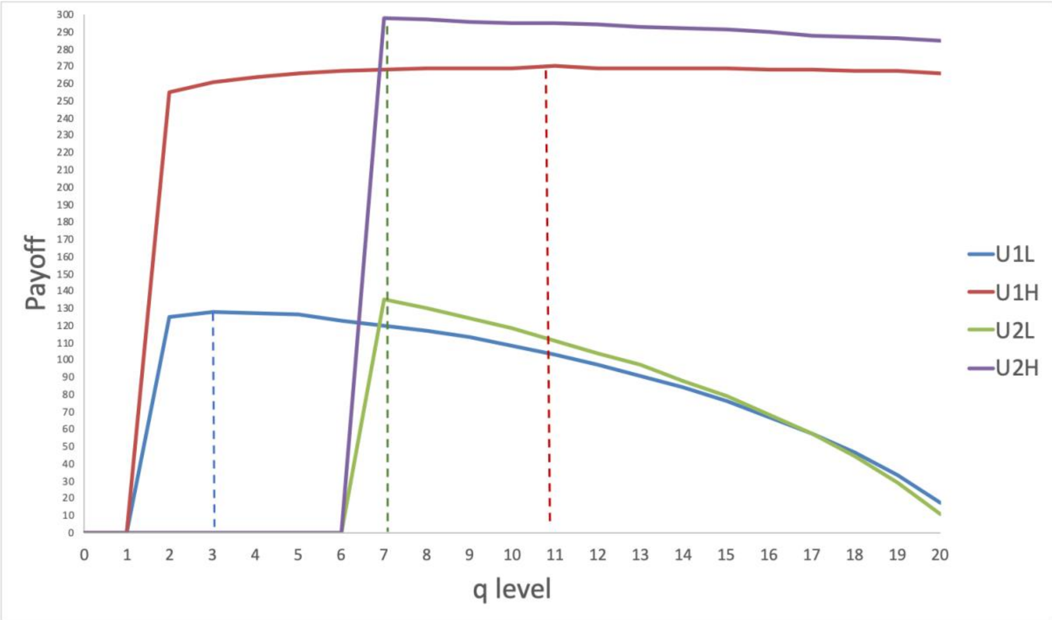
Our information is simply a permanent “recall”, and not a clarification about the pricing scheme, which was explicitly and completely explained and provided in the instructions phase at the beginning of the experiment. This is a behavioral nudge, as we provided individuals with information about a choice they face (Coffman et al. (2015)).

2.3. Theoretical predictions and behavioral conjectures

2.3.1. Theoretical predictions

Assuming perfect rationality, the optimal quantity that should be chosen by each consumer type provides the maximum payoff. Given our particular calibration of preferences à la Stone-Geary and endowments for participants, we compute the optimal solution for each consumer type, which provides us with the incentive structure for monetary payoffs that was presented to participants. The payoff function is as follows (see figure below):

Figure 4. Maximizing-payoff consumption level for each participant type



On the horizontal axis, possible consumption levels are given, from 0 to 20. The vertical axis presents the monetary payoff depending on the consumption level. Solid lines show how monetary payoffs evolve with consumption level, and dotted line indicate optimal consumption for each consumer type (e.g., $q^*=3$ for U_{1L}, $q^*=7$ for U_{2L} and U_{2H}, $q^*=11$ for U_{1H}).

2.3.2. Behavioral conjectures

In practice, details of the tariff scheme often do not appear clearly on the bill, and it can be difficult to understand it. Either the complete tariff scheme does not appear on the bill or it appears but is buried in a mass of other information, so households do not read or understand it. Therefore, as emphasized by Liebman and Zeckhauser (2003), the units for which consumers are charged are different from the units on which consumers base their consumption choices. Indeed, Binet et al. (2014) and Cabral et al. (2017) showed that consumers facing an IBR tariff respond not to the marginal price but rather to an average price indicator computed by dividing the bill, excluding the fixed part, by the consumption level. As under IBR tariff schemes, the corresponding average price is lower than the marginal price, water consumption tends to be far greater than the optimal level, which leads to the first conjecture:

Conjecture 1: *In the case of price misperception, the quantity chosen is different from the optimal value. In the case of the IBR scheme, we expect that participants will tend to choose a quantity greater than the optimal level*.

From a policy perspective, price information recall is recommended in the spirit of Thaler and Sunstein (2008), to "nudge" consumers to adopt water conservation behaviors. The general idea is that water can be saved simply by suggesting clearly the right options to households without imposing constraints. In our experimental analysis, participants do not need to search the marginal price in the form anymore. Therefore, our experimental setting will allow us to test the validity of the following prediction:

Conjecture 2: *The price recall information treatment should decrease over-consumption and favor convergence towards the optimal consumption level.*

A large body of literature provides empirical analyses to estimate the price elasticity of drinking water to evaluate the impact of price incentives; see for example Garcia-Valiñas (2005). However, there is scarce research addressing the comparison of different tariff schedules and their impact on consumption choice. Using quasi-experimental data from Australia, Ratnasiri et al. (2018) conclude that IBR is more effective than the CBR pricing scheme for water conservation. Obviously, our lab methodology addresses this challenging issue in a controlled experimental framework, by comparing, everything being equal, the consumption choices of participants under the CBR and IBR tariff schemes. However, the theoretical predictions are unclear, as shown in conjecture 3:

Conjecture 3*: Our experimental design deals with the impact of the tariff structure on consumption choices. However, two opposite effects may influence water consumption. On one hand, compared to CBR, the IBR tariff scheme may reduce over-consumption if the consumer is price sensitive. On the other hand, the IBR tariff may appear as a complex tariff scheme, increasing errors due to possible cognitive biases.*

3. EXPERIMENTAL RESULTS

All sessions were done in LABEX-EM. All participants (120) were recruited through the software ORSEE (Greiner, 2015). After an experimenter read the instructions loudly, a computerized experiment under the software Z-Tree (Fischbacher, 2007) began. We had 5 sessions of 24 participants in each experimental session. The following table summarizes the participants' characteristics and treatments of the five experimental sessions for the 4 types, U_{1L}, U_{1H}, U_{2L}, and U_{2H}

Table 2. Description of the experimental sessions

Session	**Description of the participants**	**Treatments**
1	12 participants U_{1L} 12 participants U_{2L}	CBR tariff scheme 20 first periods NIR, 20 latest periods IR
2	12 participants U_{1H} 12 participants U_{2H}	CBR tariff scheme 20 first periods NIR, 20 latest periods IR
3	12 participants U_{1L} 12 participants U_{2L}	IBR tariff scheme 20 first periods NIR, 20 latest periods IR
4	12 participants U_{1H} 12 participants U_{2H}	IBR tariff scheme 20 first periods NIR, 20 latest periods IR
5	12 participants U_{1H} 12 participants U_{2H}	IBR tariff scheme 20 first periods IR, 20 latest periods NIR

Optimal quantity is equal to 3 for U_{1L}, 7 for U_{2L}, 7 for U_{2H} and 11 for U_{1H}. IR: Information Recall, NIR: No Information Recall.

We organize the discussion of our results as follows. In subsection 3.1 we compare individual consumption choices to their corresponding optimal values and analyze the effect of the tariff type on consumption choices. We also study the shape of the learning effect. In subsection 3.2, we analyze the impact of the marginal price recall on consumption behaviors. In the remaining subsection, robustness tests are provided to disentangle the price recall treatment from learning effects.

3.1 Deviation from optimal values, tariff progressivity impact and learning effect

As the optimal choice differs across the participants in each session, we analyze the distributions by first providing basic descriptive statistics about the difference between the quantity chosen by each participant for a given period q_{it}^{obs} and the corresponding optimal level q_{it}^{*} in the following table:

Table 3. Descriptive statistics about individual deviations from the optimal quantity

$$\left(q_{it}^{obs} - q_{it}^{*}\right)$$

Sessions	**Total**	**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Session 5**
Mean	0.82	1.9	0.5	0.79	0.36	0.525
Min	-11	-5	-11	-1	-1	-8
Max	17	17	13	14	14	13
% of $\left(q_{it}^{obs} - qit*<0\right.$	3.7%	3.7%	2.6%	0.3%	6.1%	5.6%
Stand. Dev.	2.7	3.69	1.94	2.43	2.49	2.34
Sample size	4800	960	960	960	960	960

First, the results show that, on average, whatever the session considered, the quantity chosen is greater than the optimal value, which is in accordance with conjecture 1. This overconsumption bias may be explained by the under-perception of the marginal price. Obviously, our experimental design therefore provides a suitable framework to analyze the effect of various treatments, including price information on water over-consumption.

To go further, we distinguish the distributions relating to participants facing a CBR tariff scheme from those facing an IBR tariff scheme. For each type of participant, graphs describing the times series are obtained by computing the individual average values of deviation from the optimum consumption choice[2], for each time period for sessions 1 to 4.

[2]Average deviations on the graphs are computed as $AD_t = \sum_i \frac{\left(q_{it}^{obs} - q_{it}^{*}\right)}{n_i}$ $\forall t$ where AD_t is the average deviation in period t, q_{it}^{obs} is the observed consumption choice for participant *i* in period *t*, q_{it}^{*} is the optimal consumption choice for participant *i* at period *t* and n_i is the number of participants of type *i*.

Figure 5. Average deviation from the optimal individual consumption choice under the CBR tariff

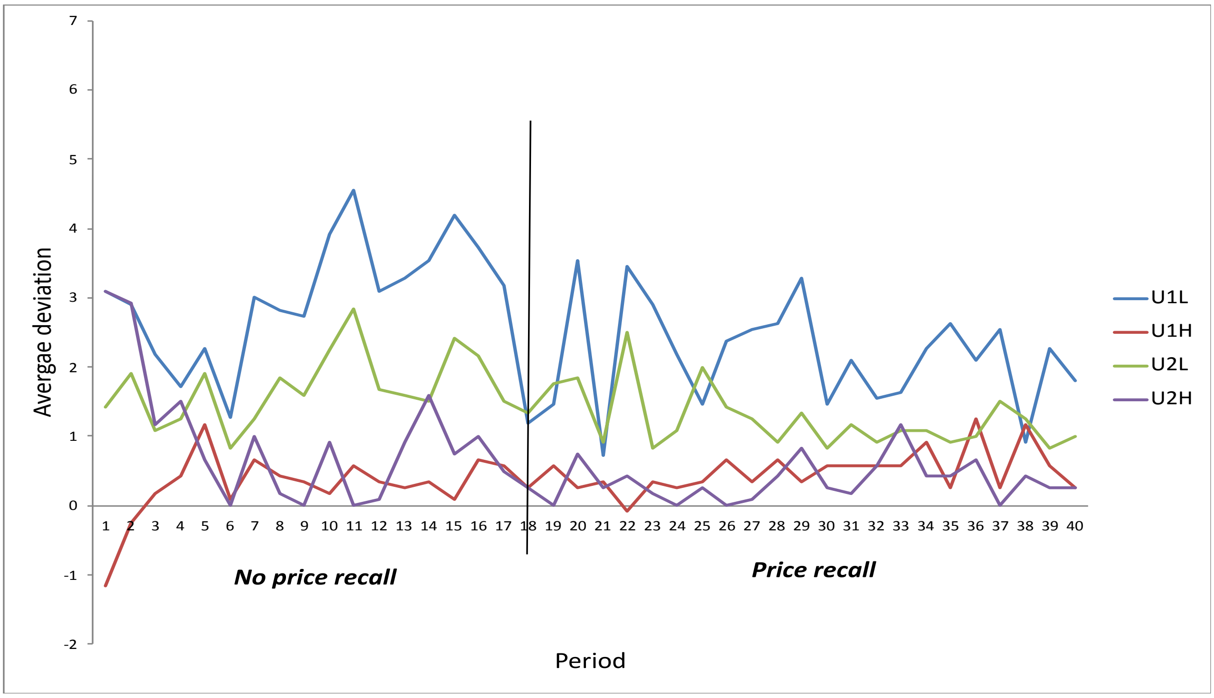
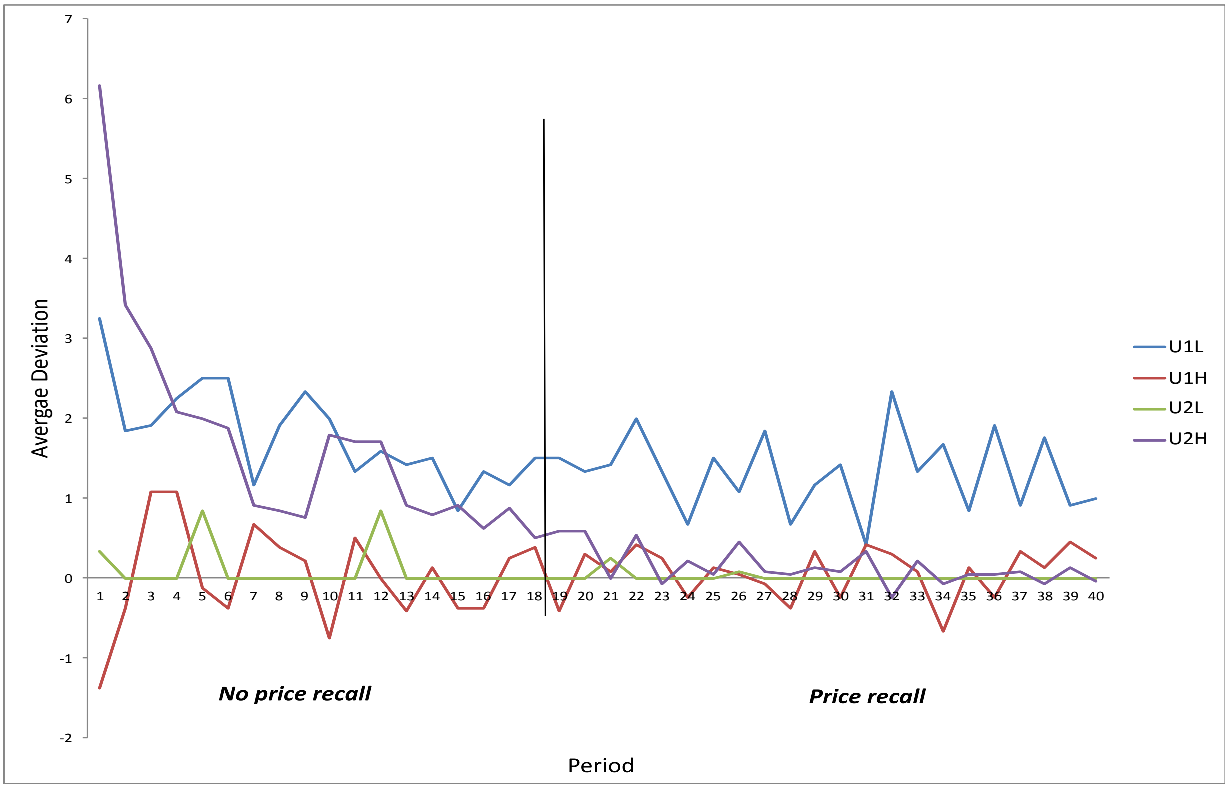


Figure 6. Average deviation from the optimum under the IBR tariff



The results confirm that, during the first periods under the treatment of no price recall, the quantity chosen is much greater than the optimal value and then converges more or less towards the optimal values. If we focus on the IBR tariff case, in the second part of the experiment, when price recall occurs, the distributions describing the U_{1H}, U_{2H} and U_{2L} types converge towards the optimal value as they become stationary around zero. This suggests that price recall treatment is more efficient under the IBR tariff scheme, for which the full understanding of the scheme is more complicated. In addition, whatever the period considered, we observe that average deviations from the optimal value are lower under the IBR case compared to the CBR case. One possible explanation is that our experiments adequately simulate the effects of the price incentives of the IBR tariff scheme in favor of water conservation. These results, in accordance with conjecture 3, suggest that the progressive ecological IBR tariff schedule is efficient for reducing over-consumption of the biggest water consumers.

As complementary evidence, we conducted Non-Parametrical Mann-Whitney statistical tests for unmatched data that focus on the consumption choices by different participants (*U1 versus U2* and *High* versus *Low* endowment). Corresponding averages and *p*-values are given in the following Table:

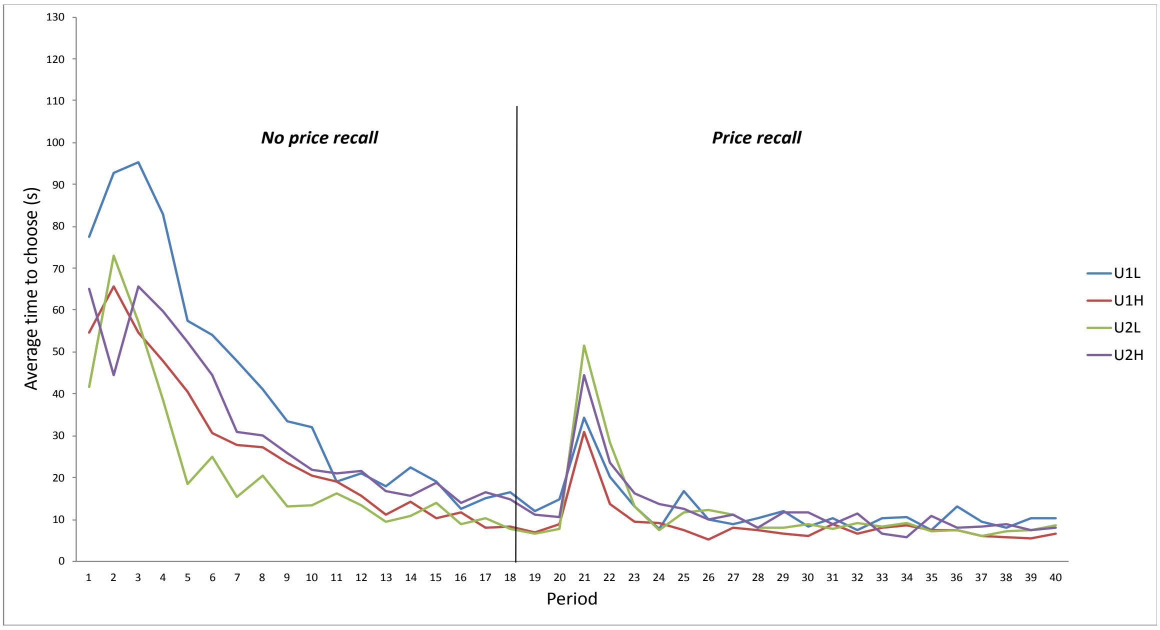
Table 4 Mann-Whitney tests of individual deviations from the optimal consumption choice

Type	*U1*	*U2*	*Low*	*High*
Average deviation $q_{it}^{obs} - q_{it}^{*}$	0.828	0.822	1.36	0.46
p-value	0.35		0.000	

We report very similar values for participants of types U_1 and U_2, with no significant differences (*p*-value=0.35). The diversity of individual preferences does not seem to influence deviation from the optimal values. By contrast, participants with an endowment that equals 200 seem to make more rational choices than those endowed with 50 (p-value of the Mann-Whitney tests equals zero). All things being equal, participants with a low endowment are characterized by lower optimal values than the others, which could partly explain this result.

Another piece of evidence related to the learning effect could be found by analyzing the average times (in seconds) that participants take to choose their consumption level. The following plot depicts the corresponding distributions if we consider the average values of participants for each type under IBR (the graph is similar under the CBR tariff scheme).

Figure 7. Average time to choose a quantity under the IBR tariff



These graphs reveal a strong decrease in average time used by participants to make their choices during the first 20 periods, when no price recall occurred, revealing a strong learning effect (the learning duration could be defined as the number of periods needed by subjects to reach a stationary state regarding decision durations). Actually, it took approximately 12 periods for subjects to have constant decision times in the first step. In the second step of sessions 1 to 4, when price recall occurred, the graphs reveal that the average times to choose and the learning duration were both shorter. Finally, both price recall and learning effects seem to favor convergence towards the optimal value. One major issue of this paper is to disentangle those two complementary effects.

3.2 Marginal price recall treatment

Our preliminary results show that, on average, participants consume more than what is economically rational. One possible explanation is that they under-estimate their marginal price. Thus, providing information recall to households about their marginal price may be an innovative means of inducing them to respond to pricing policies designed to promote water conservation. Indeed, we observe that deviation from the optimal quantity is reduced if the participants benefit from price recall (0.68 *versus* 1.12 in average). To gain further insight, we implement Wilcoxon matched-pairs signed-rank tests to compare the quantity chosen by the participants belonging to the same session, depending on the information level they faced.

Table 5. Descriptive statistics of consumption choice and p-values from the Wilcoxon test

Session	Average quantity No price recall	Average quantity Price recall	p-value Wilcoxon signed rank test
Total	8.12	7.68	0.044
1	7.35	6.74	0.028
2	9.60	9.42	0.09
3	5.93	5.65	0.0009
4	9.58	9.15	0.16
5	9.01	10.03	0.0002

In sessions 1 to 4, the quantity chosen when price recall occurs is lower than when it does not occur, with a statistically significant difference except in session 4. However, we obtain the reverse result in session 5, where participants are first submitted to a price recall. This finding supports the hypothesis that a strong learning effect occurs to favor convergence towards the optimal quantity.

To go further, we provide a multivariate regression analysis allowing us to identify the contribution of each treatment simultaneously, everything being equal. We use random-effect Tobit regressions to deal with censored data as the dependent variable, the quantity chosen, has values between 0 and 20. Two main specifications are first compared. Regression 1 includes three dummy variables: *info*, which takes a value of one under the price recall case and 0 otherwise; *type* which takes a value of one if preferences are describes by U_2 and 0 otherwise; and *tariff*, which takes a value of one if CBR and 0 if IBR. We also add a *period* variable, which ranges from 1 to 20, to check for the existence of a learning effect during the sessions and for each treatment. Initial endowments are also included. We expect, everything being equal, a negative influence of the price recall on the quantity chosen by participants but no significant effect of preference types. Next, a negative influence of *period* on the quantity chosen would reveal the existence of a learning effect. In regression 2, we add controls for participants' characteristics, including their age and sex and a variable measuring their aversion towards risk (*switch*[3]). We expect no significant effects of these individual characteristics on their decision choice. Summary statistics of the variables are reported below:

Table 6. Summary statistics of the variables used in the econometric model (4800 observations)

Variable	Unit	Mean	Min	Max	Stand. Dev
Quantity	Integer between 0 to 20	8.22	0	20	3.42
Info	1=informed, 0 NI=non-informed	0.5	0	1	0.5
Period	Times series from 1 to 20	10.5	1	20	5.76
Endowment	Integer 50, 200	140	50	200	73.49
Tariff	1=CBR, 0= IBR	0.4	0	1	0.49
Type	0=U_1, 1= U_2	0.5	0	1	0.5
Sex	1=female, 0=male	0.5	0	1	0.49
Age	Years	19.07	18	27	1.65
Switch	Integer	6.41	2	10	1.99

A first set of estimates is obtained for the whole sample including all five sessions. Second, we compare estimates from two subsamples, data from sessions 1 to 4, and then data from session 5. The results are shown in the following table:

[3] The variable *switch* corresponds to the number of safe lotteries chosen against a risky lottery in the Holt-Laury procedure for eliciting the risk-aversion level for a given participant. A switch that equals 4 implies risk neutrality. For more details, see Holt and Laury (2002).

Table 7. Regression panel data analyses of consumption choices

	regression 1	*regression 2*	*regression1*	*regression2*	*regression1*	*regression2*
Variable	*all sample*		*Sessions 1-4*		*Session 5*	
Info	-0.073*** (0.009)	-0.072** (0.011)	-0.071*** (0.007)	-0.07*** (0.006)	-0.255 (0.53)	-0.31 (0.45)
Tariff	0.10 (0.53)		0.102 (0.67)			
Type	-0.016 (0.55)		-0.0047 (0.86)		-0.64 (0.14)	-0.64 (0.15)
Period	-0.0058** (0.015)	-0.006*** (0.009)	-0.005** (0.028)	-0.005** (0.021)	-0.042 (0.23)	-0.04 (0.27)
Endowment	0.0053*** (0.00)	0.005*** (0.000)	0.0047*** (0.000)	0.0043*** (0.000)		
Age		0.018 (0.30)		0.067 (0.26)		-0.27 (0.31)
Sex		0.017 (0.91)		-0.006 (0.96)		5.63 (0.99)
Switch		0.030 (0.45)		0.032 (0.41)		
Constant	3.43*** (0.000)	2.92** (0.015)	3.41*** (0.000)	1.98* (0.096)	7.71*** (0.000)	12.37* (0.053)
log likelihood	-513	- 483	-443	-413	-36	-34
Number of observations	4798	4798	3838	3838	960	960

*P-values for the Student significance test are in brackets. *** indicates significance at the 1% risk level (** and * for 5% and 10%, respectively). Regression 1 includes all explanatory variables even if statistically insignificant. Regression 2 is obtained using a stepwise backward procedure on regression 1 and adding participants' characteristics. In session 5, endowment is dropped as all the participants have the same value. Switch is also dropped to ensure estimate convergence.*

Our results first show that the way marginal price information is presented to consumers matters. Indeed, all things being equal, if we consider the whole sample, the price information recall treatment reduces the chosen quantity by 0.07, which is not negligible, as the deviation of the quantity chosen from the optimal level is approximately 0.82 on average. This result is confirmed if we consider only sessions 1 to 4. However, convergence towards the optimum is not observed in session 5, where participants benefit from the price recall first, which confirms that the positive effect of information appears only after a preliminary learning period.

Likewise, the estimates demonstrate a significant learning effect; when the time period increases by one, the chosen quantity decreases with a corresponding value of around -0.006. Whatever the session considered, the learning effect means that, after 20 periods, consumption is reduced by -0.12. We conclude that the learning effect is at least as substantial as the information effect (both impact individual choices but at different periods of the experiment). Next, subjects with a higher endowment tend to significantly increase the chosen quantity, which could be considered as a mechanical effect as their optimal value is higher compared to less endowed subjects. Finally, as expected, the individual characteristics and preferences are not statistically significant. We observe no significant direct influence of the tariff scheme on consumption.

To go further into the analysis, we retain two subsamples, depending on the complexity of the tariff scheme (CBR *versus* IBR) and on the endowments. The corresponding results are given in Table 8:

Table 8. Regression panel data analyses of consumption choices from subsamples

Treatment	*CBR tariff*	*IBR tariff*	*Endow 50*	*Endow 200*
Info	-0.017 (0.70)	-0.11*** (0.002)	-0.064*** (0.008)	0.030 (0.92)
Type	-0.031 (0.48)	-0.0093 (0.79)	-0.0103 (0.67)	-0.054 (0.85)
Period	-0.0015 (0.68)	-0.0088*** (0.003)	-0.005** (0.014)	0.0098 (0.71)
Endowment	0.008*** (0.006)	0.0046*** (0.001)	Dropped	Dropped
Constant	3.3***	3.58***	3.64***	6.62***

	(0.000)	(0.000)	(0.000)	(0.000)
log likelihood	-224	- 285	-350	-81
Number of observations	1918	2880	1919	2879

*p-value for the Student significance test into brackets. *** indicates significance at the 1% risk level (** and * for 5% and 10% respectively).*

Finally, our results suggest that both information improvement and learning effects are significant for participants with a low endowment only, when the quantity choices are initially far from the optimal value, as shown in Table 4. Furthermore, our results also show that the price recall treatment is efficient when the consumer faces IBR, i.e., a complex tariff scheme, only. Indeed, improving information access has a significant and negative effect on quantity chosen (by -0.11).

3.3 Robustness tests to disentangle learning from price recall effects

To disentangle learning from price recall effects, we estimate regression 2 again excluding endowment for sessions 1 to 4, removing one by one the first time periods:

Table 9. Regression panel data analyses of consumption choices from the sub-periods

Time period	t=1 to 20	t=2 to 20	t=3 to 20	t=4 to 20
Info	-0.072*** (0.006)	-0.062** (0.013)	-0.043* (0.08)	-0.043* (0.08)
Period	-0.005** (0.024)	-0.0046** (0.042)	-0.0004 (0.84)	0.0009 (0.70)
Constant	4.07*** (0.00)	4.04*** (0.00)	3.88*** (0.00)	3.82*** (0.00)
log likelihood	-452	-383	-326	-307
Number of observations	3838	3646	3455	3263

Finally, the learning effect, captured by the period variable, becomes insignificant if we exclude the first two periods, whereas the negative effect of the price recall treatment on consumption remains significant at the 8% level with a corresponding estimate around -0.043.

4. CONCLUSION

In many countries, water providers may adopt an increasing block rate pricing scheme to reach both ecological and social objectives. However, for a proper price-increasing water schedule, it is essential that the consumer be perfectly informed about the tariff he faces to assess the impact on his invoice of any change in his water consumption. If the consumer is not perfectly informed, he will not react to the incentives to meet the goals set by the tariff scheme.

To examine the role played by price misperception, our experimental design consists of combining 2 extreme pricing schemes (CBR and IBR) and 2 levels of information (no price recall versus price recall) in choice situations where heterogeneous participants should make consumption choices. Given our calibration, we compute optimal consumptions levels that differ depending on participant's characteristics and on the pricing scheme. We expect the marginal price recall treatment to decrease the water consumption level compared to the case without price recall.

Roughly speaking, our results indicate, first, overconsumption compared to the optimal individual values. The second interesting result is that, in conformity with our conjectures, the price recall treatment significantly helps participants reduce overconsumption. Furthermore, we have established that information is more helpful for consumers to cope with the optimal consumption choice under an IBR pricing scheme compared to CBR. Last but not least, compared to a flat tariff scheme, we show that IBR pricing is more successful in achieving its policy goal of water conservation.

Our findings therefore have important implications for water conservation policies in countries such as France, where an IBR pricing scheme is quite uncommon. 95% of the French municipalities, as water providers, price drinking water with a single flat volumetric charge. Instead, we recommend applying an IBR structure to discourage water waste. However, to make the progressive pricing successful at achieving its policy goal of water conservation, consumers must fully understand the structure of their tariff schedule. Indeed, describing the details of the tariff scheme on the bill (in our lab experiment on the form) is not sufficient to give consumers a clear perception of the marginal price of water. Therefore, improving the way information about the marginal price appears will help consumers to respond to their actual marginal price and therefore may contribute to the sustainable use of this scare resource. Such a nudging conservation policy is an easy-to-implement alternative to raising prices and follows the recommendations of the World Bank (2016) and OECD (2016). To go further, future research based on behavioral economics (lab or field) could provide more insight into the issues of persistence of price information recall on water consumption behavior. In addition, future experiments should also address the full incentives of tariffs, including the thresholds, and compare various tariff schemes and their effect on consumption, depending on the number of block rates and on their progressivity.

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APPENDIX – Instructions for IBR scheme with No Information Recall + Information Recall (translated from French)

Welcome,

Thanks for participating to this experimental session. If you make your choices carefully, you will be able to obtain a considerable amount of money, with the amount depending on your choices.

More precisely, during this experiment, you will have to make 40 choices during 40 periods, with 2 steps, each step being made of 20 periods. During each of these period choices, you will be able to obtain a certain amount of points. At the end of the session, the computer will randomly choose for each participant 2 period choices made during the first step and 2 period choice made during the second step. The computer will add all the points the participant gained during these 4 periods randomly chosen and will convert the total number of points in euros according to the following rate: 1 euro per 20 points.

Main principle of the experiment

During each period, you will have to choose a certain amount of goods to purchase given a personal endowment (in points, displayed on your computer screen in your personal choice computer interface) that you have and for a given unit price for this good. It is not possible to have expenditures that are higher than your personal endowment. The unit price of the good to purchase will be given in the following instructions for each step, and this price may change between the first and the second step. The more units you will buy, the more points you will gain. However, you will have to deduct from this gain the amount you should pay for these units + a certain amount of administrative charges.

Your net gain will be computed in the following way by the computer:

Your net payoff = Gross Payoff – Administrative Charges – Total price for goods

The total price for the goods purchased will simply be the number of units you bought multiplied by the unit price. For instance, if the unit price equals 1 and if you choose to buy 7 units, the computer will deduct 7 points (1*7) for the total price + a certain amount of administrative charges for buying 7 unit.

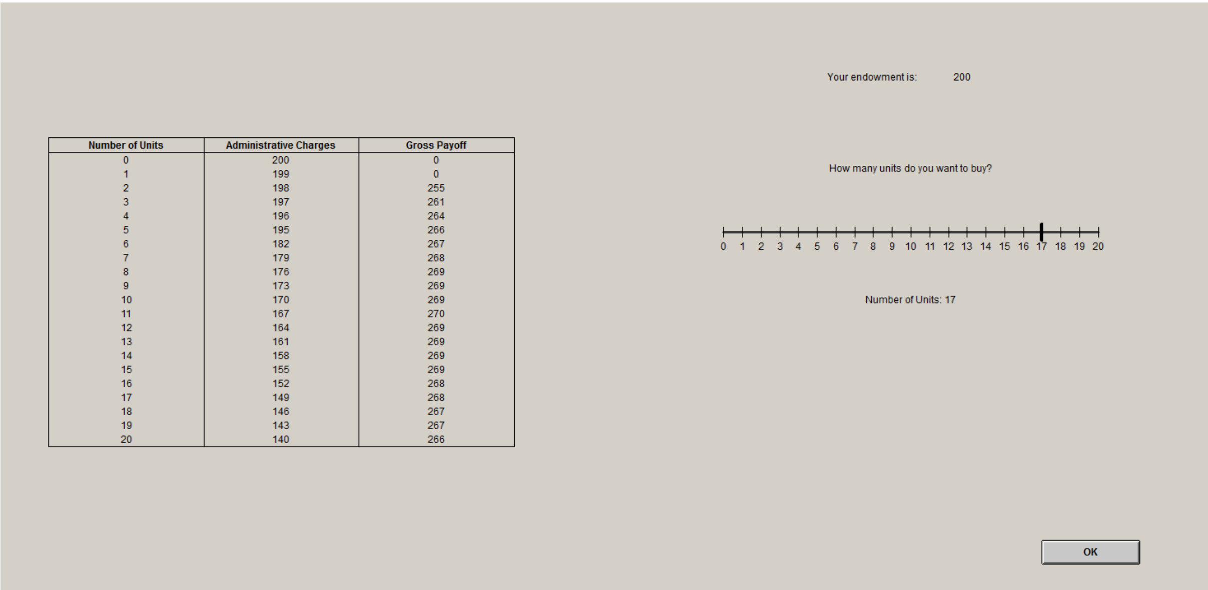
When you make your choice, the computer screen will display some information that will help you to compute your possible payoffs, namely, gains in points depending on the number of units you purchase and administrative charges.

The first step

This step will last 20 periods. During this first step, the unit price for the good will be 1 point per unit if you purchase less than 6 units and 3 points per unit if you purchase 6 units or more (up to 20). Depending on the number of units you purchase, the gross gains and the administrative charges will stay the same for each period.

The computer interface for making your choice during the first step will be as follows:

Figure 8. Screen capture of Z-Tree + no price information recall (translated from French)



Number of Units	Administrative Charges	Gross Payoff
0	200	0
1	199	0
2	198	255
3	197	261
4	196	264
5	195	266
6	182	267
7	179	268
8	176	269
9	173	269
10	170	269
11	167	270
12	164	269
13	161	269
14	158	269
15	155	269
16	152	268
17	149	268
18	146	267
19	143	267
20	140	266

(Attention please! The figures that you see in this screen capture are not necessarily the same as the ones that will be displayed when you will actually have to choose.)

Here, choosing to purchase will consist of moving the cursor to a given number of units you want to purchase, from 0 to a maximum of 20 units. In the screen capture, this fictitious participant receives an endowment of 200 points. If he chooses to buy 10 units, as this number is higher than 6, the unit price equals 3. The purchasing price would be therefore 10*3=30 points. As a consequence, this participant would receive 269 points as her gross payoff and would be charged 170 points for administrative charges. Finally, her net payoff for purchasing 10 units would be computed as follows:

Net payoff = 269 – 170 – 30 = 69 points

As a consequence, her net payoff in the first step would be the following:

Net payoff = *Gross Gain* – *Administrative Charges* – (1 point X *number of purchased units* IF the number of purchased units is less than 6)

<u>OR</u>

Net payoff = *Gross Gain* – *Administrative Charges* – (3 points X *number of purchased units* IF the number of purchased units is equal to or more than 6)

At the end of each period, the computer will display a screen that will recall your personal endowment, the number of units you chose to purchase, the amount of administrative charges for your purchase, the total purchasing price, your gross payoff and finally your net payoff.

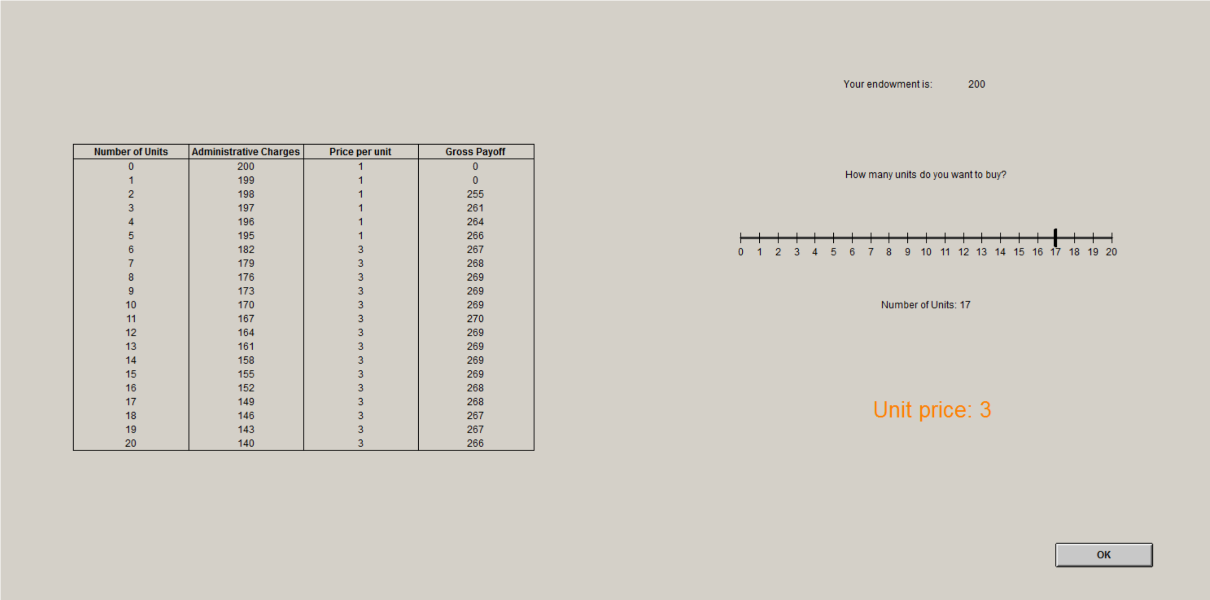
These period choices will be repeated 20 times during this first step.

Second step

For this step, the unit price for the good will be 1 point per unit if you purchase less than 6 units and 3 points per unit if you purchase 6 units or more (up to 20). Depending on the number of units you may purchase, you will obtain, similar to the first step, gross payoffs and you will be charged administrative charges. Gross gains and administrative charges during this second period will be the same as in the first period.

The computer interface for making your choice during the second step will be as follows:

Figure 9. Screen capture of Z-Tree + price information recall (translated from French)



(Attention please! The figures that you see in this screen capture are not necessarily the same as the ones that will be displayed when you will actually have to choose.)

Here, choosing to purchase will consist of moving the cursor to a given number of units you want to purchase, from 0 to a maximum of 20 units. *Differently from the first step, the unit price will be displayed on the screen below the cursor (here, as the number of units selected is 17, the unit price is recalled to be 3 points per unit).*

In the screen capture, this fictitious participant receives an endowment of 200 points. If she chooses to buy 10 units, as this number is higher than 6, the unit price equals 3. The purchasing price would therefore be 10*3=30 points. As a consequence, this participant would receive 269 points as her gross payoff and would be charged 170 points in administrative charges. Finally, her net payoff for purchasing 10 units would be computed as follows:

Net payoff = 269 – 170 – 30 = 69 points

As a consequence, her net payoff in the first step would be the following:

Net payoff = *Gross Gain* – *Administrative Charges* – (1 point X *number of purchased units* IF the number of purchased units is less than 6)

<u>OR</u>

Net payoff = *Gross Gain* – *Administrative Charges* – (3 points X *number of purchased units* IF the number of purchased units is equal to or greater than 6)

At the end of each period, the computer will display a screen that will recall your personal endowment, the number of units you chose to purchase, the amount of administrative charges for your purchase, the total purchasing price, your gross payoff and finally your net payoff.

These period choices will be repeated 20 times during this second step.

Your final payoff

When each participant completed the 40 period choices, the computer would randomly draw 4 periods for each participant as described earlier, and would display your total payoff both in points and in Euros.

Good luck!