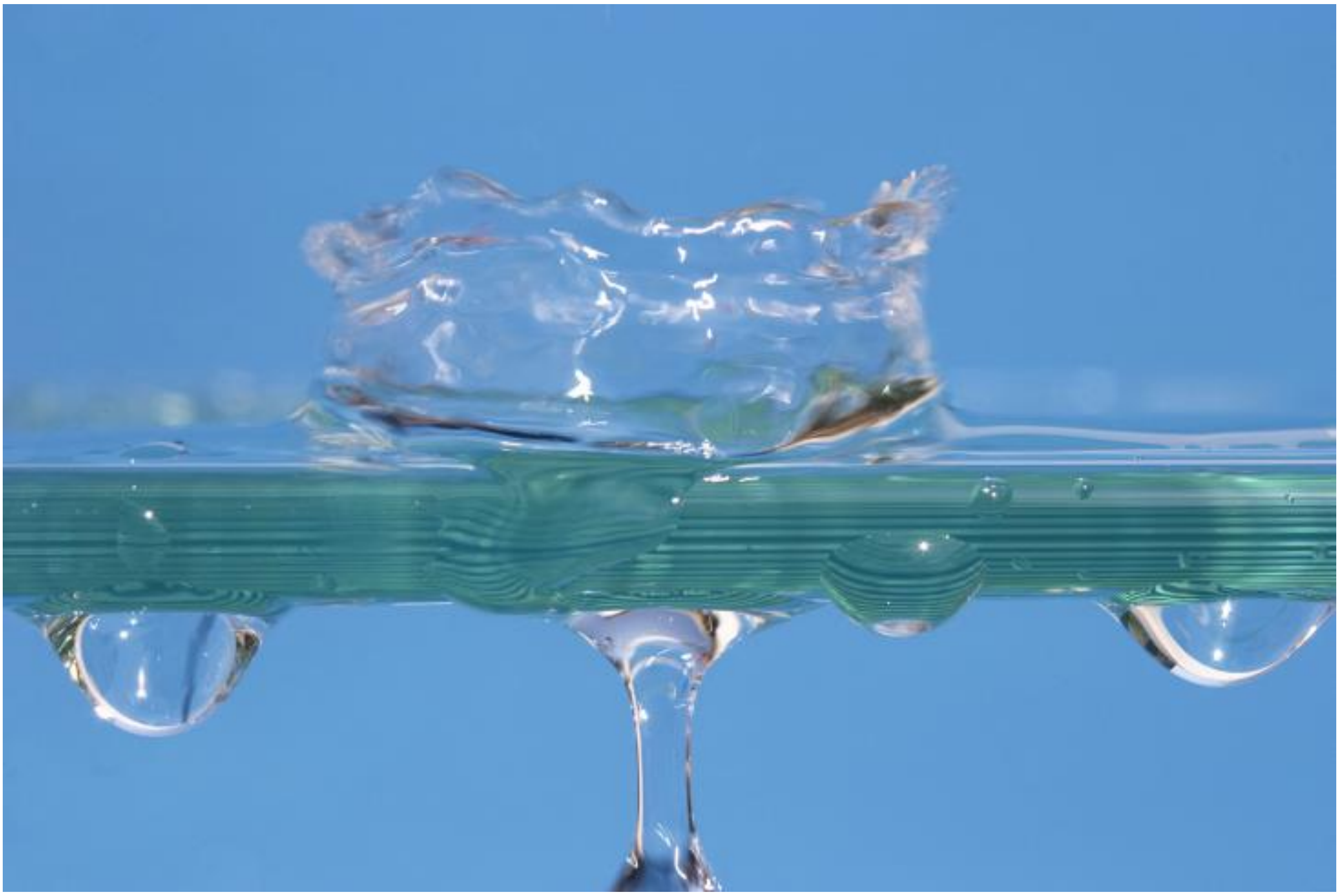

The Effect of Metering on Water Consumption - Policy Note

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May 2017

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This Project is supported by the ESRC [grant ES/K01210X/1]

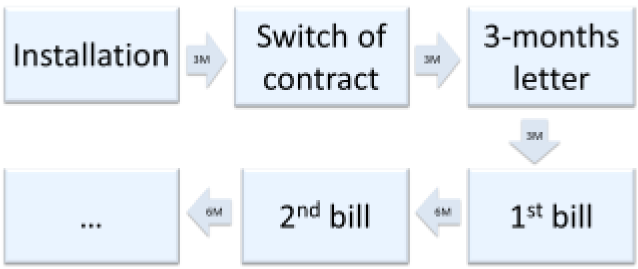
In 2010 Southern Water started a programme to meter households across its supply area in the South East of England, an area classed by the government as under water stress. This *Universal Metering Programme* (UMP) has entailed the installation of nearly 500,000 meters by the end of 2015, when more than 9 out of 10 households in the region have been metered, compared to the rate of about 40 per cent at the beginning of the programme.

In this policy note we analyse the impact of metering on water consumption using data obtained from the start of the programme until October 2016. After explaining the different aspects of the metering programme in Section 1, we introduce the methodology and the data in Section 2. We then show the results for the impact of metering on water consumption in Section 3 and for the effect of water-efficiency visits in Section 4. Section 5 concludes.

1. The UMP Programme

The typical customer journey of UMP households starts with a meter installation, followed by a switch of contract from unmetered to metered tariff, around three months after the installation. In the period between meter installation and switch of contract, water charges are still based on the previous contract - i.e. on the rateable value (RV) of the house[1] - and not on metered consumption. Three months after the switch of contract, customers receive a letter (known as 3-months letter) showing the expected metered bill they will receive based on the observed consumption in the previous 3 months. This is the first information customers receive about their water usage since the switch of contract. Figure 1 summarizes the customer journey. Note that customers usually receive a bill every six months, i.e. two bills per year.

Figure 1. Customer Journey



Meter installation not only affects water consumption because of the new tariff, but it also allows easier detection of leaks in the house pipes. This means that part of the observed reduction in water usage may be due to repairs of leaks

[1] The rateable value was used as the basis for local authority taxation prior to 1990. Rateable values were set by the Valuation Office (part of HM Revenue and Customs) to reflect the rental value of the property. The rateable value is no longer used for taxation and no longer updated. The water company normally use the rateable value quoted in the Valuation List in force on 31 March 1990.

inside property. Moreover, as part of the UMP programme, several (high-usage) customers with water-affordability problems are offered free water-efficiency audits, where they receive advices and also water-saving devices, such as save-a-flush bags. Accordingly, the total impact of the UMP programme on water usage can be divided into three different components:[2]

Total Impact of UMP	=	Price Effect	+	Leak Detection	+	Water-Audits

2. Methodology and Data

As the UMP is gradually implemented in Southern Water supply area, households go through the process outlined in Figure 1 above at different points in time. Moreover, we also observe consumption for households who live in the areas where the UMP is being implemented, but are already metered and, thus, do not switch contract. Thanks to these two facts, we can separate the effect of the UMP from any seasonal variation in water consumption, and also account for geographical variation in average consumption.

In other words, to assess the impact of introducing meters on consumption, we trace daily consumption as households' progress through the different stages of UMP and compare it to the evolution of consumption in the same period by households who are not subject to the UMP but live in the same geographical area. This latter group of households allows us to capture variation in average consumption at the postcode level and also changes in consumption due to seasonality (e.g. temperature or precipitation) or to aggregate economic conditions (e.g. unemployment), thus making it possible to isolate the effect of the UMP. In the Technical Appendix, we provide details about the equations we estimate and the econometric methodology we use.

It has to be taken into account that, for the purpose of this note, we only look at areas where customers have already received 4 bills (i.e. meters were installed more than 2 years ago). As such, our estimates, for instance of average consumption, may not reflect the whole of Southern Water customers.[3]

The data used for this policy note refer to the period from January 2011 to October 2016 and include only households whose daily consumption is below

[2] In conjunction with meter installation, Southern Water has conducted an information campaign about the benefits of water conservation. This campaign also affects already metered households in areas subject to the UMP.

[3] Note also that it is standard in the water industry to perform various technical adjustments when calculating average consumption. For instance, a meter under-registration allowance should be added to the recorded consumption given that meters cannot record very low flow rates. These adjustments are not relevant for the purpose of the current note and, as such, are ignored.

2,000 litres per day. We use two different datasets. The first reports consumptions at five points in time:[4] at switch of contract and then at bill 1, 2, 3 and 4 (that is, every six months over a period of 2 years). The second will use 7 data points: three for the pre-switch period (typically one, two and three months after installation) and then at bill 1, 2, 3 and 4.[5] This second dataset is useful to investigate whether households start adjusting their consumption behaviour already in the period between meter installation and switch of contract. Although customers are still subject to unmetered charges, they may take into account that changing water consumption patterns takes time and, therefore, they may modify their consumption before the actual change in pricing. We will refer to the first dataset as "Billing" data and to the second as "Arad" data.

Table 1: UMP Households

	Billing Data	*Arad Data*
# Household	246,665	167,976
# Observations	1,233,325	1,175,832
Consumption: Daily Litres of Water		
Mean	325	340
Median	295	305
Min	0	0
Max	2,000	2,000
Percentile 1	32	51
Percentile 99	971	1,032

Table 1 shows descriptive statistics for UMP customers' consumption in each of the two datasets. Using billing data, we observe 246,665 households at five points in time for a total of 1,233,325 observations. With Arad data the number of households for which we can construct a balanced panel over the seven data points is 167,976. The higher mean and median consumption for the Arad data is due to the fact that 3 readings refer to the pre-switch period, when consumption is generally higher. Section 3 presents results for the two dataset.

[4] Meters are set to 0 at the time of installation.

[5] The two datasets come from difference sources. The first has been provided to us by Southern Water and it is based on billing data. The second has been provided to us by Arad Group UK, which provides water service to Southern Water. Consumption in the Arad dataset is observed with higher frequency, but data need major work of cleaning. ARAD meter usually stores water consumption at the end of each calendar month. Consumption is also registered anytime a reading machine passes in the area, thus leading to a very unbalanced dataset. The ARAD data has also problems of measurement errors due to faulty meters. So while the ARAD data are more detailed, the number of observations in the clean dataset we construct is lower.

3. Results for Metering

Billing Data

As explained above, meter installation generates water savings because of two different reasons: (i) behavioural change triggered by a variation in prices and (ii) more effective detection of leaks. In this section, we analyse the overall effects of these two channels. In the following section, we assess the reduction in water consumption due to pricing only, net of leaks.

Table 2 shows the change in water consumption over the four bills for UMP customers. The average daily water consumption for metered households not involved in the UMP is 248.4 litres.[6] During the pre-switch period UMP households consume 122 litres more.[7] The coefficient for the dummy D_1 in Column (1) shows that there is a reduction in daily consumption of around 38 litres of water during the six-month period that goes from switch of contract to the 1st bill. Similarly, the coefficients for the dummy D_2, D_3 and D_4 suggest that, compared to their pre-switch consumption level, UMP customers consume, respectively, 55 litres, 61 and 66 litres of water less in the periods leading to the 2nd, 3rd and 4th bill. The figures above suggest that two years after the installation of a meter (i.e. when the 4th bill arrives), we observe an average reduction in water usage of 17.8%, from 370 to 304 litres.

Estimates in Column (1) do not take into consideration the fact the typical UMP household has a larger number of occupants than non-UMP customers, which can explain part of the difference in average consumption between the two groups. Although we do not have a direct measure of the number of occupants, we can use the ex-ante expected consumption (known as "periodic consumption") to control for this and other unobserved characteristics of the household (see the Appendix for details). Column (2) shows the results when adding the "periodic consumption" as a control variable to the specification. The lower number of observations is due to the fact that "period consumption" is not available for some households in our dataset.[8] Two things are worth noting.

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[6] This is the average consumption for all available observations of non-UMP customers. Discussion with managers at SW confirmed that 250 litres per day is a very reasonable measure of average consumption of the "already" metered customers.

[7] It should be noted that customers that were metered prior to UMP consist of 'Households living in New Dwellings' and 'Optants' (i.e. customers who chose to be metered). 'Optants' are typically low-occupancy households in properties with high rateable value who are likely to save money by moving on to metered charge. These customers are already conscious of their water consumption and their characteristics may differ from UMP households. As indicated above, this group has primarily been used to correct for the impacts of weather and seasonality on consumption. Note also that, as part of UMP, all customers who can be metered are being metered and, therefore, there is no selection bias in being part of UMP.

[8] Note that similar results to those in column (1) are obtained when using the sample of households with non-missing periodic consumption: the largest difference being for the coefficient on Bill 4 which is -62.6, i.e. three litres less than the corresponding coefficient reported in the column (1). This suggests that periodic consumption is missing at random and we do not have a problem of sample selection along this dimension.

First, the average UMP customer is now found to consume around 59 litres of water more in the pre-switch period. This means that half of the 122 litres difference reported in Column (1) can be attributed to differences in the characteristics of UMP and non-UMP households. Second, the reduction at bill four of -61 litres suggests that there is almost perfect convergence in the water usage between the two groups two years after installation. This result gives strong support to the assumption that periodic consumption can effectively capture structural differences between households, as similar households, when facing the same incentives for a sufficient period of time, should indeed consume similar amounts of water, irrespective of being part of UMP or not. Similarly, results in Column (3) show that the reduction observed at Bill1-Bill4 using OLS is confirmed when using a Fixed-Effect (FE) estimator (which also control for any unobserved heterogeneity across customers, including number of occupants).

Finally, in Column (4) we run the same specification of Column (1) using only the (smaller) sample of households for which we have Arad data. We can see that this sub-sample of customers tend to consume 10 litres of water less in the pre-switch period (111 litres vs 121 litres). The estimated effect of metering is a reduction in consumption at 4th Bill of 48 litres, i.e. a 13.5% decrease with respect to the pre-switch period. This means that Arad meters tend to be installed in households experiencing a smaller decrease in their consumption, thus the results based on the Arad data discussed in the next section may represent a lower bound of the actual impact of the UMP programme on water consumption.

Table 2: Meter and Water Consumption

Variable Description	Name	OLS (1)	OLS-Per (2)	FE (3)	OLS-Arad (4)
non-UMP		248.4	248.4	248.4	248.4
UMP:					
Pre-Switch	D_{PS}	121.968*	59.082*		111.255*
		(0.53)	(0.46)		(0.55)
1st Bill	D_1	-38.054*	-42.543*	-41.446*	-19.168*
		(0.66)	(0.53)	(0.36)	(0.71)
2nd Bill	D_2	-54.600*	-56.309*	-55.670*	-36.581*
		(0.64)	(0.52)	(0.38)	(0.69)
3rd Bill	D_3	-61.261*	-59.262*	-60.048*	-43.237*
		(0.64)	(0.53)	(0.40)	(0.69)
4th Bill	D_4	-65.712*	-60.978*	-62.868*	-48.359*
		(0.64)	(0.53)	(0.41)	(0.69)
Nmb Obs		5,298,961	3,294,522	5,298,961	4,905,471

Robust Standard Error in Parenthesis * p<0.001

Arad Data

In this section we assess the effect of metering on average water consumption together with the response of households at different points of the distribution of water consumption using quantile regression. We then study whether the effects of metering vary by income. Finally, we investigate the heterogeneous reaction to metering between households that experience a large increase in their water bill compared to those that receive a lower bill due to metering.

Table 3 below shows the results obtained using the ARAD data. Given that we now have three different observations for the pre-switch period, we can observe if there is any adjustment in the period between installation and switch of contract. The first important result we obtain is that there is indeed a drastic reduction in consumption during the pre-switch period: Column (1) shows that UMP customers consume 155 litres more than non-UMP at the very beginning of the pre-switch period, but only 93 (=155-62) litres more at the end of the pre-switch period. This means that the 111 litres reported in Column (4) of Table 2 underestimate the baseline consumption of UMP customers.[9] Estimates in Column (1) suggest that the average water usage two years after installation is 22.6% lower, from 403 (=248+155) to 312 (=403-91) litres per day. Results in Columns (2) and (3) confirm the findings already discussed in Table 2, in particular the fact that we find almost perfect convergence between UMP and non-UMP once we use periodic consumption to control for structural differences between the two groups of customers. These numbers are higher than those resulting from the so-called National Metering Trials that took place in England in the late '80-early '90 and saw an average reduction in demand of 11%. They are, however, in line with the results of the Isle of Wight universal metering that saw the installation of 50,000 meters in the period 1989-91 and resulted in a reduction in demand of 21% (Herrington, 2007).

As mentioned above, part of this reduction may be driven by the fact that meters allow to detect (and fix) leaks in the house. If, for instance, 5% of houses were affected by leaks taking place in the section of the pipeline between the meter and the house, and assuming that around 400 litres of water would leak every day and that all leaks would be fixed thanks to the installation of meters, then out of the 90 litres drop, 20 would be due to a reduction in leakage. Using these numbers in combination with the results in column (1), we can place the percentage of water reduction due to behavioural changes, net of leaks, at 18%, from 387 litres (the revised baseline consumption, given that 20 of the 403 litres are wasted) to 312 litres. In this scenario, leaks may account for 5% of the average reduction in water consumption we computed in the Arad dataset. This would be in line, for instance, with what has been estimated in the case of Christchurch in New Zealand, where installation of meters, although not used for charging purposes, allowed to discover domestic leakage, thus resulting in in a 4% decline in water usage (OECD, 1999).

The last three columns of Table 3 report the results for quantile regression at percentile 25, 50 and 75. These results allow us to analyse the heterogeneous effects of metering at different points of the distribution of water consumption. Note that, differently from OLS regression, these estimates are substantially

[9] We assume that consumption observed at the very beginning of the pre-switch period is indeed a better approximation of water usage when households were unmetered.

unaffected by high baseline water usage due to leaks because households with severe water leaks are likely to be concentrated above percentile 75 of the distribution. Results reported in Columns (4), (5) and (6) show that at quartile 1, 2 and 3, we observe a reduction in water consumption of respectively, 13.5%, 16% and 20.5%.

Table 3: Metering and Water Consumption

Variable Description	Name	OLS (1)	OLS-Per (2)	FE (3)	Q25 (4)	Q50 (5)	Q75 (6)
non-UMP		248.4	248.4	248.4	124	216	329
UMP:							
Pre-Switch (1st)	D_{PS1}	154.930*	90.461*		105*	129*	171*
		(0.71)	(0.59)		(0.44)	(0.45)	(0.78)
Pre-Switch (2nd)	D_{PS2}	-54.564*	-58.311*	-55.688*	-3.0*	-22.0*	-53.0*
		(0.82)	(0.57)	(0.48)	(0.60)	(0.63)	(1.08)
Pre-Switch (3rd)	D_{PS3}	-61.665*	-66.723*	-64.362*	-17.0*	-37.0*	-69.0*
		(0.82)	(0.57)	(0.51)	(0.60)	(0.63)	(1.08)
1st Bill	D_1	-62.437*	-69.149*	-67.476*	-16.0*	-39.0*	-78.0*
		(0.84)	(0.66)	(0.54)	(0.60)	(0.63)	(1.08)
2nd Bill	D_2	-79.835*	-83.684*	-82.266*	-24.0*	-49.0*	-95.0*
		(0.82)	(0.65)	(0.56)	(0.60)	(0.63)	(1.08)
3rd Bill	D_3	-86.278*	-86.902*	-86.201*	-29.0*	-54.0*	-101.0*
		(0.82)	(0.66)	(0.58)	(0.60)	(0.63)	(1.08)
4th Bill	D_4	-91.370*	-89.211*	-89.336*	-31.0*	-56.0*	-102.0*
		(0.82)	(0.66)	(0.58)	(0.60)	(0.63)	(1.08)
Nmb Obs		5241488	3246210	5241488	5241488	5241488	5241488

Robust Standard Error in Parenthesis * p<0.001

The impact of UMP is also likely to vary across households with different income levels. There is large evidence that high income households use more water than low income household and that the price elasticity of water demand decreases as income increases (see Agthe and Billings, 1987, among others). Under the assumption of declining marginal utility in the use of water, the welfare loss due to a reduction in a unit of water in a lower income household exceeds that of a higher income household.[10] In this context, a uniform increase in the marginal price for any quantity consumed may aggravate inequalities in water use given that low income households may reduce water consumption proportionally more than high income households (given that their demand is more elastic) and they may stop using water for activities that are generally considered more "essential".

The first three columns of Table 4 show the impact of metering for three different income groups created using the income deprivation index at the level of Lower layer Super Output Area (LSOA) provided by National Office of

[10] For instance, a low-income household may use its marginal water for laundry while a high-income household may use their marginal water to clean the car.

Statistics.[11] As expected, average water consumption for non-UMP is higher in richer areas. The table shows that the difference in consumption between non-UMP and UMP at the first observation of the pre-switch period is also larger in richer areas. Wealthiest areas are found to have a larger reduction in the absolute number of litres of water but, rather interestingly, the percentage reduction in consumption is almost identical among the three groups: 23% (=-87.5/238.5+147.2) for UMP living in low income areas, 22% and 23% for UMP living respectively in medium and high income areas.

For most of UMP customers we also have access to the socio-economic classification of Mosaic, a dataset published by Experian.[12] While it is difficult to rank the sixteen groups in Mosaic from low to high income, it is easier to create two clusters of households: one with low income and the other with high living standard. The last two columns in Table 4 confirm that the reduction in consumption is larger for high-income households, while we find a larger percentage drop in consumption for low income families (24.5%) compared to high income families (21.5%).

Table 4: Water Consumption and Income

Variable		AREA INCOME			MOSAIC INCOME	
		LOW	MEDIUM	HIGH	LOW	HIGH
Description	Name	(1)	(2)	(3)	(4)	(5)
non-UMP		238.5	248.9	269.7	248.4	248.4
UMP:						
Pre-Switch (1st)	D_{PS1}	147.21*	156.95*	165.56*	133.288*	226.725*
		(1.16)	(1.02)	(2.04)	(1.49)	(1.71)
Pre-Switch (2nd)	D_{PS2}	-53.222*	-52.841*	-65.008*	-55.357*	-68.608*
		(1.32)	(1.18)	(2.36)	(1.81)	(2.09)
Pre-Switch (3rd)	D_{PS3}	-58.432*	-60.615*	-72.143*	-62.131*	-74.961*
		(1.32)	(1.17)	(2.37)	(1.78)	(2.06)
1st Bill	D_1	-56.341*	-60.842*	-71.172*	-62.637*	-75.324*
		(1.37)	(1.20)	(2.40)	(1.76)	(2.02)
2nd Bill	D_2	-75.308*	-77.982*	-87.276*	-81.243*	-91.678*
		(1.34)	(1.18)	(2.35)	(1.73)	(1.99)
3rd Bill	D_3	-81.661*	-84.941*	-92.806*	-87.595*	-98.479*
		(1.34)	(1.18)	(2.35)	(1.73)	(1.99)
4th Bill	D_4	-87.492*	-89.386*	-99.051*	-93.730*	-102.479*
		(1.33)	(1.18)	(2.35)	(1.72)	(1.99)
Nmb Obs		1873868	2408201	736345	4302490	4259988

Robust Standard Error in Parenthesis * p<0.001

The advantage of this measure is that it is at the household level, rather than at the LSOA level. The drawbacks are that we do not have the measure for non-UMP

[11] There are 32,855 LSOA in England with a min/max number of households of 400/1,200. Our three income groups have been created using the income-score assigned to LSOA in South-East England: low, medium and high income groups correspond to areas that are respectively, in the lower quartile, between quartile 1 and 3, and in the upper quartile of the income-score distribution.

[12] Experian web page describes mosaic as a "powerful cross-channel consumer classification designed to help you understand the demographics, lifestyles, preferences and behaviours of the UK adult population in extraordinary detail."

households and the classification of households into the high and low income categories is not clear-cut. The message across the two measures is, in any case, that a substantial reduction in consumption is shared across income levels, rather than being concentrated in low-income households, as one could have expected.
Changes in the tariff may imply a substantial change in the water bill paid by customers. For instance, given that unmetered tariff is based on the RV of the house, switching to a metered tariff is likely to be very costly for large families living in small properties and rather beneficial to singles living in expensive houses. In the last part of this section, we analyse the change in consumption between households that receive a bill that is at least 10% lower (winners), those with a bill 10% higher (losers) and those between -10% and +10% (on par). Ideally, this classification should be determined by the change in the bill due to the new tariff keeping water consumption fixed at the normal (or average) unmetered level.[13] However, there is no measure of this average unmetered consumption. Using instead consumption observed during the pre-switch period would suffer from a problem of reversion to the mean.[14] To avoid this problem, we first construct a "fictional" metered bill based on the consumption observed at the very beginning of the pre-switch period ("fictional" because households are still on the unmetered tariff). We then compute the difference between this bill and the unmetered bill and we regress this difference on periodic consumption and RV to obtain the predicted difference in the two bills, that is the difference that is explained by exogenous characteristics that are highly correlated with the unmetered bill (RV) and the metered bill (periodic consumption). Indeed, we find that these two variables can explain around 90% of the variability in the dependent variable.

Using this predicted difference between metered and unmetered bills, we find that 55% of the households are better off under the new tariff, with mean and median savings of respectively 6.5% and 6%.[15]

The coefficients reported in columns (4)-(6) of Table 5 show water savings are dramatically different between winners and losers, with the former experiencing a drop of 24 litres of water by the 4th bill, equivalent to a 9% reduction, while the latter using 193.6 litres of water less, equivalent to a 32% reduction compared to

[13] Defining a winner on the basis of the difference between the last unmetered bill and the first metered bill is problematic because we know that UMP customers react to meter installation very fast and therefore some households that are worse-off under the new tariff (given the pre-installation level of consumption) may reduce consumption enough to actually receive a lower bill.

[14] For instance, there may be cases in which consumption in the first part of the pre-switch period is unusually high (or low) because of in-laws staying over for some days (or all the family going away on holidays). Then, we may wrongly classify these families as losers (winners), observe a large reduction (increase) in consumption and wrongly attribute it to the change in bills, rather than to the fact that the in-laws have left (or the family is back from holidays) and the household goes back to the usual level of consumption.

[15] Recall that we compute the metered bill using consumption at the very beginning of the pre-switch period, accordingly average savings will be higher in the following years, when households fully react to the new pricing structure.

the pre-switch period. The large difference in the (absolute number of) litres of water saved could be explained by the larger number of occupants in the "loser" group. However, it is interesting to note that the percentage change is also significantly higher, which is less intuitive given that consumption per-capita tends to decrease as the household size increases due to economies of scale.

Table 5: Water Consumption and Billing

Variable: Description	Variable: Name	BILLING: WINNER (4)	BILLING: ON PAR (5)	BILLING: LOSER (6)
non-UMP		248.4	248.4	248.4
UMP:				
Pre-Switch (1st)	D_{PS1}	4.703*	140.09*	356.685*
		(0.66)	(1.13)	(1.30)
Pre-Switch (2nd)	D_{PS2}	-23.644*	-48.559*	-106.147*
		(0.76)	(1.33)	(1.55)
Pre-Switch (3rd)	D_{PS3}	-26.166*	-53.736*	-118.621*
		(0.76)	(1.31)	(1.53)
1st Bill	D_1	-13.837*	-50.894*	-138.104*
		(0.81)	(1.33)	(1.51)
2nd Bill	D_2	-18.844*	-61.470*	-173.723*
		(0.81)	(1.34)	(1.49)
3rd Bill	D_3	-20.979*	-66.397*	-186.976*
		(0.81)	(1.35)	(1.49)
4th Bill	D_4	-24.118*	-70.645*	-193.580*
		(0.82)	(1.36)	(1.50)
Nmb Obs		4564203	4267431	4442032

Robust Standard Error in Parenthesis * p<0.001

The findings in Table 5 are relevant for the future implementation of compulsory metering programmes in other parts of the country or in other countries. The larger the absolute change in consumption following the new tariff, the larger the benefit of eliminating the deadweight cost of over-consumption (see Cowan, 2010). Given the large heterogeneity in water usage, policy makers should ponder the possibility of implementing a compulsory (free) metering program only to large-size households, while leaving metering available to small households on an optional basis, possibly with the payment of a fee.

4. Results for Water-Efficiency Visits

As part of the UMP programme, Southern Water offers to several UMP customers (typically households that have problems in paying their water bill) the possibility of receiving free water audits. During these visits, households are given (or installed) water-saving devices together with general advices on how to save water and energy; the household financial situation, including a benefit entitlement check, may also be discussed.

We obtained from Southern Water the list of UMP customers that have received a water-efficiency visit. There are around 20K households that we can match to the UMP consumption data.[16] Given that this represents around 1% of the households in the Billing data, results reported in Section 3 are substantially unchanged when we eliminate these households from the sample of UMP customers. In other words, water-efficiency visits do not play any relevant role in explaining the reduction in water usage discussed in the previous section.

Nevertheless, it is interesting to estimate the effect of water-efficiency visits for the "treated" sample. To this aim, we use the Arad readings to construct a new database with monthly observations for more than 5 thousands UMP households. For most of the households, this dataset includes 27 observations: 3 for the pre-switch period, and then 24 monthly observations covering the first 4 billing cycles.[17] For identification, we exploit the fact that these visits take place at different points in time of the UMP programme. In particular, around half of the households in the dataset receive their visits around the period of meter installation or during the pre-switch period. These "early treated" cannot be (or can be hardly) used to assess the impact of water visits because we do not have reliable information on their water consumption before the visits. Nevertheless, we can use them to define the consumption dynamics to which the "later treated" household should converge after the visit.

Our approach consists in selecting 2,708 UMP households that receive the visit at least 6 months after installation (i.e. we have 6 data points before the audit) and in matching each of them to the control group of "early-treated" UMP household based on their periodic consumption.

Table 6 shows that average consumption of treated and matched customers is very different in the pre-switch period (first three observations), but it converges to similar levels for the last six observations of our time window. This gives support to our econometric approach as it indicates that matching is done properly.

Table 6: Efficiency-Visits and Water Consumption

	Treated	Matched
Pre-Switch (3 observations)	470.76	436.71
Last Billing Cycle (6 observations)	380.79	381.01

[16] We also find around 3K non-UMP households receiving a visit. We do not have systematic information on the type of activities and services provided, in particular on whether water-saving devices have been left with the customers or have been directly installed in the property.

[17] For some customers, we have gaps in water consumption data over the 27 months, so we work with an unbalanced panel.

Table 7 reports the results of the specification we use to estimate the impact of water efficiency visits. This shows that before the visit, still untreated households consumed around 30/35 litres of water more than already treated customers. Consumption falls to the same level in the month of the visit and even to a lower level in the second month after the visit (-10 litres) to stabilize again to the same level in the following months. This patter is consistent with the fact that households may try to implement tips and use water-saving devices soon after the visits and then decide which of those changes may work for them.

Table 7: Meter and Water Consumption

Variable Description	Name	(1)	(2)
Before Visits			
	D_{BF}	32.841***	26.964***
		(2.46)	(4.66)
	D_{-3}		32.797***
			(4.69)
	D_{-2}		35.024***
			(4.69)
	D_{-1}		36.328***
After Visits:			(4.68)
	D_1	-0.142	-0.242
		(3.86)	(3.86)
	D_2	-10.028**	-10.100**
		(3.95)	(3.95)
	D_3	-7.017*	-7.087*
		(4.01)	(4.01)
	D_4	-3.848	-3.910
		(4.08)	(4.08)
	D_5	-4.981	-5.017
		(4.08)	(4.08)
	D_6	-4.025	-4.035
		(4.10)	(4.10)
Nmb Obs		120483	120483

RE Estimator. Standard Error in Parenthesis ***p<0.01, **p<0.05, *p<0.10

5. Conclusions

The analysis presented above suggests that households are responding to the installation of meters through the "Price Effect". In particular, we find a decrease in consumption between 16% and 20% depending on how much weight we may attribute to leakage. As mentioned, these figures are substantially higher than those assumed based on National Metering Trials, but in line with what experienced in a similar programme in the Isle of Wight (Herrington, 2007).

This note offers evidence that the percentage reduction in consumption is very similar across income groups, while there is a dramatic difference in reaction between households that benefit from the change in tariff (winners) and those that are worse-off (loser). Finally, this note provides the first large-scale evidence that the effects of water efficiency visits can be placed at around 30 litres of water per day.

Acknowledgements

We would like to thank Carlos Pineda for excellent research assistance and Southern Water for providing assistance with the data and giving us invaluable feedback during all the phases of this project.

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Technical Appendix

We estimate equations of the following type:

$$c_{i,t} = \alpha_i + \gamma * D_{UMP} + \sum_{j=0}^{3} \beta_j * D_j + \gamma X_i + \eta_t + \eta_p + \varepsilon_{i,t} ,$$

where $c_{i,t}$ is the average daily consumption of household *i* in period *t*, D_{UMP} is a dummy variable taking value one for UMP customers and zero otherwise, D_j is a set of dummies taking value one when the household is at phase *j* of the UMP, with *j=1,2,3,4* indicating that households have received the first, second, third and fourth bill. The estimation includes a complete set of monthly dummies, η_t, and (4-digit) postcode dummies, η_p, and other control dummy variables X for the income group of household *i* and type of property (flat, house or bungalow). The socio-economic groups are based on a classification provided by a commercial information services provider.

For some of the specifications we also include "periodic consumption" as control variable. This variable is an estimate of the expected consumption at the beginning of a contract, with main inputs the information provided by the owner about the number of household members, plus, potentially, some characteristics of the property (e.g. presence of a garden or swimming pool or dishwasher usage). Note that this variable is determined before observing the actual consumption of the households, and it is not changed afterward. This variable then is useful to control for different unobserved ex-ante characteristics of the households, in particular the number of occupiers.

We estimate the equation above using pooled OLS (including time dummies and pot-code dummies) and FE. We do not find major differences between the two results. This suggests that the behavioural response estimates reported in the Tables above are robust to unobserved characteristics that are invariant over the time window considered (e.g. family size). With Fixed Effects it is of course not possible to identify the difference in the level of consumption between customers subjects to UMP and customers already metered.