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Social and nonlinear tariffs on drinking water: Cui bono? Empirical evidence from a natural experiment in France

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Social and nonlinear tariffs on drinking water: cui bono?

Empirical evidence from a natural experiment in France

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Abstract

This empirical study discusses both the incentive and redistributive effects of nonlinear tariffs on the drinking water of developed countries. Using an original panel database based on a natural experience with drinking water in France, we econometrically explore the impact of tariffs changes on consumption (linear versus nonlinear). We demonstrate that this measure reduces global consumption. However, small consumers (<75 m3) benefit from the new tariff program and increase their consumption, whereas the consumption of the others (>75 m3) decreases. Public policy implications of such tariffs on drinking water may lead to a discussion on the design of these tariffs and the quality of the information given on water consumption.

Keywords: tariffs, drinking water, public policies, social tariffs, nonlinear tariffs, monopolies

Codes JEL: D04; D42; L11

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1 Introduction

Some goods, such as waste, energy, transport, and drinking water, have experienced recent changes in the paradigms around tariffs. First, the emergence of environmental concerns seeks to empower consumers and encourage them to limit waste. In developing countries, control of water resources is a public health issue that enables the improvement of network quality (Basinga et al. (2011)). For developed countries, limiting wastage can smooth demand peaks and reduce regional inequalities (Erdlenbruch et al. (2013)). Second, consumer empowerment must be reconciled with the accessibility challenge of resources.

Generally, drinking water management is primarily the responsibility of local authorities, who may delegate it or manage it themselves in a local, natural monopoly. The choice of the tariffs depends on the political authority and its goals. The issue of tariffs in developed countries was not discussed until the 1990s; however, prices have become a major political issue. Privatization has renewed the problem of the existence of a trade-off value between the public management and the private delegation (Hart and Moore (1998), Chong et al. (2006), Chong et al. (2015)). Moreover, new technologies make improved pricing possible (smart grids, smart meters). Finally, the government wants to implement new goals in the public utilities (social, environmental). Because of the shortcomings of coordinating the rules or bureaucracy, the instrument price rehabilitated in public services seems to decentralize the implementation of these objectives. Thus, in 2010, French law allowed the introduction of incentive tariffs and social tariffs in drinking water. Before 2010, the tariff design was standardized and disincentivized. The economic literature asks, can we find a tariff on drinking water that is both incentivized and fair? Following Tinbergen (1956), we can ask whether one instrument is able to meet several objectives. These contradictions refer to different articles showing the three main objectives of water pricing (Fauquert and Montginoul (2011); Arbués et al. (2003); Dalhuisen and Nijkamp (2002); OCDE (1987)): efficiency; equity and cost coverage.

Theoretically, drinking water pricing patterns can be analyzed through the pricing of monopolies (Pigou (1929)). First-degree price discrimination would offer every consumer an optimal range on price. If the first-order optimum is not feasible due to a lack of information, second-degree price discrimination suggests differentiating tariffs according to the amount consumed (nonlinear prices). Third-degree price discrimination is based on the consumer's profile (for example, a different tariff for households and a different tariff for agriculture). Finally, another option would be a constant variable rate price to better cover the costs of monopoly. These solutions (except the discrimination of degree 1) all generate distortions that must be compared.

In recent years, there have been discussions about whether nonlinear tariffs are more effective than linear tariffs in inciting demand management and redistribution.

The comparison between these forms types of tariffs has been studied both theoretically and empirically. Theoretically, Crampes and Lozachmeur (2014) compared linear versus nonlinear tariffs based on electricity. They concluded that the degree 2 discriminatory tariffs generate too much distortion due to the heterogeneity of the consumers. Nonlinear tariffs are unsuitable for some consumers who perform a significant deadweight loss. Empirically, the literature is ambivalent about the impact of these tariffs. The authors show that perfectly rational assumptions about consumers are not valid in practice. Consumers, when faced with complex tariffs and nonlinear rates, have a sub-optimal reaction to the price signal (same results: Ito (2014)).

Experiences (natural or controlled) indicate that consumers will react more positively to the expected average price than the marginal price. In addition, the consumer has a biased perception of complex tariffs (Borenstein (2008), Borenstein (2012), Ito (2014)). In the case of drinking water, the literature suggests a more nuanced impact of nonlinear rates. Typically, Meran and Von Hirschhausen (2009) or Grafton et al. (2011) have shown that the nonlinear tariffs encourage the reduction of consumption. Moreover, Montginoul and Alexandre (2014) showed that a 10% price increase would lead to a 1 to 3% decrease in water consumption. The consumers could also react to the price changes. However, Barraqué et al. (2007) highlight the information concern according to the mode of billing (e.g., monthly, quarterly, annually, individual, collective). The local context could strongly change the impact of the different prices (for instance, many studies were conducted in developing countries). This is why it is difficult to extrapolate the results from local studies without econometric and experimental methods.

The present study is based on a pioneer experiment conducted in France. The experiment introduced a nonlinear (three tiers) tariff backed with a social tariff on drinking water on the first tier. This tariff, called "tarification eco-solidaire", was introduced in 2012 in Dunkerque (France) and is original for the following two reasons: it is the first experiment of this kind in a large city in France, and it explicitly pursues the two social and ecological goals described earlier. Using a public policy analysis, this study assesses the impact of this tariff on the consumption of water.

The main results are as follows: the introduction of the new tariff decreases the global consumption of the agents by about -10%; next, the consumer responses are not the same according to their type, as small consumers (<75 m3) increase their consumption, whereas large consumers (>75 m3) decrease theirs. Moreover, the design of the tiers appears to not be perfectly efficient because the different tiers are not related to the size of the households. Large families, for instance, cannot reduce their consumption according to the price and have to pay more. The "CMU" criteria used to give the social tariff is very restrictive (only 2% of the population). We suggest using another indicator, the "quotient familial", based on the incomes and the size of the households, to discriminate among the consumers.

The results indicate a global efficiency of the nonlinear tariff while raising the issue of the equity of such a mechanism, specifically considering large families and the criteria for the attribution of social tariffs. Moreover, we agree with the proposal made by some authors (Barraqué et al. (2007)) to bill the water monthly to improve the information. In effect, to introduce this tariff, the municipality of Dunkerque installed individual meters and promoted ecological concerns in water consumption. In addition, the provider has significantly improved access to information on consumer behavior with invoice simulations and suggestions for change. These contextual elements also explain the magnitude of the results. This study questions the efficiency of this tariff according to the heterogeneity of the consumers.

Each household is not able to react to the marginal price, following the main results showed by Ito (2014) or Crampes and Lozachmeur (2014). However, the municipality of Dunkerque follows the proposition of Fauquert and Montginoul (2011) by introducing a flat-rate subsidy ("chèque eau") for the large families in order to correct the distortions. However, only 12 families requested this subsidy due to a specific procedure. Additionally, we show that the progressive tariff in Dunkerque is quite sophisticated, building incentives and redistributing according to the type of household. However, the impact of this type of measure is strongly related to the information about incentives, consumption, and billing.

2 Case study and proposition: the Dunkerque experience

In France, municipal authorities are in charge of drinking water management. They can either manage these utilities in-house on their own or delegate this management to a private operator. In France, the tariff's design is based on the principle that "water pays water" ((Chong et al., 2006)) to ensure the self-financing of such a system by billing the users. The French design of the price is based on a binomial tariff: a variable component based on consumption, and a fixed component based on a subscription to get access to the goods. To these two parts, the taxes must be added. In most cases, the variable component is based on a constant marginal price. However, since 2010, the French law legalized pricing experiments to better discriminate amongst consumers on the basis of social criteria. This legal innovation paved the way to discriminating tariffs in the drinking water sector.

Dunkerque city's experiment introduced, by the end of 2012, a nonlinear, tier-progressive pricing in the variable component of the price. Dunkerque and its suburbs (in Northern France) delegate the management of drinking water provision to a unique private operator. This provider serves 27 townships and more than 90,000 subscribers, with 84,000 domestic subscribers [1] , representing a population of 221,836 people[2].

We will explain the design of the "éco-solidaire" tariff (2.1) before presenting the assumptions that we test empirically in our models (2.2).

2.1 Dunkerque's "éco-solidaire" tariff

In 2012, after requests from representatives, a private operator set up a nonlinear tariff with social tariffs. Before the introduction of this new tariff, the provider was using a standard price for drinking water through linear pricing for the variable component and subscription fees for the fixed component. From 2012, the Dunkerque authorities initiated the tier-progressive pricing for the variable component (1.01 €/m3), leaving the fixed component of the price unchanged.

The new tariffs are based on three tiers depending on the volume of water consumed. Tier one is called the vital consumption tier and entails any consumption below 75 m3/year. Tier two, useful consumption entails consumption levels between 75 and 200 m3/year. Finally, tier three (called

[1]http://www.leaududunkerquois.fr/index.php?page=chiffres
[2]Source : SISPEA

Tier	Name of the tier	Type of consumer	Consumption	Price
1	Vital consumption	Standard	from 0 to 75 m3	0.84€/m3
1	Vital consumption	Social	from 0 to 75 m3	0.32€/m3 (social discount : -70%)
2	Useful consumption	Standard and social	from 75 to 200 m3	1.56€/m3
3	Comfort consumption	Standard and social	>200 m3	2.07€/m3

Table 1. The different tiers of the tariff in 2012

comfort) entails consumptions above 200 m3/year. If we refer to the Crampes and Lozachmeur (2014) study, we can assume that this mechanism is redistributive among the small consumers and the others. In effect, the provider would like to increase the consumption for small consumers (if they are in tier one) by decreasing the price. Moreover, this discount on vital consumption is financed by the other categories. It is the reason why the nonlinear tariffs are considered redistributive.

A second mechanism complements the pricing scheme: the social beneficiaries of the universal health care coverage (couverture maladie universelle or CMU[3]) have access, at tier one, to a 70% discounted tariff from the normal price. This social tariff is automatically assigned.

The new tariff (in 2012) can be summarized in table 1.

The subscription is unchanged (10 €/year). We can represent in a graph this new pricing system to compare it with the linear pricing system. In Figures 1 and 2, we can compare the linear tariff and the nonlinear tariff.

Figures 1 and 2 represent the Price (**P**) and the quantity in cubic metres (**Qt**) to compare the previous and the new tariffs in Dunkerque and their impact on social and standard consumers. These graphs do not include the fixed component of the price. On the two graphs, the previous tariff is the horizontal line because the average price (**AP**) was equal to the marginal price (**MP**) (AP_P=MP_P). The new marginal price (MP_N) is a nonlinear tariff, and the curve of the new average price (AP_N) depends on the tiers.

[3]This information is systematically collected by the provider from the social administration (CAF).

Fig. 1. Price for standard consumer

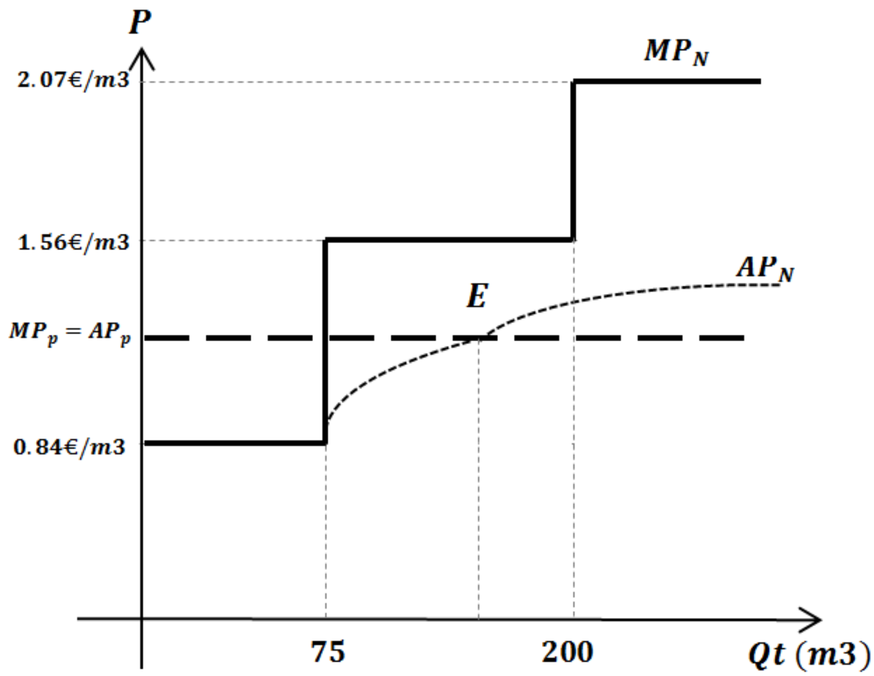
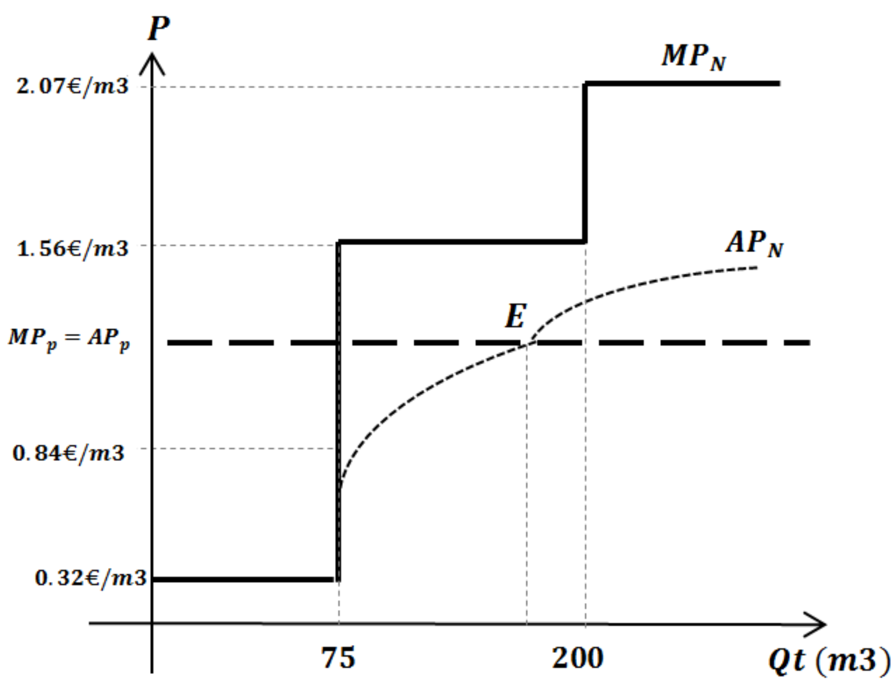


Fig. 2. Price for social consumer



"E" is the point where $AP_P = MP_P = AP_N$. The three main results obtained are as follows:

If **Qt** $<$ **E** the consumer **wins** with the new tariff on the total price If **Qt** $>$ **E** the consumer **loses** with the new tariff on the total price If **Qt** $=$ **E** there is **no change** for the consumer on the total price

The theoretical impact of the new non-linear tariff is strongly related to the behavior of the consumers. Following Ito (2014), we know that if consumers are perfectly rational, they react to the marginal price and change their consumption according to the marginal tier; instead, if they have a bounded rationality or cognitive bias, as identified by Liebman (2004) and Ito (2014), they react to the average price. However, this paper does not try to estimate the elasticities or measure if the consumers react to the marginal or average price. The aim of this study is instead to measure the impact of the introduction of a non-linear tariff by using policy analysis methodology. In another study (Mayol and Porcher (2017), by using a different database and methodology, we try to estimate the demand and the elasticities in drinking water.

2.2 Propositions

The Dunkerque experiment pursues both social and ecological goals simultaneously[4]. The main idea is the following: by implementing nonlinear progressive pricing, consumers will be incentivized to reduce their consumption, either to avoid reaching a higher tier or to avoid increasing their loss in a higher tier (opportunity cost). At the same time, the implementation of a social tariff should allow vulnerable consumers to be favored in comparison with others. Our objective is to assess the impact of this change in tariffs on the consumption of households while considering the different profiles of consumers.

Two criteria were examined here:

1. **Ecological goal**: Does the new tariff decrease consumption after the change? How do the different types of consumers react according to their different characteristics (i.e., size or level of consumption)?

[4]Website:http://www.leaududunkerquois.fr/index.php?menu=9&page=page&pageID=6

2. **Social goal**: How are the standard and social consumers compared to others after the change?

Several propositions can thus be formulated and tested to evaluate this policy:

The first proposition follows the empirical results of Grafton et al. (2011) or Montginoul and Alexandre (2014) and considers that the implementation of a nonlinear tariff will be not neutral on the consumption by lowering the global consumption of the agents. We can expect a negative impact on global consumption with this new pricing design. This assumes that the elasticity is nonzero for consumers and that consumers react to the price change.

Proposition 1 *A nonlinear tariff decreases the aggregated consumption of drinking water.*

According to the empirical results of Meran and Von Hirschhausen (2009), small consumers should benefit from the windfall effect of the new tariff to increase their consumption. The second proposition follows the Crampes and Lozachmeur (2014) model about non-linear tariffs: the small consumers increase their consumption after the discount (here, if the consumption is <75 m3), and the others decrease their consumption after the discount (if the consumption is >75 m3). This is a standard redistributive mechanism between the different categories of consumers. Moreover, the different studies on the elasticity of French water demands show a negative elasticity (-0.08 and -0.22, according to the place in France (Nauges and Reynaud (2001)). We can assume that the consumers react to the price-change according to their level of consumption.

Proposition 2 *A nonlinear tariff positively impacts the consumption of the small consumers and negatively impacts the consumption of the others.*

Renwick and Archibald (1998) show that in California, high incomes are much less sensitive to changes in water prices than low incomes. In our experiment, the social consumers win more than do the others with the new non-linear tariff. Additionally, we can expect that the social consumers consume more than the others after the new tariff. This proposition tests the fairness of this tariff; because we suppose that the social consumers need to be supported with a social discount to consume more drinking water (cf. Crampes and Lozachmeur (2014)).

Proposition 3 *Social consumers consume more than other consumers do with the new tariff.*

The last proposition refers to the study by Crampes and Lozachmeur (2014) on nonlinear tariffs on electricity. They show that households are heterogeneous and that not all can react to price changes. For instance, the level of consumption of electricity, gas, or water could be related to the size of the household or the type of home (house or flat). In the drinking water sector, Fauquert and Montginoul (2011) show that the inefficiency of the non-linear model is due to the different characteristics of the households (especially for the large families). This is the reason why these authors suggest specific subsidies to correct this heterogeneity for the large families. In Dunkerque, we assume that the size of the household is strongly related to their consumption. Moreover, we test the following proposition to observe how the different types of households react to the price change. For instance, if large families do not react to the non-linear tariff, this confirms the inefficiency of the non-linear tariff on the consumption of some categories of households.

Proposition 4 *The impact of the tariff change is related to the size of the household.*

3 Data

3.1 Sample

Dunkerque's provider specifically tracks consumption data of a representative panel of consumers before and after the new tariff (2012). The consumers were randomly selected. The panel entails 1387 consumers whose consumption was tracked from 2010 to 2013. Consumers were spread over the 22 townships of Dunkerque District (37% living in Dunkerque and 6.85% in rural areas), and 68.3% of the consumers lived in an individual house (the rest lived in flats). The distribution of the size of the households is shown in Figure 3.

3.2 Variables

3.2.1 Dependent variable: the logged consumption

The dependent variable is the logarithmic annual consumption. This variable from the panel assesses the subscriber's annual consumption of drinking water. By using this variable, we can assess the annual variations of consumption before and after the introduction of a new tariff. Some observations must be formulated on the water consumption reported on the database.

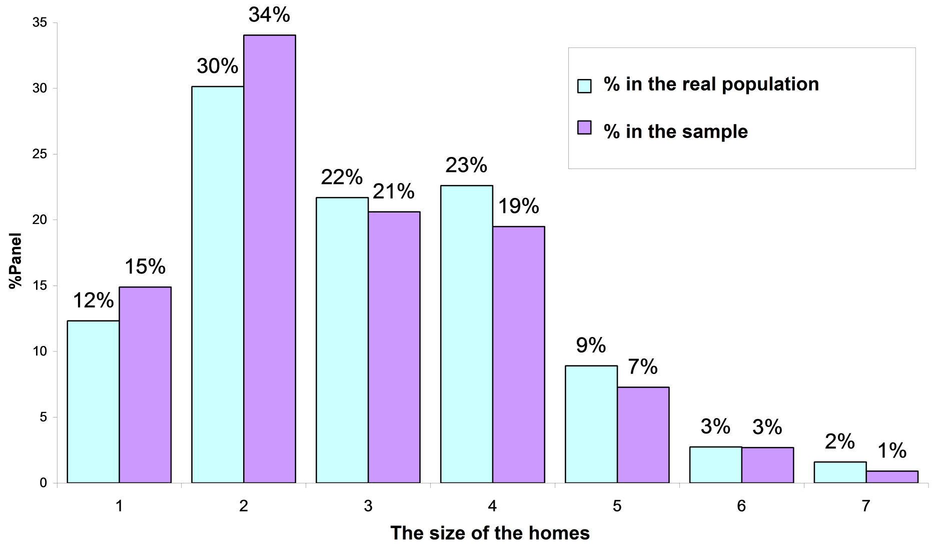


Fig. 3. Size of the households (Source: Eau du Dunkerquois)

Obs.	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Year**
858	89.04	58.06	2	691	2010
978	83.38	55.41	2	602	2011
1110	81.95	50.63	1	323	2012
1267	80.43	55.89	1	464	2013

Table 2. Descriptive statistics of the consumption

In this study, we built three categories of consumers according to their marginal tier:

- **Small consumer** when Q < 75 m3 (i.e., marginal tier is 1)
- **Medium consumer** when Q ∈ [75;200] (i.e., marginal tier is 2)
- **Large consumer** when Q >200 m3 (i.e., marginal tier is 3)

First, the panel is unbalanced for consumption[5]. This can be explained by the fact that clients could register for new subscriptions (after moving houses) after the start of the data collection (in 2010). Second, the consumption for the provider has faced a decreasing trend since 2009. The following table (2) summarizes the main descriptive statistics in the original data (before the outliers dropped).

As such, there is the same decreasing trend of water consumption in Dunkerque district. However, there are some outliers with very low consumption (<10 m3) that represent fewer than 20

[5]The econometric results are not impacted if the panel is balanced.

Obs.	Mean	Standard Deviation	Minimum	Maximum	Year	Social
838	89.41	58.04	2	691	2010	No
954	83.80	55.34	2	602	2011	No
1081	82	50.61	1	323	2012	No
1234	80.52	55.60	1	464	2013	No
20	73.5	58.25	14	203	2010	Yes
24	66.95	56.69	11	223	2011	Yes
29	73.10	51.39	16	192	2012	Yes
33	76.84	66.66	3	341	2013	Yes

Table 3. Descriptive statistics of the consumption (standard vs social)

observations. These outliers can be explained by moving houses, possible secondary houses, or specific situations in a rural zone (house with a private source). Finally, it is useful to observe the average consumption for each user profile, with a distinction between social and standard consumers.

From this Table 3, the following were observed:

- On average, social consumers consume less than other users.
- Their number in the sample is quite small, which may impact the average

In these conditions, it seems relevant to focus on the universal health care coverage beneficiaries and the non-beneficiaries to know if the new tariff benefited one of the two categories more.

3.2.2 Independent variables

Control variables.

Consumption is a function of two intuitive factors: the number of potential users on the same water meter and the characteristics of the housing. The variable HOUSEHOLDSIZE indicates the number of people residing the household. The variables FLAT, HOUSE, and HOUSEWITHOUTGARDEN indicate if the householders live in a flat or a house. There is a control variable (ECOLOGICALSENSIBILITY) relative to the “psychological profile” of the individuals concerned with environmental issues (the question was “Are you ready to reduce your consumption to save the resource?”, with a yes/no answer). ECOLOGICALSENSIBILITY is a dummy variable allows us to assess if the household is naturally willing to make efforts to reduce its consumption. The variable

Variable	Average	Standard Deviation	Minimum	Maximum
Householdsize	2.792	1.355	1	10
Flat	0.316	0.465	0	1
House	0.622	0.484	0	1
Housewithoutgarden	0.061	0.239	0	1
Ecologicalsensibility	0.781	0.413	0	1
Rural	0.068	0.252	0	1
Eastsector	0.832	0.373	0	1
Pluviometry	685.97	111.72	558.6	865

Table 4. Control variables

RURAL indicates the location of the house. We introduced a meteorological variable indicating the rainfall from the data provided by Météo France. We tested an alternative on the temperature, which had no effect on the results. Finally, the variable EASTSECTOR specifies if the consumer is in the eastern or western sector (EAST/WEAST) because the two sectors are not managed by the same provider for waste collection. The following Table 4 summarizes the descriptive statistics for the control variables. These variables are constant and thus do not change over time.

Categorical variables.

We created the following categorical variables to draw a distinction between several profiles of individuals:

- The variable "CMU" indicates (dummy) if the household is a beneficiary of the universal health care coverage. The French social administration (Caisse d'Allocations Familiales) provides this information.
- Three dummy variables indicate if the consumer is in the first, second, or third tier.
  - **Tier 1** if consumption $\in [0 \, ; 75]$
  - **Tier 2** if consumption $\in [75 \, ; 200]$
  - **Tier 3** if consumption > 200

Additionally, Tier 1 and Tier 3 are farther from the E point than Tier 2. We assume that the impact of the new tariff could be more significant for farther consumers.

4 Empirical Strategy

The main models used in this study are related to the standard methods in public policy evaluations. Our objective in this first part is to assess the impact of an exogenous change of tariff on the agent's consumption using econometrics. To do so, this study uses two methods: the diff-in-diff and a standard linear regression that includes dummy variables.

The Fisher test confirmed individual effects on consumers, whereas the Breusch-Pagan[6] (1979), the Hausman test [7] (1978) and the Mundlak test [8] (1973) confirmed the presence of random effects. Moreover, the presence of numerous time-invariant variables in our database (i.e., almost all of the variables of control do not vary over time) excludes using a fixed effects model with this database. The results from random effects are crossed with a standard ordinary least square regression.

4.1 Diff-in-diff model for the global consumption

First, to compute the impact of the measure on the global consumption, this study uses a diff-in-diff model. This method used in public policy evaluation aims to compare two groups: a control group and a treated group. Our main problem was that there were only consumers who received the treatment in the database. We thus had to identify a good control group.

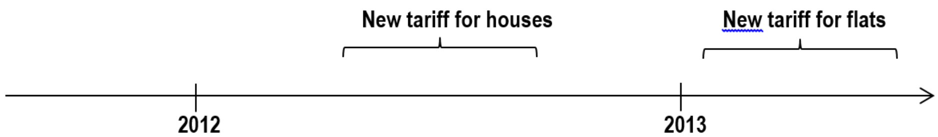
The type of housing was used to identify the control group. Indeed, the tariff change was implemented in the Dunkerque area during the last semester of 2012. However, the previous drinking water pricing system generates a dualism between individual houses and collective housing (mostly flats). Indeed, each individual house has an individual meter. However, this was not necessarily the case for flats. In most of the cases, the price of the water was implemented in rental charges according to a repartition key that accounts for the surface area. The installation of individual water meters in Dunkerque took a long time, and the impact of the new tariff was realized mainly in 2013 for all of the users.

As such, the consumers living in a flat—excluding social housings that anticipated the change—were considered a control group because in 2012, they did not have the new tariff. This distinction be-

[6]Results of the Breusch Pagan test: Chi2 = 390.19 and Probability > chi2 = 0.0000 (if p > 0.1 there are no random effects).

[7]Results of the Hausman test: prob > Chi2 = 0.5981 (if p < 0.1 there is a reject of H0 on the absence of systematic difference between Fi Effect and Random Effect).

[8]Results of the Mundlak test: p < 0.0000, which confirms the presence of random effects.



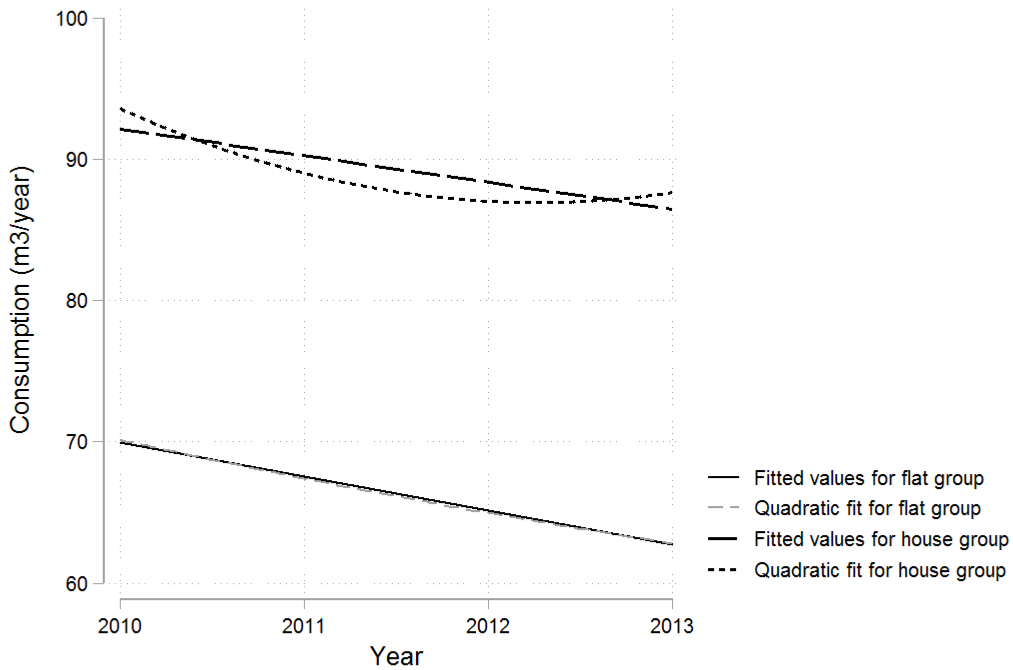


Fig. 4. Fitted values of the consumption for the two groups of consumers

tween the groups was also made in studies by Ito (2010), who distinguished between two sectors to observe the different reactions to tariffs. The following graph summarizes the delay in the introduction of the measure according to the housing:

The comparisons of the trends confirm that the housing is a good criterion to distinguish between the two categories of users. Moreover, Figure 4 shows that the quadratic fit of the consumption for the consumers in house diverges in 2012. There is no divergence for the flat consumers. This result confirms that the housing is a good variable to run the diff-in-diff model.

Thus, the housing type appeared to constitute the right discriminative variable between the control group and a treatment group. Formally, we look to estimate the log for individual consumption with individual (α_t) and temporal (τ_t) random effects, giving the following formula:

$$
\begin{aligned}
LogConso_{it} = \beta_0 \quad & +\beta_1 HOUSE_{it} \\
& +\beta_2 MEASURE_{it} \\
& +\beta_3 HOUSE_{it} \times MEASURE_{it} \\
& +\beta_4 ControlVariables_{it} \\
& +\tau_t + \alpha_t + \varepsilon_{it}
\end{aligned}
$$

i designating agent i and t designating the reference year. Thus, the β_3 coefficient will give the double difference effect of the tariff change for the treated group of consumers living in individual housing. This model should confirm the impact of the tariff change on global consumption.

4.2 Model for the different types of consumers

Since the global impact on consumption is confirmed, the following model uses a random effect regression model using dummy interaction variables to test the impact of the tariff change according to the user's profile (small-middle-large). It was not possible to use the previous diff-in-diff model because the distribution of the type of consumers was not symmetrical in the two groups. Indeed, the large consumers are more important in the houses than in the flats. We use three groups of consumers according to their TIER during the t-1 year.

Formally, the model is as follows:

$$
\begin{aligned}
LogConso_{it} = \beta_0 \quad & +\beta_1 TIER_{it-1} \\
& +\beta_2 MEASURE_{it} \\
& +\beta_1 TIER_{it-1} \times MEASURE_{it} \\
& +\beta_4 ControlVariables_{it} \\
& +\tau_t + \alpha_t + \varepsilon_{it}
\end{aligned}
$$

The different β_3 coefficients give both the sign and magnitude of the impact of the new pricing system on consumptions according to the type of consumers.

4.3 Impact of the tariff on social consumers

The number of social consumers (approximately 25) in the database is not sufficiently significant to use in an econometric model. In effect, the average is too sensitive to the variance of this group. However, to analyze the impact of this tariff change on the consumption, this study uses a graphical analysis with a quadratic fit to compare before and after.

5 Results

This section presents successively the different results from the models exposed previously. The main conclusions from our empirical study are presented in a summary, with possible interpretations from economic theory and literature.

5.1 Results from the diff-in-diff model

The following table presents the results from the first diff-in-diff realized for all consumers, excluding the social beneficiaries (the extended version of table 5 is presented in the appendix).

Dependent variable : LogConsumption	RE	OLS
HOUSEHOLDSIZE	0.222***	0.221***
	(15.68)	(16.59)
MEASURE	-0.834***	-0.175***
	(-17.22)	(-2.82)
HOUSE	0.349***	0.309***
	(5.91)	(5.17)
MEASURE x HOUSE	-0.107***	-0.089*
	(-2.85)	(-1.85)
Cons.	0.000	2.886***
	(.)	(21.90)
Number of obs.	2870	2870
Number of groups	1085	-
Year effect	yes	yes
R2	0.2125	0.2134

* p<0.10, ** p<0.05, *** p<0.010

Table 5. Results for diff-in-diff model

Several remarks can be made concerning the results from this diff-in-diff model:

- The household size is a leading explanatory variable of the drinking water consumption.
- Living in a house has a positive impact on consumption. The intuitive interpretation is that people living in houses usually have larger families than people living in flats. Moreover, a house usually comes with a garden, which implies more water requirements.
- The final result from the diff-in-diff (MEASURE*HOUSE) shows a negative impact of the tariff change on consumption. In other words, the new tariff program significantly decreases (-10.7%) the households' consumption. This result is confirmed by the alternative model realized with a simple linear regression.

Overall, the impact of the tariff change is thus negative on the global consumption. This result is similar to empirical results, showing that nonlinear progressive threshold tariffs tend to lower consumption (Grafton et al. (2011)). This model confirms our main propositions.

However, it is possible to discuss the magnitude of the result found. Indeed, this result is very high compared to other studies, which show variations on the order of 2 to 3% (Montginoul and Alexandre (2014)). There are several possible explanations. First, the treatment group is not exactly the same as the control group. The consumption trend of apartments and houses was the same before 2011 (cf. graph). However, the reaction of consumers in the house may have been stronger due to the possibility of substitutes (rainwater harvesting for example). At the aggregate level, consumption has not decreased by 10% because the (majority of) apartments have mitigated this effect. Moreover, the magnitude of the overall variation can also be explained by the very important communication of the provider to the users. Indeed, individualized information was provided to the consumers to explain the tariff, to make simulations and to make suggestions for changes in behaviour in the case of an increase in the invoice. Foaming has also been widely distributed to reduce the consumption of drinking water. It is therefore important to account for the very proactive local context in terms of reducing drinking water consumption, which explains why consumers respond effectively to price. This joins the discussion on the quality of information about individual consumption.

5.2 Results for the different categories of consumers

This random effect model (non diff-in-diff) tries to assess the measure's impact ceteris paribus by dissociating the consumers' profiles using categorical interaction variables.

Some general remarks:

- The global impact of the measure with this model is harder to interpret since the impact goes in opposite directions with respect to the consumers' profiles.
- Small consumers tend to increase their consumption following the introduction of the measure.
- In contrast, medium and large consumers reduce their consumption.

These results (table 6) confirm the proposition that the main financial beneficiaries of the measure are small consumers. As a consequence, they will tend to increase their consumption to benefit from the windfall effect of the new tariff. In contrast, for large consumers, the measure is highly disadvantageous from the financial perspective since it encourages them to reduce their own consumption.

Dependent variable : LogConsumption	RE	RE
HOUSE	0.187***	0.187***
	(3.97)	(3.97)
HOUSEHOLD	0.250***	0.250***
	(17.64)	(17.64)
MEASURE	-0.050***	0.063***
	(-2.79)	(2.78)
MEASURE x LAG.TIER1	0.113***	
	(3.81)	
MEASURE x LAG.TIER2	-0.113***	
	(-3.81)	
MEASURE x LAG.TIER3	-0.128*	-0.241***
	(-1.77)	(-3.23)
Cons.	3.483***	3.394***
	(39.82)	(40.49)
Number of obs.	3352	3352
Number of groups	1294	1294
Year effect	yes	yes
R2	0.329	0.329

* p<0.10, ** p<0.05, *** p<0.010

Table 6. Results for the different categories of consumers

5.3 Graphical analysis of the trends for the social consumers

Due to a small number of social consumers, this study uses an imperfect way to measure the impact of the new tariff program on the social consumers. We expect that these consumers increase their consumption for two main reasons. First, before the new tariff, they consume less than the other standard consumers. Second, they benefit more from the new tariff. The following graph shows two trends: the trend for the social consumers and the trend for the others. Moreover, two curves represent the quadratic fit to observe the divergence in the quadratic fit from 2012 (introduction of the measure).

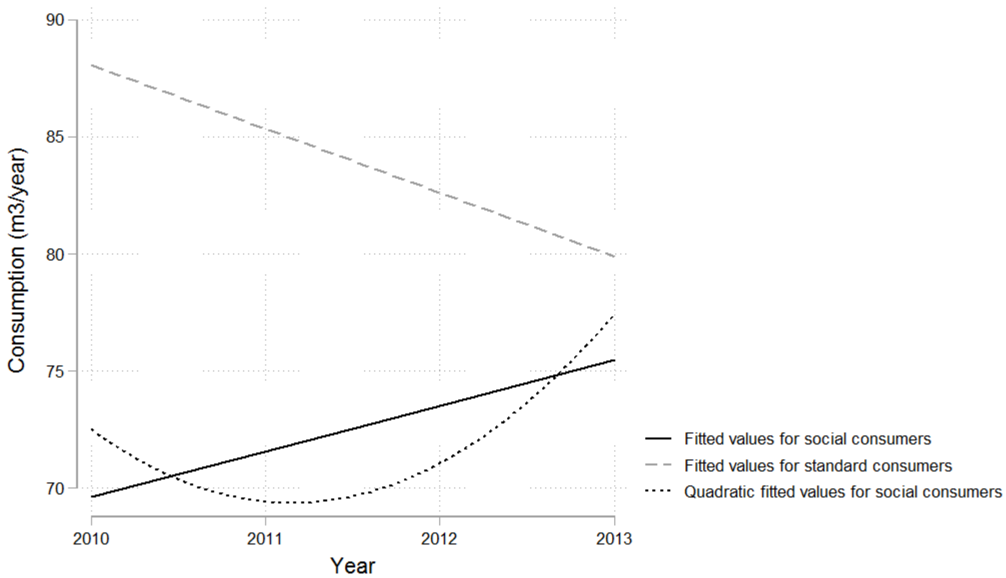


Fig. 5. Fitted consumptions for social consumers

This graph (Figure 5) gives an interesting interpretation framework of the previous variations: the standard consumers tend to decrease their consumption during the new tariff implementation, whereas the social consumers overconsume slightly after the implementation. This difference could be interpreted as a catch-up effect of the social consumers, whereas the other users will, on average, temper their own consumption. However, this interpretation is not based on an econometric model.

5.4 Relationship between consumption and size of the household

Nonetheless, on fairness, the results are more ambiguous. Who is actually carrying the cost of such a tiered pricing system? It appears that numerous families have a different elasticity than the others. We observe in graph 6 that the evolution of the trend is highly related with the size of the household when $N \in [2;4]$. Additionally, the larger the household is, the smaller the decrease of the trend is. There is an exception when the size is 1.

This situation can be explained by the presence of an incompressible consumption. Thus, we can think that the design of the slices was made for a representative family with at least two people. This result recommends improving the design of the tiers. The actual uniform design has to be adapted according to the type of households and housing, especially for the large families. In effect, the very small households (N=1) win with the new tariff, whereas the large families pay much more.

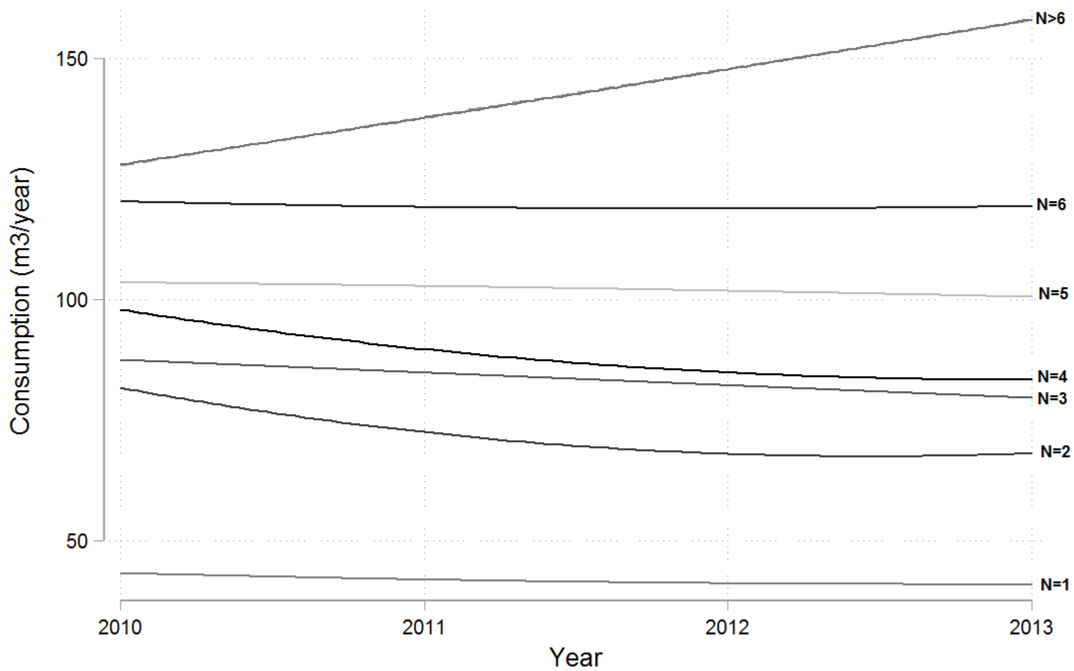


Fig. 6. Mean of consumption and size of households (N) - 2010-2013

This is the reason why our discussion could be more focused on these households. However, we can discuss the heterogeneity of the elasticities according to the households.

5.5 Summarize

This study questions who actually benefits from the implementation of nonlinear and social tariffs for drinking water. This is a pioneering contribution aimed at empirically assessing the overall impact of a complete pricing change on drinking water users' consumption. What can be concluded from it? First, we confirm the results from the literature according to which tiered pricing usually causes a decrease in consumption. Second, by observing the different types of consumers more precisely, it actually appears that small consumers are more sensitive to windfall effects caused by a lower tariff but that large consumers are incentivized to reduce their consumption. Finally, a social device on such pricing designs seems to increase the consumption but is more of a catch-up effect. We can summarize the results as follows (Table 7):

Proposition	Results
Proposition 1: A nonlinear tariff decreases the aggregated consumption of drinking water.	**Confirmed**
Proposition 2: A nonlinear tariff positively impacts the consumption of the small consumers and negatively impacts the consumption of the others.	**Confirmed**
Proposition 3: Social consumers consume more than other consumers do with the new tariff.	**Not confirmed**
Proposition 4: The impact of the tariff change is related to the size of the household.	**Confirmed**

Table 7. Final Results

6 Conclusion

How do we interpret these results? The overall efficiency of the new pricing mechanism seems good since it did not cause global overconsumption. However, as Crampes and Lozachmeur (2014) explain, the several limitations of this type of tariff are related to the redistributive mechanism. In effect, to decrease the price for "vital consumption" (tier 1), the monopoly must increase the price for the others who pay the discount. From our results, we observe that the small consumers increase their consumption significantly. They represent approximately 50% of the population in Dunkerque. Additionally, the losses for the monopoly from this discount are very important (the marginal cost of the new price is –0.17 €/m3). This is why the monopoly increases the marginal price strongly for the other consumers (+0.55 €/m3 for the tier 2; +1.06 €/m3 for the tier 3). The legal obligation to have a financial equilibrium suggests that the monopoly transfers the cost of the measure to others with low price elasticity. Additionally, the redistributive mechanism generates distortions and social costs for 50% of the consumers (tier 1 + tier 2). Moreover, the heterogeneity of the households is not considered in the mechanism design. We show that the consumption seems to be strongly related to the size of the household. However, the different tiers were designed according to a representative type of household. This standard design could be negative for large families.

Until 2013 and the Brottes Law, it was forbidden for the providers to discriminate between consumers. A better tariff should consider the individual characteristics when designing the tiers.

Moreover, we can discuss the criteria for the social consumers. The actual criteria (CMU or not) is quite limiting because only 2.45% of the population is concerned. Additionally, a social criterion based on fiscal and social information could be more efficient (e.g., the "quotient familial"). Since 2013, the French Law permits the use of fiscal information to design special social tariffs. We suggest introducing redistributive mechanisms (e.g., special tiers, subventions) for the large families to correct the negative impact of the progressive tariff, following the Fauquert and Montginoul (2011) proposition. For instance, in Dunkerque in 2012, a special measure called "chèque eau" (flat-rate) was created to subsidize the consumption for the large families (N>5). However, because receiving this grant implies a specific demand, only 12 families benefited from it in 2012.

The present study extends the debate on the plurality of the goals assigned to public policies. In their note to the Conseil d'Analyse Economique, Saussier and Tirole (2015) reminded us of the difficulty to simultaneously drive several objectives in public orders. We show, through the analysis of this experiment, that two objectives can be reached by accepting some social costs.

We could compare our article with another natural experiment in France from Niort. Some studies (EauAnd3E – ANR Villes Durables and Aubert (2013)) tried to measure the impact of the progressive tariff on the consumption in Niort. The different studies show that the consumption decreases with the progressive tariff (from -1 to -2%). However, this study differs from ours for several reasons. First, the geographic and social contexts are very different. In Niort, the average drinking water consumption is 110 m3/year against 80 m3/year in Dunkerque. Moreover, the region of Niort was confronted with an important drought during the period studied (to recall, the rainfall in Dunkirk is different from Niort). This may have impacted the rate change. In addition, the data used in this study were aggregate data.

Our study could be supplemented by a more detailed analysis of possible transfers between individual and professional consumers. Indeed, the presence of agriculture modifies considerably the ecosystem of the monopoly of drinking water. In addition, ex ante and ex post analysis of incremental tariffs must account for the local context because the consumption of drinking water depends on multiple factors (income for instance).

Moreover, we can renew the debate on the monthly billing of drinking water. Several authors, such as Barraqué et al. (2007), highlighted the need to improve the quality of information on drinking water consumption. From this point of view, the installation of individual meters and, above all, monthly payments, appear to be indispensable for improving the effect of the price signal. With smart meters, we can hope that the meter reading will improve to make discriminatory tariffs more efficient. Without up-to-date and easily accessible information, the price signal cannot play its role, particularly among the precarious public. In Dunkerque, the impact of the new tariff can be largely explained by the pro-activity of the supplier to help consumers react well to the marginal price, as observed in, e.g., invoice simulations, communication operations, and suggestions for changes in behavior. These elements all agree with the authors' proposals (Ito (2014), Barraqué et al. (2007)) to improve the quality of information to improve the efficiency of progressive tariffs.

Therefore, our study raises the question of the design of tariffs and the information available to consumers.

This study, however, presents some serious econometrical limitations. First, the absence of a real control group and the lack of more precise sociodemographic data make our interpretation of the results quite fragile. Second, due to the very small number of social consumers in the panel, it is impossible to run an econometric model on this group.

The second limitation lies in the "public policy" approach of this paper. The aim was to assess the overall impact of a measure without trying to quantify the elasticity of the consumers. Finally, we raised the question of the profit and loss associated with this measure only from the point of view of the consumers. It could be useful to observe who benefits from the measure on the collective surplus level by considering the different financial constraints of the provider. Therefore, the evaluation of the tiers and their implications on the final profit should be the subject of a deeper study to determine who (the supplier or the consumer) actually benefits with a nonlinear pricing system. These points will be analysed in another study by using different database and econometric models (Mayol and Porcher (2017)).

This first paper seeks to shape part of the social and environmental concerns in utility management. Pricing innovations deserve to be encouraged and studied, if we consider the institutional constraints and behaviours that can influence their success. Because drinking water in France is in perpetual development, we hope that this empirical contribution will lead to more global thoughts on the efficiency and fairness of public services pricing.

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7 Appendix

7.1 Extended results for diff-in-diff model

Dependent variable : LogConsumption	RE	OLS
HOUSEHOLDSIZE	0.222***	0.221***
	(15.68)	(16.59)
ECOLOGICALSENSIBILITY	-0.045	-0.069
	(-0.91)	(-1.54)
RURAL	-0.137*	-0.065
	(-1.69)	(-0.89)
EASTSECTOR	-0.093*	0.078*
	(1.84)	(1.71)
PLUVIOMETRY	0.005***	0.001***
	(36.28)	(4.85)
MEASURE	-0.834***	-0.175***
	(-17.22)	(-2.82)
HOUSE	0.349***	0.309***
	(5.91)	(5.17)
MEASURE x HOUSE	-0.107***	-0.089*
	(-2.85)	(-1.85)
Cons.	0.000	2.886***
	(.)	(21.90)
Number of obs.	2870	2870
Number of groups	1085	-
Year effect	yes	yes
R2	0.2125	0.2134

* p<0.10, ** p<0.05, *** p<0.010

Table 8. Extended results for diff-in-diff model

7.2 Extended results for random effect regression

Dependent variable : LogConsumption	RE	RE
HOUSE	0.187***	0.187***
	(3.97)	(3.97)
HOUSEHOLDESIZE	0.250***	0.250***
	(17.64)	(17.64)
RURAL	-0.063	-0.063
	(-0.94)	(-0.94)
EASTSECTOR	-0.023	-0.023
	(-0.49)	(-0.49)
PLUVIOMETRY	0.000	0.000
	(0.55)	(0.55)
MEASURE	-0.050***	0.063***
	(-2.79)	(2.78)
LAG.TIER1	-0.090***	
	(-3.56)	
MEASURE x LAG.TIER1	0.113***	
	(3.81)	
LAG.TIER2		0.090***
		(3.56)
MEASURE x LAG.TIER2		-0.113***
		(-3.81)
LAG.TIER3	-0.543***	-0.454***
	(-11.96)	(-9.78)
MEASURE x LAG.TIER3	-0.128*	-0.241***
	(-1.77)	(-3.23)
Cons.	3.483***	3.394***
	(39.82)	(40.49)
Number of obs.	3352	3352
Number of groups	1294	1294
Year effect	yes	yes
R2	0.329	0.329

* p<0.10, ** p<0.05, *** p<0.010

Table 9. Extended results for the different categories of consumers