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Working Paper No. 280

February 2009

Advertising to boost energy efficiency: the Power of One campaign and natural gas consumption*

Seán Diffney, Seán Lyons and Laura Malaguzzi Valeri

Subsequently published in "Evaluation of the Effect of the Power of One campaign on Natural Gas Consumption", Energy Policy, Vol. 62, November 2013, pp.978–988, Published online 12 August 2013

Abstract: In this paper we study the recent awareness and persuasion campaign launched by the Irish government to increase energy efficiency and we assess its effect on residential natural gas consumption. We first analyse changes in the daily consumption of natural gas and find that advertising leaflets had a significant effect on natural gas consumption. We then study three surveys administered to 1000 consumers prior to and during the campaign. This repeated cross-section allows us to determine that the efficiency campaign has increased self-reported interest in energy efficiency and awareness of behaviours that curb natural gas consumption. However we do not find any positive effect of the campaign on self-reported energy-saving behaviours.

Key words: energy efficiency policy, advertising, Ireland, natural gas

JEL Classification: Q48; Q41

Corresponding author: laura.malaguzzi-valeri@esri.ie

* We thank Bord Gáis for providing daily natural gas consumption, Cawley Nea\TBWA for extensive information on the campaign and B&A for the micro data on the surveys they conducted. Funding from the Environmental Protection Agency and the ESRI Energy and Policy Research Centre is gratefully acknowledged.

1. Introduction

In September 2006 the Irish Department of Communications, Energy and Natural Resources started a campaign to boost energy-efficient behaviour. The campaign aimed to increase awareness of energy efficiency issues and push towards a more efficient behaviour. The campaign targeted energy consumption including use of natural gas, electricity and transport fuel (petrol and diesel) both at home and at work.

In this paper we analyse the impact of the campaign on residential natural gas consumption the bulk of which is used for heating. We are interested in determining if a broad advertising and awareness campaign is an effective tool in reaching the energy savings advocated by the European Union in its climate change strategy.[1] We have access to daily consumption of natural gas between 2004 and 2008 and information gathered from three surveys that were conducted between September 2006 (prior to the beginning of the campaign) and November 2007. We find that the campaign greatly enhances general interest in energy efficiency and increases awareness of behaviours that lead to lower heating bills. This does not translate into clear changes in behaviour within the time frame of our study. We find no clear effect on daily or weekly natural gas consumption, nor any evidence that the campaign changed self-reported heating habits. Section 2 surveys existing literature. Section 3 gives details of the advertising campaign. Section 4 introduces the data. Section 5 describes the estimation strategy and the regression results for daily and weekly natural gas demand, whereas section 6 concentrates on the estimation strategy and the results of the survey analysis. Section 7 offers concluding comments.

[1] See http://ec.europa.eu/environment/climat/climate_action.htm for an overview of the European Union's climate action strategy.

2. Literature

This paper relates both to studies of the effect of advertising and studies of energy efficiency campaigns.

The effect of advertising on consumers has been analysed from a marketing, economic, social and psychological point of view (for a useful overview see Vakratsas and Ambler, 1999). Bagwell (2001) reviews economic studies of advertising, classifying them as following the persuasive view, the informative view or the complementary view. In the persuasive view advertising is assumed to change preferences, make customers more loyal and thus decrease the price elasticity of demand for the advertised product. The informative view assumes that advertising provides information either directly or by signalling the high quality of the product through the firm's willingness to spend money on its promotion. In this view advertising lowers barriers to entry and increases the price elasticity of demand. The complementary view assumes that preferences are fixed, but the act of acquiring advertised goods increases utility (for example because of their effect on perceived social status).

The empirical literature applies models based on these different views mostly to assess the effect on firm profitability. While these findings are not directly relevant to our study, changes in customers' purchasing choices are. Most empirical research of advertising finds that it does not affect aggregate product demand, but changes the market shares of individual companies (see studies cited in Jung and Seldon, 1995, and in Bagwell, 2001). This is true not only when advertising targets a specific brand (and is therefore expected to benefit that brand's market share) but also for broader forms of advertising (Chakravarti and Janiszewski, 2004). Nelson (2001) reports that broadcast advertising for alcohol in the US changes the market share of each type of alcohol (beer, spirits, wine), but does not increase alcohol use as a whole. Conversely, past bans on alcohol advertising have affected market shares, but did not decrease total alcohol consumption.

Studies that specifically focus on energy efficiency campaigns can be classified as either Demand Side Management (DSM) or as Market Transformation (MT) studies, although the two groups overlap. The MT studies focus on permanent (or long-run) market changes due to higher energy efficiency behaviour that does not require continued intervention in the marketplace. The policies studied tend (or are expected) to have some sort of 'step' effect in energy consumption (Blumstein et al., 2000). As such they typically emphasise supply side policies and address changes in building regulations or appliance efficiency ratings more than (possibly temporary) changes in personal behaviour.

Gillingham, Newell and Palmer (2006) review DSM programs in the United States and conclude that the most effective policies are the ones that offer incentives to buy energy-efficient durable goods. The authors point out that advertising campaigns promoting energy efficiency account for a very small part of the overall spend on demand-side management and are therefore likely to be responsible for small savings. Disaggregating the savings of overall campaigns is very difficult. Starting in the 1980s DSM programs have been used as an alternative to supply-side intervention and considered a cheap way to decrease the cost of energy. Typically DSM programs have been run by the utilities themselves, who then publish DSM costs and their associated energy savings. The utilities have access to very detailed data, allowing them to obtain precise estimates. On the other hand Loughran and Kulick (2004) have questioned the methodology of these studies and their implied energy savings. Wirl (2000) has suggested that overall these programs do not have much of an impact and this is at least partly because utilities have the incentive to keep demand high and therefore run campaigns that are not effective. Auffhammer et al. (2008) review DSM programs enacted in the 1990s and find that they cannot statistically reject the amount of saving cited by the utilities, on average 1.8 per cent. The average cost of reducing consumption, which the utilities declare to be between $0.02 and $0.03 per kilowatt-hour, is also statistically within the boundaries calculated by the authors. Typically larger programs create more savings at lower costs. Such programs focus on changing lifetime consumption by giving incentives to buy appliances that are more efficient (especially refrigerators) and improving insulation in buildings. Woods (2008) analyses households' reaction to the high electricity prices in California in 2001. He finds that households do react at times of high electricity prices by reducing consumption. Some of the behaviours adopted are transient and easily reversible, such as turning off lights, and as such benefit from continued policy intervention. On the other hand continued prompting of widespread behaviours, such as turning down the thermostat, are unlikely to have a significant effect. Reiss and White (2008) show that households in San Diego reduced their electricity consumption by 7 percent over a six month period in response to public appeals. Whereas no monetary incentive was offered, appeals came on the heels of the California electricity crisis in 2000, in the midst of limited rolling blackouts and with the threat of much larger ones. This occurred during the summer, suggesting that changes in air conditioning use were a major factor in the reduction. Finally, the authors find that different households respond differently, with larger consumers decreasing their use at a higher rate than smaller consumers.

Nolan et al. (2008) survey a group of consumers in California and find that the most effective campaigns exploit peer pressure. In their study the authors show that electricity consumption decreases more when consumers are told that their neighbours are also saving electricity than when they are informed that saving energy will save them money and be good for the environment. Some utilities have adopted 'comparative billing', where customers are told how much energy they consume with respect to their peers in an effort to increase energy efficiency. Kaufman (New York Times, 2009) reports that in Sacramento, California, this approach decreased energy use by about 2 percent.

There are a few articles that study energy use in Ireland. Dulleck and Kaufmann (2004) study a previous energy-efficiency campaign run by the main electricity utility in Ireland in 1990. They find that households responded to the campaign by decreasing consumption in the medium run by 7 per cent but there was no short-run effect. The authors conclude that the effect is most likely driven by the adoption of energy efficient appliances in the long run. Their data set runs from 1976 to 1993 and is based on households' bimonthly bills. Their campaign variable increases gradually from 0 in January 1990 to 1 in December 1990 and stays at 1 thereafter. It is difficult to separate the effect of the campaign from other time-varying influences.

Finally, there are studies that specifically address natural gas consumption. Baker and Blundell (1991) report an average (across households) own-price elasticity of demand for natural gas of -0.50 for the United Kingdom. They rely on household-level data from 1972 to 1988. Asche, Nilsen and Tveterås (2008) find that in the short run, consumption of natural gas is inelastic to changes of the price of alternative fuels, such as oil and coal. This is most likely due to the large fixed costs associated with the change from one heating source to another. Elasticity of natural gas to its own price is also quite low, although it differs significantly by country. For Ireland the authors find a statistically price inelastic demand in both the short and in the long run.

Natural gas use in Ireland has been growing rapidly, although from low levels. Conniffe (2000) analyses the Household Budget Survey (HBS) of 1994-1995 and finds that only 26.3 of urban and 17.9 percent of all houses were connected to a gas line. In the same survey the 'higher' social groups were most likely to have a natural gas connection and income elasticity of natural gas was high by international standards at 0.75. The author explains that this is likely due to the fact that all households aspire to a clean heating system as income increases. In fact Conniffe also finds that income elasticity of less convenient fuels (turf, LPG and coal) is negative. Scott et al (2008) use the 2004-2005 Household Budget Survey for Ireland and find that gas line connections have increased to 31 percent of all houses. The difference in connection to gas lines between income groups persists. Only 19 percent of households in the poorest decile are connected to natural gas, as opposed to 46 percent of the wealthiest decile. Income elasticity of natural gas has declined to 0.39 but is still the highest income elasticity across all fuels.

3. Power of One campaign – description

The Power of One campaign is an energy efficiency information campaign funded by the Irish Department of Communications, Energy and Natural Resources. It started in September 2006 and lasted until March 2008. It was then followed by another campaign focussing on climate change, where many of the original messages continued to be addressed. The campaign aimed to inform consumers of energy-saving behaviours. It used television ads, radio ads, billboards, internet ads, ads in movie theatres, ads in the press and also partnered with utilities to include leaflets in bills. Typically the television campaign targeted a specific topic each month. After the general launch at the end of September 2006, ads in November explained the advantages of not consuming electricity during peak time (5-7 p.m.). In early December the ads suggested investing in energy-efficient Christmas lights. The late December and January campaign focused on home heating habits. February aimed to decrease electricity use for lighting, March targeted appliance use, April was dedicated to suggestions for efficient appliance purchases, and May concentrated on how to improve automobile mileage. During July and August a 'reminder' campaign was aired. At the end of September 2007 the campaign entered its second year with a month dedicated to reducing energy use in the office, followed by a focus on lighting use in November and heating habits again around Christmas. Radio ads reinforced the television message, although they typically ran for two weeks while the television campaign ran for 4 weeks at a time. The total cost of the Power of One campaign over the two years was about €3 million.

This study sets out to identify if changes in behaviour are driven by the advertising campaign. We focus on the effects of the campaign on the consumption of natural gas. The main use of natural gas in households is for heating. We therefore limit our attention to the elements of the campaign that targeted heating habits. One module addressed heating specifically and ran on both radio and TV around Christmas in 2006 and again in 2007. This module cost about €109 thousand in the first year, including the cost of about 1220 television spots, and €257 thousand in the second year when about 1700 television ads and 280 radio ads were aired. It was complemented by leaflets enclosed in consumers' February or March natural gas bills (consumers are billed every other month) in both 2007 and 2008. Nearly 90 percent of all natural gas and electricity consumers received the leaflets.

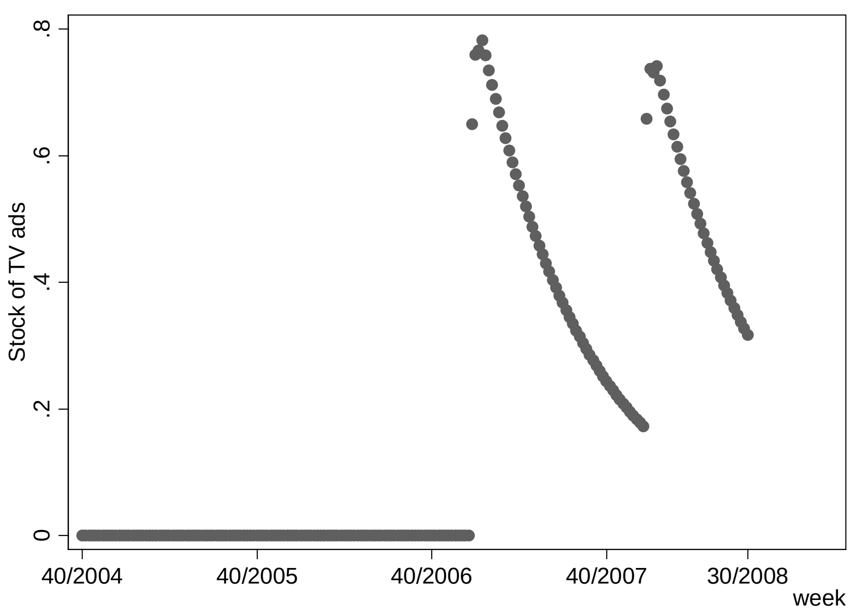
4. Data description

The advertising data variable is based on weekly information of the reach of advertising, that is the percentage of the population reached by the campaign, provided by Cawley Nea/TBWA, the advertising agency that undertook the campaign. The data also specifies the average number of times each person is exposed to the campaign each week. We build an advertising time series that varies between 0 and 1 and is equal to the share of the population that was reached at least three times by the television campaign during the weeks the campaign on heating is active.[2] It depreciates over time at a constant rate. The stock of advertising at time *t* is calculated as the stock of advertising at *(t-1)*, appropriately depreciated, plus any new advertising within the campaign of interest that takes place at time *t*. More formally:

$$A_t = A_{t-1}(1-\delta) + AF_t \qquad (1)$$

where *A* represents the stock of advertisement, δ is the depreciation rate and *AF* is the advertising flow. We are studying the effect of advertising on lowering the thermostat temperature, a behaviour that cannot be repeated indefinitely (Woods, 2008). Reberte et al (1996) also find that, in the New York campaign aimed towards increasing dairy consumption, the second round of advertising was less effective than the first. We therefore allow each year of advertising to have a separate effect on natural gas use. Figure 1 illustrates the pattern in the weekly television advertising stock when the stock depreciates by 80 percent after one year.

Figure 1. Weekly stock of reach of TV campaign on heating



[2] This is based on the established result that the response to advertising levels off after the third exposure (see studies cited in Vakratsas and Ambler, 1999).

In addition to the broadcast ads, consumers received Power of One information leaflets in their February or March natural gas bills. We take this into account by building a dummy variable that is equal to 0.5 for February and March of 2007 and measures the proportion of households reached by the leaflets. The stock for this advertising also depreciates over time. A separate variable is built for the 2008 campaign. The total effect of the advertising campaign is measured by the sum of the television and leaflet variables, the two modes with the highest overall consumer reach. We do not take into account other forms of advertising: internet, movie theatres, radio or billboard.[3] Ads in movie theatres and on billboards are likely to have had limited additional effect. Internet hits grew over the course of the campaign, but the largest number of unique visits to the Power of One website through internet ads was about 12,000 in November 2006, far fewer than those reached by television, radio and leaflets in bills.

Daily natural gas consumption data for the 'Non-daily metered' (NDM) sector comes from Bord Gáis, as does the monthly data on the total number of natural gas customers. We divide total natural gas consumption by the number of customers to obtain consumption per customer. The data runs from October 2004 to the 24th of August 2008, yielding 1425 daily observations. When we aggregate the data by week the number of observations is 203. The main group of consumers in the NDM sector is households, but there are also a few small commercial and industrial businesses. As shown in Table 1, the total number of customers varies between 474 thousand at the beginning of our sample to 614 thousand at the end, a 30 percent increase. Ireland experienced a large increase in housing completions in the period we are studying. This was accompanied by an increase in vacancies. Since this implies that part of the 30 percent increase

[3] The data provide reach for each radio campaign, but not its disaggregation by week. This makes it difficult to build an indicator that is consistent with the television one. The radio ads ran at the same time as the television ads, with a very similar total reach, so we assume it has the same penetration pattern and its effect is captured by the television ad variable. Ads in movie theatres and on billboards are likely to have had limited effect.

in customers could be vacant housing, we also include the average vacancy rate, calculated on a quarterly basis.[4] The weather variables are from the European Climate Assessment and Dataset (Klein Tank et al., 2002). We use the daily temperature and rainfall measurements for Dublin. Using this information we build a time series of heating degree days designed to measure the need for heating for each day. There is one heating degree day if the average temperature is one degree below 15.5 ºC. Colder days are characterised by a larger number of degree days. Since there is a missing observation for the daily temperature this provides 1424 observations. We then calculate the difference between current degree days and their 50-year average and also allow for non-linear effects of weather variables. A detailed description of the weather variables can be found in Appendix A.

Table 1. Summary statistics of daily data

	Obs	Mean	Std. Dev.	Min	Max
Gas Demand (MWh)	1425	32442.52	18702.2	5726.641	74138.38
Personal consumption (million €)†	1425	20965.68	1299.305	18504	22575
Customers	1425	553,479.4	41,081.83	474,364	613,697
Population, thousands	1425	4267.613	108.9763	4089.5	4442.88
degree days	1424	5.70	3.85	0	15.6
50-year avg. degree days	1425	6.37	3.38	1.4	11.2
Rain (0.1 mm)	1425	20.43228	46.32733	0	560
TV advert flow, prop.	1425	0.11	0.87	0	9.29
Leaflet advert flow, prop.	1425	0.14	2.64	0	50
CPI – no energy (2006=100)	1425	99.17	4.54	93.4	106.8
Vacancy rate	1425	14.88	1.66	12.03	16.67
Gas Price (Index, 1995=100)	1425	157.48	26.68	114.1	204.7
Electricity Price (Index, 1995=100)	1425	163.77	11.78	138.9	180.5

† constant 2006 prices

[4] We thank David Duffy for providing us with the vacancy rate on a quarterly basis, first used in the Autumn 2008 issue of the Quarterly Economic Commentary.

Indexes of residential quarterly energy prices for electricity and natural gas come from the International Energy Agency's *Energy prices and taxes* and are then deflated to 2006 euro using the monthly Consumer Price Index (CPI) from the Central Statistics Office (CSO). We use the CPI –excluding energy– to capture the real cost of energy products. As a proxy for income we use information on personal expenditure of goods and services at constant 2006 market prices, available on a quarterly basis from the quarterly national accounts. To determine personal expenditure per capita we use yearly estimates of population from the CSO and interpolate to obtain quarterly values.

We add dummy variables for the day of the week and month of the year, together with dummies for 'special days', including bank holidays, Christmas and the typical holiday period during the first two weeks of August.

In addition to the daily natural gas consumption we have access to data from three face-to-face surveys that were conducted prior to and during the campaign. The first survey dates to September 2006 and the other two were carried out in May 2007 and in November 2007. This allows us to assess the first year of the campaign more thoroughly. These data are described in more detail in section 6.

5. Methodology and results

We assume that the demand for gas depends on several variables:

$$\ln GD_t = \alpha + \sum_n \rho_n \ln GD_{t-n} + \beta_i W_{it} + \gamma \ln X_t + \nu V_t + \vartheta_j \ln P_{jt} + \pi_s A_{st} + \zeta Z_t + \varepsilon_t \quad (2)$$

Where *GD* represents natural gas demand per customer, *W* represents weather variables, such as heating degree days, which measure the expected intensity of heating in each period, the amount of rain, etc. The lagged dependent variable accounts for possible inertia in heating behaviour (it includes both a one period and seven period lag). If the heating was on yesterday it is more likely to be on today (all other things being equal). *I* represents personal expenditure per capita on goods and services, V_t is the housing vacancy rate for Ireland as a whole, $P_j = \{P_{NG}, P_E\}$ is the unit price of natural gas and electricity for households and *t* indexes time. A_s represents the stock of advertisement, $s = \{TV, L\}$ represents either television or direct mail advertising. As mentioned in section 4, we limit our attention to the parts of the campaign that addressed heating behaviour. Finally *Z* includes dummies that pick up the effects of months, holidays and days of the week. The detailed specification of the dummy variables can be found in Appendix A. We correct for heteroscedasticity by using the Huber-White estimator. The log specification allows us to interpret the coefficients as elasticities.

The weather variables are modelled following Conniffe (1996). They are the main determinant of natural gas consumption, explaining more than 90 percent of natural gas variation. We expect γ to be positive, since the amount of natural gas used will grow when disposable income increases. This reflects the fact that as personal consumption per capita (used as a proxy for income) increases there is a tendency to warm homes more and also the longer term effect of the increase in housing sizes (cubic meters).[5] We expect ϑ_{NG} to be negative and ϑ_E to be positive. In many households electricity heating exists in addition to gas heating, so limited switching of heating sources is fairly easy. We expect π_s to be negative denoting a reduction in consumption in line with the increase in energy efficiency advertising. If the two coefficients (for TV ads and leaflets) are jointly significant, we conclude that the campaign has had an effect.

[5] We only have information on the average disposable income per capita for the whole population. We know from the 2004-2005 Household Budget Survey that households with a gas connection have an average disposable income that is 15 percent higher than the general population. We assume that the ratio of personal disposable income per capita of those with a natural gas connection with respect to overall personal disposable income per capita is constant over time.

We do not explicitly take into account the possible effect of other ongoing programs, such as Sustainable Energy Ireland's (SEI) 'Lower Income Housing' program or additional efforts to improve insulation in local authority housing. These programs are unlikely to have a large effect on natural gas consumption for two reasons. First of all, as noted in section 2, lower-income households are less likely to have a natural gas connection. Second, between 2004 and 2007 the SEI program involved 2000 to 3000 dwellings a year (Dáil Éireann, 2007), a number too small to have a measurable effect on aggregate natural gas consumption (the total number of dwellings in the Republic of Ireland is about 2 million).

The 2004-2005 Household Budget Survey (HBS) shows that households spend on average €30.65 per week on fuel, or 4 percent of their total weekly expenditure. Natural gas expenditure is 13 percent of households' fuel expenditure, with the wealthiest decile spending a higher percentage (19 percent) and the lowest decile spending a lower percentage (9 percent).

In Table 2 we present the results for select variables when the dependent variable is the log of daily natural gas consumption per customer for different levels of depreciation of the advertising variable. We estimate the regression with OLS, using the Huber-White correction for heteroskedasticity.[6] Complete results are reported in Appendix B. The first column of Table 2 shows the results when depreciation of advertising is assumed to be 80 percent after 12 months and the second column shows the results when depreciation is 95 percent after 12 months. The third column shows the results for a steeper depreciation rate, such that all the advertising effect is extinguished within 6 months and finally the fourth column assumes that there is no depreciation whatsoever. The assumption of zero depreciation is not realistic, but is included to show how the results would change if the advertising campaign were modelled as a once-off

[6] OLS with lagged dependent variables are consistent as long as there is no residual serial autocorrelation, which is true in this case.

event. Analysing daily consumption allows us to account for special days (holidays, days of week) and for weather variables more precisely. The disadvantage is that the television advertising variable is defined at the weekly level. In order to obtain daily information we need to make additional assumptions on its growth over the week. In the following results we have assumed that the advertising variable changes linearly over the week.

Table 2. Log of daily natural gas consumption per customer

	80%	**95%**	**100%**	**0%**
(Gas Demand)(t-1)	0.74*** (0.02)	0.74*** (0.02)	0.74*** (0.02)	0.74*** (0.02)
(Gas Demand)(t-7)	0.053*** (0.014)	0.052*** (0.014)	0.053*** (0.014)	0.054*** (0.014)
Consumption per capita	0.144 (0.36)	-0.021 (0.38)	-0.134 (0.43)	0.309 (0.35)
Power of One TV – year 1	-0.001 (0.021)	-0.01 (0.022)	0.002 (0.028)	0.001 (0.019)
Power of One TV – year 2	0.033 (0.027)	0.034 (0.029)	0.034 (0.038)	0.031 (0.025)
Power of One leaflet - year 1	-0.034* (0.018)	-0.050** (0.019)	-0.062** (0.027)	-0.015 (0.015)
Power of One leaflet – year 2	-0.002 (0.020)	-0.001 (0.022)	0.013 (0.027)	-0.002 (0.018)
Log of Gas Price	0.010 (0.038)	0.020 (0.036)	0.015 (0.035)	0.002 (0.048)
Log of Electricity Price	0.229 (0.20)	0.264 (0.20)	0.176 (0.20)	0.101 (0.19)
Vacancy rate	-0.014 (0.009)	-0.012 (0.009)	-0.009 (0.009)	-0.016* (0.009)
Weather Variables	Yes***	Yes***	Yes***	Yes***
Dummy Variables	Yes***	Yes***	Yes***	Yes***
Constant	-2.111*** (0.65)	-2.114*** (0.63)	-1.492*** (0.56)	-1.634** (0.64)
Observations	1417	1417	1417	1417
R-squared	0.98	0.98	0.98	0.98

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The results are quite robust for different levels of the depreciation rate (as long as it is not zero). Across all specifications we find a large inertia effect measured by the lagged dependent variable. This suggests that people do not adjust instantly to changes in the outdoor temperature. Personal consumption of goods and services per capita does not have a significant effect on the demand for natural gas, possibly because it varied little during the period and because it might not be representative of the customers we are observing. Consumption per capita went from €4,520 to €5,150 per quarter in real 2006 prices during our sample period, an increase of about 14 percent. We do not have the disaggregation of customers by region and therefore rely on national expenditure information. However, natural gas consumers are not randomly distributed around the country. Historically the bulk of the customers are in the Dublin and Cork area and typically have a higher income. Recently connections have expanded in Western counties, where average income tends to be lower. Since we cannot properly account for this the coefficient on disposable income could be biased. The increase in connections has been large over our sample period, at almost 30 percent. The gas price is not significantly different from zero. This is in line with the general finding that natural gas demand is quite inelastic to price (see e.g. Baker and Blundell, 2001 and Asche et al., 2008). We have estimated the same regression with lagged price variables (lagged one, two or six months) and obtain the same result, probably because nominal prices only change about once a year in our sample period. The electricity price elasticity of natural gas demand is the expected sign, although not significantly different from zero. Again, this continues being the case if we allow for lags of the electricity price.

Our main variables of interest are the advertising variables. The literature suggests that complete depreciation occurs between six months and a little over a year (Schmalensee, 1972; studies cited in Vakratsas and Ambler, 1999). The only advertising variable that had a statistically significant effect is the first year of leaflet advertising. For the 80 percent depreciation rate the result says that for every 10 percent increase in the proportion of people reached by the leaflet ads there is a 0.34 percent reduction in natural gas consumption, increasing to a 0.62 percent reduction for the 100 percent depreciation column. This corresponds to a long run reduction rate of 1.6 percent to

3 percent.[7] This result is robust to different levels of depreciation, although it disappears under the assumption that there is no depreciation. As mentioned earlier the literature suggests that 5 to 20 percent of the power of advertisement persists after one year.

Bord Gais, the local natural gas utility, has reported an ongoing decrease in per-capita natural gas consumption, most likely caused by the uptake of gas connections in second homes and the increase in vacancy rates. We introduce a national level vacancy rate but it turns out to be not significantly different from zero. Again this might be due to the fact that the population of natural gas customers is significantly different from the national average. In particular we would expect a lower uptake of natural gas in second homes, since the cost of dual fuel connection will be larger for many than the additional cost of electricity heating over natural gas heating.

Table 3. Log of weekly gas demand

	80%	**95%**	**100%**	**0%**
Log Gas demand (t-1)	0.313***	0.313***	0.315***	0.310***
	(0.058)	(0.058)	(0.058)	(0.059)
Log consumption per capita	0.327	0.333	0.588	0.406
	(1.018)	(1.079)	(1.068)	(0.885)
	(0.110)	(0.111)	(0.110)	(0.109)
Power of One TV – year 1	-0.016	-0.016	0.003	0.022
	(0.056)	(0.060)	(0.075)	(0.061)
Power of One TV – year 2	0.120	0.118	0.109	0.121*
	(0.079)	(0.081)	(0.084)	(0.072)
Power of One leaflet, year 1	-0.142***	-0.145***	-0.145***	-0.170***
	(0.048)	(0.046)	(0.048)	(0.064)
Power of One leaflet, year 2	-0.059	-0.048	-0.016	-0.091
	(0.057)	(0.061)	(0.064)	(0.057)
Log natural gas price	-0.062	-0.064	-0.073	-0.017
	(0.125)	(0.119)	(0.115)	(0.171)
Log electricity price	0.842	0.807	0.641	0.730
	(0.510)	(0.525)	(0.488)	(0.476)
Vacancy rate	-0.035	-0.035	-0.037	-0.042
	(0.027)	(0.025)	(0.024)	(0.029)
Constant	-5.413***	-5.243***	-4.716***	-5.105***
	(1.640)	(1.612)	(1.418)	(1.616)

[7] In the case of a long-run reduction of 1.6 percent, this is equivalent to a reduction of about a 181 GWh (taken at the mean of natural gas consumption during 2007) on a yearly basis, which is equivalent to a yearly decrease of about 37 thousand tonnes of CO_2, using the emission factors specified in SEI (2008).

Observations	201	201	201	201
R-squared	0.98	0.98	0.98	0.98

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

To check the robustness of the results we aggregate all the variables at the weekly level and then run an OLS regression correcting for heteroskedasticity. This allows us to use 202 observations. Table 3 shows select results. A full table of results can be found in Appendix B. As can be seen, the results are consistent with the daily regression results. The first year of leaflet advertising has a negative and significant effect on natural gas consumption. The implied long run effect of under all depreciation scenarios is a decrease in natural gas use of about 2.1 percent, in line with the 1.6 percent we found for the daily regression results.

As a caveat to these results we note that there is evidence that ‘public good’ campaigns take decades rather than years to have an impact on behaviour. An example is the ‘participACTION’ campaign in Canada that ran from 1971 to 2001 and aimed to increase the population’s participation in physical activity (Bauman et al, 2004). Since the natural gas consumption data spans less than four years, we are not able to asses its long-term impact. In the next section we use individual level data to identify not only self-reported changes in behaviour, but also changes in attitudes towards energy efficiency issues.

5. Survey description and results

In addition to the data on daily consumption of natural gas we have access to data from three face-to-face surveys that were conducted prior to and during the campaign. The first survey dates to September 2006 and the other two were carried out in May 2007 and in November 2007. This allows us to assess the first year of the campaign. Each survey had about 1000 respondents, chosen to be representative of Ireland’s households with respect to area of residence, gender and age distribution. The surveys asked about general interest in energy efficiency, awareness of the effects of specific behaviours and about how people actually behaved.

In this section we first address changes in the general attitude towards energy efficiency and then analyse the change in self-reported energy saving behaviour and in the awareness of the savings that can arise from such behaviour. Since we are interested in the effect of the campaign on natural gas use, we limit our attention to the elements of the campaign that targeted heating habits. Specifically there was one question in the survey that asked respondents if they were aware that decreasing the thermostat setting by one degree Celsius could lead to savings of up to 10 percent. The response to this question forms the awareness variable we analyse below. Another question asked people if they actually turn down the thermostat in order to save on the heating bill. This forms our 'behaviour' variable.

Table 4 presents summary statistics for the sample, disaggregated by survey wave. General interest in energy efficiency (defined as either high or some interest in energy efficiency) reaches 79 per cent in the second survey and does not change in the third. There is no clear trend during the sample period for people who have a high interest in energy efficiency. Awareness of the effect of reducing the temperature on heating bills increases over time. Changes in behaviour (reports of an actual decrease in the thermostat setting) are more difficult to evaluate since in the first survey this question is asked only of the customers who report awareness of the issue. We address this in more detail later. About 25 per cent of the sample uses natural gas for home-heating.[8] The share is slightly higher in the survey taken in November 2007.

The age of the respondents and the area where they live are roughly in line with Census 2006 figures (CSO, 2007), although rural areas are somewhat overrepresented, as are residents of

[8] This is a slight underestimation since only those uniquely or jointly responsible for paying natural gas bills are classified as natural gas users.

Munster. The sample somewhat underrepresents the higher social classes (managerial and professional) with respect to the 2006 Census. Apartment dwellers are also underrepresented, as is usually the case in face-to-face interviews in Ireland due to the difficulty in gaining access to apartment buildings. There are 32 unclassified observations for the type of housing and we drop those observations from the analysis.

Table 4. Survey, summary statistics by survey date

	First survey Sep. 2006		**Second survey May 2007**		**Third survey Nov. 2007**	
	Obs	Mean	Obs	Mean	Obs	Mean
Awareness	1077	.61	937	.68	989	.72
Change behaviour	653	.60	1050	.44	1003	.50
Efficiency interest	1070	.73	1041	.79	1003	.79
Efficiency interest-high	1070	.27	1041	.26	1003	.30
Natural gas payer	1095	.25	1050	.25	1003	.30
Age 15-17	1095	.10	1050	.07	1003	.05
Age 18-24	1095	.11	1050	.11	1003	.10
Age 25-34	1095	.20	1050	.20	1003	.21
Age 35-44	1095	.19	1050	.19	1003	.23
Age 45-54	1095	.14	1050	.13	1003	.17
Age 55-64	1095	.12	1050	.14	1003	.13
Age 65 +	1095	.13	1050	.17	1003	.12
Class – AB (Professional & Managerial)	1095	.07	1050	.08	1003	.07
Class - C1 (White collar)	1095	.31	1050	.32	1003	.34
Class – C2 (Skilled manual)	1095	.25	1050	.23	1003	.27
Class – DE (unskilled manual & other)	1095	.27	1050	.28	1003	.23
Class - Farmer	1095	.10	1050	.09	1003	.09
Male	1095	.48	1050	.50	1003	.49
Female	1095	.52	1050	.50	1003	.51
Dublin	1095	.28	1050	.29	1003	.28
urban Leinster	1095	.11	1050	.10	1003	.14
Rural Leinster	1095	.15	1050	.12	1003	.12
Munster - Cork	1095	.09	1050	.10	1003	.06
Urban Munster	1095	.06	1050	.07	1003	.10
Rural Munster	1095	.13	1050	.13	1003	.12
Urban other	1095	.05	1050	.05	1003	.06
Rural other	1095	.14	1050	.13	1003	.13
Total rural	1095	.41	1050	.38	1003	.36
Apartment	1086	.02	1045	.04	981	.03
Detached	1086	.41	1045	.32	981	.38

Semidetached	1086	.38	1045	.43	981	.36
Terrace	1086	.19	1045	.21	981	.23
Other house	1086	.01	1045	.01	981	.00

Energy Efficiency

We estimate the probability of being interested in energy efficiency given a person's characteristics and the general environment the person lives in. In more formal terms we calculate the probability that there is an interest in energy efficiency ($EE_i = 1$) as follows:

$$prob(EE_i^j = 1) = F(\mathbf{Z}_i \boldsymbol{\beta}) \qquad (3)$$

where EE_i represents the interest in energy efficiency of person *i*, the index *j ={high; at least some}* indicates the level of interest and $\boldsymbol{Z_i}$ represents the variables that influence such interest for person *i*, including the Power of One campaign.

If energy expenses are a large proportion of total household expenses there is a higher incentive to be well informed about energy efficiency and reduce costs. This may be the case for low-income households or for households with large energy expenses (perhaps because they live in a large dwelling). On the other hand we expect that individuals in higher social classes are more likely to have a higher education level and be more informed about energy efficiency issues. The coefficient on social class will grow if the education effect is stronger than the income effect and decrease otherwise. We also expect people with larger homes to be more interested in energy efficiency since larger homes imply larger energy expenditures. Finally we expect the Power of One campaign to have increased interest and awareness of energy efficiency issues. We control for other characteristics such as age, gender and area of residence of the respondent. To summarise, we estimate the following probit equation:

$$EE_i^j = \alpha + \beta H_i + \gamma Y_i + \varphi S_i + \kappa G_i + \rho A_i + \tau T_i + \varepsilon \qquad (4)$$

Equation (4) assumes that being interested in energy efficiency *(EE)* for person *i* is a function of the type of house one resides in, *H*, a person's age *Y*, social class *S*, gender *G*, area of residence *A* and the time of the interview *T*. The superscript *j ={high; at least some}* indicates the level of interest.

Table 5. Interest in energy efficiency

	High interest	High interest	At least some interest	At least some interest
Wave 2 – May 2007	-0.0199 (0.0195)	-0.0197 (0.0195)	0.0547*** (0.0174)	0.0552*** (0.0174)
Wave 3 – Nov. 2007	0.0093 (0.0199)	0.0091 (0.0199)	0.0403** (0.0179)	0.0391** (0.0179)
Gas bill payer		0.0085 (0.0236)		0.0304 (0.0218)
Detached	0.0445 (0.0536)	0.0447 (0.0536)	0.1009** (0.0410)	0.1120*** (0.0408)
Semidetached	0.0288 (0.0513)	0.0281 (0.0513)	0.1040*** (0.0402)	0.1033** (0.0401)
Terrace	-0.0049 (0.0520)	-0.0057 (0.0520)	0.0583 (0.0398)	0.0568 (0.0399)
Other house	-0.0962 (0.1122)	-0.0960 (0.1122)	0.0850 (0.0765)	0.0853 (0.0763)
Age 15-17	-0.2316*** (0.0182)	-0.2309*** (0.0185)	-0.3332*** (0.0433)	-0.3243*** (0.0438)
Age 18-24	-0.1781*** (0.0221)	-0.1775*** (0.0222)	-0.1797*** (0.0374)	-0.1754*** (0.0374)
Age 25-34	-0.0786*** (0.0256)	-0.0787*** (0.0256)	-0.0020 (0.0268)	-0.0027 (0.0268)
Age 35-44	-0.0072 (0.0278)	-0.0077 (0.0278)	0.1043*** (0.0227)	0.1027*** (0.0228)
Age 45-54	-0.0188 (0.0287)	-0.0188 (0.0287)	0.0673*** (0.0249)	0.0670*** (0.0249)
Age 55-64	-0.0209 (0.0295)	-0.0208 (0.0295)	0.0499* (0.0261)	0.0502* (0.0260)
Class – AB (Professional&Managerial)	0.1669*** (0.0390)	0.1667*** (0.0390)	0.1001*** (0.0235)	0.0996*** (0.0235)
Class - C1 (White collar)	0.1238*** (0.0239)	0.1233*** (0.0239)	0.1274*** (0.0174)	0.1262*** (0.0175)
Class – C2 (Skilled manual)	0.0919*** (0.0255)	0.0917*** (0.0255)	0.0886*** (0.0183)	0.0880*** (0.0183)
Class - Farmer	0.0359 (0.0365)	0.0355 (0.0365)	0.0616** (0.0264)	0.0610** (0.0265)
Female	0.0353** (0.0161)	0.0352** (0.0161)	0.0322** (0.0152)	0.0315** (0.0152)
Area dummies	Yes***	Yes***	Yes***	Yes**

Pseudo R-sq	0.0539	0.0539	0.100	0.101
Observations	3080	3080	3080	3080

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Coefficients measure marginal effects

We estimate a probit on the 3080 observations available. Table 5 reports the results.[9]

The coefficients reported are marginal effects and measure the percentage change in interest in energy efficiency when the explanatory variable goes from 0 to 1.

The first two columns present the results when the dependent variable is the probability of having a high interest in energy efficiency. Higher social classes are more likely to be highly interested in energy efficiency, which suggests that the education effect dominates the income effect in this case. The reference social class is lower skilled and unemployed. The reference age group is 65 years and over. Younger age groups (up to age 34) are substantially less likely to have a high interest in energy efficiency (23 percent less likely for the 15-17 age group). This is probably driven by the fact that younger people tend to live with their parents and have a smaller incentive to save. This suggests information on energy efficiency is not widely distributed at secondary school or college. Females are about 3 percent more likely than males to have a high interest in energy efficiency. Respondents who pay for natural gas bills are not significantly different from the rest of the population, as shown in the second column of Table 4. Finally, the Power of One campaign has not affected the likelihood that people have a high interest in energy efficiency.

Columns 3 and 4 of Table 5 display the results when the dependent variable is any interest in energy efficiency (i.e. those who declared to have either a high or at least some interest in energy efficiency). Columns 3 and 4 of Table 5 show that the larger the house the more likely people are

[9] Estimating the regression with a logit does not change the results. The Hosmer-Lemeshow test (Hosmer and Lemeshow, 1989), which measures the fit of the model by decile, shows that the model fits the data well.

to be interested in energy efficiency, as expected. The age group that is most likely to have at least some interest in energy efficiency is the 35-44 group. As before, the unskilled workers and unemployed (and males in general) are the least likely to be interested in energy efficiency. As column 4 reveals there is no additional effect from being a natural gas bill payer.[10] The results show that the Power of One campaign had a positive effect on having at least some interest in energy efficiency. There is no statistical difference between the second and the third survey and they both increase the probability of being interested by about 4 percent. We conclude that the campaign shifted consumers from being neutral to energy efficiency issues to being somewhat interested. The estimates on the Power of One variable might be overstating its effect slightly: during this period energy prices had been rising, which could have independently increased the interest in energy efficiency. Unfortunately we cannot control for this directly since the data do not allow us to identify the price effect separately from the Power of One effect.

AWARENESS

We then move on to consider how the measure of awareness has changed with the Power of One campaign. There might be some unobserved characteristics of respondents that make them more likely to be aware of issues related to heating efficiency and these might change over time. We are able to control for this by including a dummy variable that is 1 for people who have a high interest in energy efficiency. We estimate the following probit equation:

$$A_i = \alpha + \beta H_i + \gamma Y_i + \varphi S_i + \kappa G_i + \rho A_i + \tau T_i + EE_i^{H} + \varepsilon \quad (5)$$

[10] If we do not include area dummies being a gas bill payer increases the likelihood of having some interest in energy efficiency by about 4 percent. This depends on the fact that gas connections in Ireland are unevenly distributed across the country and therefore the probability of having a gas connection depends strongly on where one lives. We should note that these results are fairly robust: the coefficients of all other variables are virtually unaffected by the inclusion of area dummies instead of the natural gas bill paying variable, or for that matter including both of them.

Awareness of the fact that lower thermostat settings lead to lower heating costs depends on the type of housing *H*, the age of the respondent *Y*, social class *S*, area of residence *A* and time of the survey *T*. As before we expect that larger houses will induce a higher awareness. We do not have a prior on how age, social class or area of residence will affect awareness of this specific issue. We expect that people with a high level of interest in energy efficiency (EE^H) will be more aware and that the Power of One campaign will increase awareness. The subscript *i* indexes the respondent.

Unfortunately the wording of the question we use for awareness has changed over time. In the first survey awareness of the issue was couched in a general context:

> *I am going to read out some other energy saving tips. Please tell me which, if any, you are aware of already:*
> *Turn the heat down by 1˚C to save up to 10% off heating bill*

Respondents were allowed to answer either “Yes” or “No” to this question.

Subsequent surveys linked the question the ongoing advertising campaign:

> *Which of the following suggestions do you remember from the Power of One campaign?*
> *Turn the heat down by 1˚C to save up to 10% off heating bill*

In this case respondents could choose amongst more answers: “I remember that suggestion very clearly”; “I vaguely remember that suggestion”; “I don’t remember that suggestion at all”. For the second and third surveys we classify a respondent as being ‘not aware’ if he or she answers “I don’t remember that suggestion at all” and ‘aware’ otherwise. The results are presented in Table 5 using the 2942 available observations. Awareness of the issue increased by about 8 percent in May 2007 and a further 9 percent by November 2007.

BEHAVIOUR

We are also able to assess if the first year of the Power of One campaign has affected self-reported behaviour. However, as in our analysis of awareness, the wording of the question has changed. In September 2006 it was the following:

September 2006 *(Ask for each aware)*
Which, if any, do you tend do to?
Turn the heat down by 1˚C to save up to 10% off heating bill

The answer could be either "Yes" or "No". In May and November 2007 the question specifically referred to the advertising campaign:

May & November 2007 *(Ask all)*
This advertising campaign has been running since September 2006. It has featured a number of specific recommendations. I am going to read out these to you and for each one I would like you to tell me which of the phrases on this card best summarises how you feel about each of those suggestions?

Turn the heat down by 1˚C to save up to 10% off heating bill

Respondents could answer "I was doing that regularly before the campaign started"; "I have been doing that much more often since the campaign started"; "I have been doing that a little more often since the campaign started"; "I have done nothing about that".

The behaviour variable is set to 0 if the respondent answers that they do not turn down the heat by 1 degree Celsius in order to save up to 10 percent off heating bill (September 2006) or if they answer that they have done nothing about turning down the heat (May and November 2007). For all other answers it takes the value of 1.

It is important to note that in the first survey the behaviour question was asked only of those who declared to be aware of the issue, whereas in subsequent surveys it was asked of all respondents. If people who are aware are for some reason different from the general population, for example because they are more tuned in to environmental issues, this means that the subsection of the population in the first survey is more likely to report decreases in the use of heating. In this case using the whole population in the later surveys would introduce a (downward) bias in the percentage of people who report changing their behaviour. We therefore only use observations for people who declared to be aware across the three surveys. This reduces the sample size from 2942 observations to 2089.

$$B_i = \alpha + \beta H_i + \gamma Y_i + \varphi S_i + \kappa G_i + \rho A_i + \tau T_i + EE_i^{H} + \varepsilon \qquad (6)$$

B_i is the change in behaviour variable. It is 1 if the respondent answers that they have turned down the thermostat and 0 otherwise. Energy-saving behaviours tend to decrease with income since their opportunity cost is lower and increase with the size of homes as shown in Reiss and White (2008). On the basis of the results reported in Table 5 having a high interest in energy efficiency is not affected by the Power of One campaign. This allows us to use the variable as an independent measure of pre-survey attitudes towards environmental issues.

Table 6 displays the results for the awareness regression specified in equation (5) and the behaviour regression presented in equation (6). When analysing the effect on awareness we use the 2942 available observations. Awareness of the need to control the thermostat in order to reduce heating bills increased by about 8 percent in May 2007 and a further 9 percent by November 2007. Other variables have similar effects on awareness as they did on energy efficiency interest. Higher social classes tend to display larger awareness, whereas the younger segment of the population is less aware. Those who pay natural gas bills are not significantly different from the rest of the population, as shown in the second column of Table 6. As in the previous model, a Homer-Lemeshow test finds that the model fits the data well.

The results are quite different for self-reported behaviour. In this case the Power of One exhibits no positive effect. In fact when calculating the behavioural effect of the Power of One campaign it appears to be zero or negative. This is still the case if we control for there being differing numbers of people with a high interest in efficiency or different numbers of people who heat their house with natural gas. Natural gas paying consumers appear much more likely to lower their thermostat. In part this might be due to their greater likelihood of having central heating in the first place.

TABLE 6. Effects of campaign on self-reported awareness and behaviour

	Awareness	Awareness	Behaviour	Behaviour
Wave 2 – May 2007	0.0843*** (0.0206)	0.0846*** (0.0206)	-0.0481* (0.0275)	-0.0472* (0.0276)
Wave 3 – Nov. 2007	0.0981*** (0.0205)	0.0978*** (0.0205)	0.0028 (0.0277)	0.0005 (0.0278)
Gas bill payer		0.0130 (0.0263)		0.0673** (0.0315)
Detached	0.1184** (0.0519)	0.1191** (0.0519)	-0.0755 (0.0764)	-0.0794 (0.0764)
Semidetached	0.0741 (0.0513)	0.0737 (0.0513)	-0.0786 (0.0742)	-0.0871 (0.0743)
Terrace	0.0429 (0.0523)	0.0421 (0.0523)	-0.1032 (0.0774)	-0.1139 (0.0775)
Other house	-0.0315 (0.1314)	-0.0315 (0.1314)	-0.0374 (0.2009)	-0.0473 (0.2014)
Age 15-17	-0.1572*** (0.0439)	-0.1541*** (0.0443)	-0.3239*** (0.0551)	-0.3123*** (0.0564)
Age 18-24	-0.0983** (0.0386)	-0.0967** (0.0387)	-0.1221** (0.0502)	-0.1132** (0.0505)
Age 25-34	0.0843*** (0.0292)	0.0841*** (0.0292)	-0.0185 (0.0402)	-0.0188 (0.0402)
Age 35-44	0.0999*** (0.0288)	0.0992*** (0.0288)	0.0380 (0.0392)	0.0347 (0.0393)
Age 45-54	0.1196*** (0.0289)	0.1196*** (0.0289)	0.0636 (0.0401)	0.0634 (0.0401)
Age 55-64	0.0832*** (0.0307)	0.0834*** (0.0307)	-0.0120 (0.0431)	-0.0110 (0.0431)
Class – AB (Professional & Managerial)	0.0902*** (0.0337)	0.0899*** (0.0337)	0.0640 (0.0432)	0.0643 (0.0432)
Class - C1 (White collar)	0.0854*** (0.0227)	0.0847*** (0.0228)	0.0477 (0.0303)	0.0461 (0.0303)
Class – C2 (Skilled manual)	0.0760*** (0.0237)	0.0757*** (0.0237)	0.0637** (0.0315)	0.0654** (0.0315)
Class – Farmer	0.0159 (0.0358)	0.0154 (0.0358)	-0.0119 (0.0466)	-0.0119 (0.0465)
Female	0.0066 (0.0178)	0.0065 (0.0178)	0.0027 (0.0221)	0.0019 (0.0221)
High interest in energy	0.1511***	0.1510***	0.1399***	0.1394***

efficiency	(0.0188)	(0.0188)	(0.0230)	(0.0230)
Area dummies	Yes***	Yes***	Yes***	Yes**
Observations	2942	2942	2089	2089
Pseudo R-squared	0.0805	0.0806	0.0520	0.0535

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Coefficients measure marginal effects

Since it is hard to believe that advertising for energy efficiency would actually decrease the likelihood that people decrease the use of natural gas we conclude that the decrease is due to one of two reasons. The first is that decreasing the thermostat setting is a behaviour that cannot be repeated more than a few times. As argued by Woods (2008) prompting this behaviour over time is unlikely to lead to larger and larger savings. The second could simply be the change in the wording of the survey. It made people much more likely to report that they were saving in the first survey rather than in subsequent surveys, where the savings were directly linked to the advertising campaign.

We have also run the results limiting the observations to those who pay natural gas bills and the results (not reported) remain the same.

6. Conclusion

In this paper we study the effect of the Power of One campaign on natural gas consumption. We start by analysing daily and weekly consumption of natural gas in the Non-Daily Metered sector in Ireland during and following a national energy efficiency campaign. Our results show that the first year Power of One leaflets were included in customers' bills they helped reduce consumption by a long-run equivalent of about 1.6 – 2.1 percent. There are no further effects in the second year. In addition the results do not show any significant effect of the TV campaign, either in its first or in its second year.

We also use a series of three surveys administered to 1000 people each before and during the campaign. We find that interest in energy efficiency and awareness of the size of savings that can be reaped by decreasing the thermostat setting has significantly increased after the campaign. On the other hand, self-reported heating behaviour has not become more efficient after the first year of the campaign.

There are a couple of caveats to our results. First, questions in the surveys vary over time, which potentially introduces biases that we are unable to account for. Second, large 'public good' campaigns may take decades, rather than years, to attain their goals. These types of campaigns and their effects are typically extremely difficult to measure. A couple of examples are the health campaign in Canada and the 'drink milk' campaigns in the US that have been running –on and off– for several decades, although Reberte et al (1996) find that a second wave of the 'drink milk' campaign in New York had a smaller effect than the first one, which is in line with the general finding that the effect of advertising tends to decrease as the campaign becomes longer (e.g. studies cited in Vakratsas and Ambler, 1999).

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Appendix A

This appendix gives details on the specification of the effect of weather variables and dummy variables (and their interaction) on natural gas consumption.

$$\sum W_{it} = LRDD_t + DDif_t + \left(DDif_t\right)_2 + \left(DD_t * LRDD_t\right) + (DD_t - \sum_{k=1}^{13} (1/2)^k \cdot DD_{t-1}) + R_t \quad (1A)$$

Where DD represents degree days, DDif is the difference between the current degree days and their 50 year average (LRDD) and R is the amount of daily rainfall. A more thorough explanation of the variables follows.

Degree Days (DD)

Degree Days provide a measure of the impact of temperature on heating or cooling requirements. When the average daily temperature is one degree below the base temperature (15.5 ºC here) this is defined as one heating degree day. We use the daily average between the minimum and maximum temperature as recorded for Dublin in the European Climate Assessment and Dataset (Klein Tank et al.). We take the temperature for Dublin as it is the area with the highest population density in Ireland.

Long Run Degree Days (LRDD)

While current temperatures are of undoubted importance it is also likely that expected temperatures will impact on the use of heating. Some of this effect could be captured using lagged temperature variables but there will be an additional effect caused by expectations and habits built up over years. We account for this by including a long run temperature variable. This variable is constructed by calculating the average degree days on a calendar day over the previous 50 years. Even over the course of 50 years it is still possible that a particularly cold or hot day could distort the results. To correct for this, the 11 – day average (centred on the current day) is taken to smooth the data. Since the data on temperature for January 1965 are missing, we calculate the 49 year average for each day in January.

The actual degree days on a given day enters the model as the difference between the current degree days and the smoothed 50 year average degree days: $DDif_t = (DD_t - LRDD_t)$.

Lagged Degree Days Measure

The effect on current gas demand of the temperatures in recent days is captured using the following measure:

Lagged Temperature Measure = ½ DD_{t-1} + ¼ DD_{t-2}+ 1/8 DD_{t-3} + …+ (1/8192) DD_{t-13}

Where DD_{t-n} refers to the number of degree days at time (t-n). Thus the impact of a days' temperature on gas demand declines as time passes.

Interaction between current and long run degree days

Reaction to a particularly cold day may differ at different times of the year. It may be the case that a cold day in the summer may not result in the same heating response as a similar day in the spring or autumn. Consequently an interaction term between the long and short run temperature is introduced.

Non linear Degree Days Measure $(DDif_t)_2 = (DD_t - LRDD_t)_2$

It may not be reasonable to believe that 1 degree day increase when it is already cold will have the same impact as would otherwise be the case. To take account of this non – linear impact of temperature a variable is added which is equal to zero if the temperature is below a threshold (7.5 degree days) and is equal to DIFDD otherwise.

Rain

While the reason for the impact of temperature on gas use is clear, it is not so obvious for rain. There may be an effect of the rain on need for heating for drying purposes, or else the effect may be largely psychological, however whatever the cause the rain variable has repeatedly shown a high level of significance so it has been included. The rain variable is set equal to the amount of rain that fell in Dublin on a particular day, provided the degree days are greater than 0. Thus rain is not expected to have an influence on a warm day but may have if the day is cold.

Dummy variables in regression for daily consumption of natural gas

$$Z_t = \left\lfloor WD_{it}; M_{jt}; C_t; B_t; \left(WD_{kt} * LRDD_t\right)\right\rfloor \quad (2A)$$

WD represents the day of the week (where 1 = Monday, and Friday is the reference day), M represents the month of the year (July is the reference month), C is equal to one for the two weeks of Christmas and is zero otherwise, B is one if a day is a bank holiday. Finally, Saturday and Sunday (k = 6, 7) are interacted with the 50 year average degree days to capture possible day-specific reactions to weather changes. Other weekdays interactions are not significantly different from the reference case (the interaction with Friday).

Appendix B

Table 2, complete: Log of daily natural gas consumption per customer

COEFFICIENT	80%	95%	100%	0%
Log Gas demand (t-1)	0.741***	0.740***	0.744***	0.744***
	(0.020)	(0.020)	(0.020)	(0.020)
Log Gas demand (t-7)	0.0526***	0.0517***	0.0528***	0.0540***
	(0.014)	(0.014)	(0.014)	(0.014)
Log consumption per capita	0.144	-0.0207	-0.134	0.309
	(0.36)	(0.38)	(0.43)	(0.35)
Long Run Degree Days (LRDD)	0.0285***	0.0290***	0.0282***	0.0277***
	(0.0058)	(0.0057)	(0.0058)	(0.0058)
Degree Days - LRDD	0.0322***	0.0321***	0.0313***	0.0317***
	(0.0050)	(0.0050)	(0.0050)	(0.0050)
(Degree Days – LRDD)-nonlinear	-0.000158	-0.000341	-0.000183	0.000169
	(0.0024)	(0.0024)	(0.0024)	(0.0024)
Degree Days * LRDD	-0.00233***	-0.00231***	-0.00224***	-0.00230***
	(0.00046)	(0.00046)	(0.00046)	(0.00046)
Degree Days – 13day moving	0.0192***	0.0192***	0.0194***	0.0193***
average DD	(0.0020)	(0.0020)	(0.0020)	(0.0020)
rainfall	0.000529***	0.000530***	0.000528***	0.000526***
	(0.000085)	(0.000085)	(0.000085)	(0.000085)
Saturday	-0.113***	-0.113***	-0.113***	-0.113***
	(0.019)	(0.019)	(0.019)	(0.019)
Sunday	-0.114***	-0.114***	-0.114***	-0.113***
	(0.019)	(0.019)	(0.019)	(0.019)
Saturday * LRDD	0.00593***	0.00594***	0.00594***	0.00593***
	(0.0021)	(0.0021)	(0.0021)	(0.0021)
Sunday * LRDD	0.00883***	0.00885***	0.00882***	0.00880***
	(0.0020)	(0.0020)	(0.0020)	(0.0020)
Bank holiday dummy	-0.0618***	-0.0618***	-0.0615***	-0.0615***
	(0.014)	(0.014)	(0.013)	(0.013)
Christmas dummy	-0.0208	-0.0210	-0.0211	-0.0206
	(0.014)	(0.014)	(0.014)	(0.014)
January	0.0804*	0.0786*	0.0823*	0.0841*
	(0.046)	(0.045)	(0.046)	(0.046)
February	0.0846*	0.0848*	0.0887**	0.0856*
	(0.044)	(0.044)	(0.044)	(0.045)
March	0.105***	0.107***	0.108***	0.103***
	(0.038)	(0.038)	(0.038)	(0.038)
April	0.0805**	0.0812***	0.0801**	0.0793**
	(0.031)	(0.031)	(0.031)	(0.031)
May	0.0433*	0.0433*	0.0427*	0.0430*
	(0.023)	(0.023)	(0.023)	(0.023)
June	0.00460	0.00418	0.00469	0.00532
	(0.016)	(0.016)	(0.016)	(0.016)
August	0.0189	0.0185	0.0190	0.0196
	(0.013)	(0.013)	(0.013)	(0.013)
September	0.0700***	0.0685***	0.0694***	0.0722***
	(0.017)	(0.017)	(0.017)	(0.017)
October	0.132***	0.131***	0.128***	0.131***
	(0.024)	(0.024)	(0.024)	(0.025)
November	0.130***	0.128***	0.125***	0.129***
	(0.037)	(0.037)	(0.037)	(0.038)
December	0.103**	0.101**	0.0991**	0.103**
	(0.043)	(0.042)	(0.042)	(0.043)
Power of One TV – year 1	-0.00893	-0.00968	0.00182	0.000790
	(0.021)	(0.022)	(0.028)	(0.019)
Power of One leaflet, year 1	-0.0337*	-0.0496**	-0.0617**	-0.0145

	(0.018)	(0.019)	(0.027)	(0.015)
Power of One TV, year 2	0.0331	0.0340	0.0344	0.0305
	(0.027)	(0.029)	(0.038)	(0.025)
Power of One leaflet, year 2	-0.00180	-0.000853	0.0130	-0.00245
	(0.020)	(0.022)	(0.027)	(0.018)
Log natural gas price	0.0104	0.0196	0.0152	0.00242
	(0.038)	(0.036)	(0.035)	(0.048)
Log electricity price	0.229	0.264	0.176	0.101
	(0.20)	(0.20)	(0.20)	(0.19)
Monday	0.0906***	0.0905***	0.0909***	0.0910***
	(0.0095)	(0.0095)	(0.0095)	(0.0096)
Tuesday	0.0102	0.0102	0.0102	0.0103
	(0.0086)	(0.0086)	(0.0086)	(0.0086)
Wednesday	-0.00272	-0.00280	-0.00286	-0.00266
	(0.0089)	(0.0089)	(0.0089)	(0.0090)
Thursday	0.00305	0.00305	0.00309	0.00305
	(0.0090)	(0.0090)	(0.0090)	(0.0090)
Vacancy rate	-0.0142	-0.0121	-0.00912	-0.0163*
	(0.0089)	(0.0088)	(0.0093)	(0.0093)
Constant	-2.111***	-2.114***	-1.492***	-1.634**
	(0.65)	(0.63)	(0.56)	(0.64)
Observations	1417	1417	1417	1417
R-squared	0.98	0.98	0.98	0.98

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 3, complete; Log of weekly natural gas consumption per customer

COEFFICIENT	80%	95%	100%	0%
Log Gas demand (t-1)	0.313***	0.313***	0.315***	0.310***
	(0.058)	(0.058)	(0.058)	(0.059)
Log consumption per capita	0.327	0.333	0.588	0.406
	(1.018)	(1.079)	(1.068)	(0.885)
Long Run Degree Days (LRDD)	0.003	0.003	0.003	0.003
	(0.007)	(0.007)	(0.007)	(0.007)
Degree Days - LRDD	0.030***	0.030***	0.030***	0.029***
	(0.005)	(0.005)	(0.005)	(0.005)
(Degree Days – LRDD)-nonlinear	-0.007	-0.007	-0.007	-0.007
	(0.005)	(0.005)	(0.005)	(0.005)
Degree Days * LRDD	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Degree Days – 13day moving average DD	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Rainfall	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Christmas dummy	-0.037	-0.037	-0.038	-0.042
	(0.029)	(0.029)	(0.029)	(0.029)
Bank holiday dummy	-0.031	-0.031	-0.032	-0.031
	(0.022)	(0.022)	(0.022)	(0.022)
Winter	0.787***	0.784***	0.781***	0.774***
	(0.227)	(0.228)	(0.227)	(0.225)
Spring	-0.238	-0.238	-0.239	-0.234
	(0.164)	(0.164)	(0.164)	(0.163)
Autumn	0.102	0.101	0.101	0.106
	(0.110)	(0.111)	(0.110)	(0.109)

Power of One TV – year 1	-0.016	-0.016	0.003	0.022
	(0.056)	(0.060)	(0.075)	(0.061)
Power of One TV – year 2	0.120	0.118	0.109	0.121*
	(0.079)	(0.081)	(0.084)	(0.072)
Power of One leaflet, year 1	-0.142***	-0.145***	-0.145***	-0.170***
	(0.048)	(0.046)	(0.048)	(0.064)
Power of One leaflet, year 2	-0.059	-0.048	-0.016	-0.091
	(0.057)	(0.061)	(0.064)	(0.057)
Log natural gas price	-0.062	-0.064	-0.073	-0.017
	(0.125)	(0.119)	(0.115)	(0.171)
Log electricity price	0.842	0.807	0.641	0.730
	(0.510)	(0.525)	(0.488)	(0.476)
Vacancy rate	-0.035	-0.035	-0.037	-0.042
	(0.027)	(0.025)	(0.024)	(0.029)
Quarter 1 dummy	0.125**	0.126**	0.129**	0.117**
	(0.057)	(0.056)	(0.055)	(0.056)
Quarter 2 dummy	0.074	0.075	0.077	0.070
	(0.051)	(0.051)	(0.050)	(0.050)
Quarter 4 dummy	0.171***	0.170***	0.165***	0.167***
	(0.055)	(0.055)	(0.055)	(0.055)
Winter * LRDD	0.001	0.001	0.001	0.001
	(0.007)	(0.007)	(0.007)	(0.007)
Spring * LRDD	0.017**	0.017**	0.017**	0.017**
	(0.008)	(0.008)	(0.008)	(0.008)
Autumn * LRDD	0.011	0.011	0.011	0.011
	(0.007)	(0.007)	(0.007)	(0.007)
Constant	-5.413***	-5.243***	-4.716***	-5.105***
	(1.640)	(1.612)	(1.418)	(1.616)
Observations	201	201	201	201
R-squared	0.98	0.98	0.98	0.98

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

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