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Demand-side management by electric utilities in Switzerland: Analyzing its impact on residential electricity demand *

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Abstract

In this paper we use panel data from a survey conducted on 30 Swiss utilities to estimate the impact of demand-side management (DSM) activities on residential electricity demand using DSM spending and an energy efficiency score. Using the variation in DSM activities within utilities and across utilities over time we identify the impact of these programs and find that their presence reduce per customer residential electricity consumption by around 5%. If we consider monetary spending, the effect of a 10% increase in DSM spending causes around a 0.14% reduction in per customer residential electricity consumption. The cost of saving a kilowatt hour is around CHF 0.04 while the average cost of producing and distributing electricity in Switzerland is around CHF 0.18 per kilowatt hour. We conclude that current DSM practices in Switzerland have a statistically significant effect on reducing the demand for residential electricity.

Keywords: Residential electricity; demand-side management; energy efficiency score; difference-in-differences; Switzerland.

JEL Classification Codes: C33, C36, Q41, Q48.

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1 Introduction

Increasing energy efficiency in recent years has been a part of the strategy of many industrialized nations to reduce the emissions of greenhouse gases, the leading cause of climate change. However, policies to increase energy efficiency have been promoted since the oil crises of the 1970s. Energy efficiency policies have also been promoted to reduce air pollution from pollutants such as sulfur dioxide, nitrogen oxides, ozone and particulate matter, to improve energy security and to prevent the need for constructing increasingly expensive new power plants. The World Energy Outlook 2009 (International Energy Agency, 2009) and several other studies (Creyts et al., 2007; Granade et al., 2009; Nauclér and Enkvist, 2009) highlight the huge potential of CO_2 reductions from increased end-use energy efficiency. In view of these advantages of energy efficiency, policy instruments that promote the increase in energy efficiency play an important role. Apart from its impact on greenhouse gas emissions, the literature on energy efficiency argues that promoting energy efficiency costs less than building new power plants. There are also environmental reasons. Utility companies need to follow a number of environmental regulations. There are emissions control strategies in place and saving energy on the margin will allow the more polluting plants to be removed from producing electricity. Reducing electricity demand also reduces the need to upgrade the transmission and distribution network. Lastly, reducing peak demand combined with reducing energy demand can lead to grid reliability.

The discussion on energy efficiency, and energy policy in general, received an added impetus due to the Fukushima Daiichi nuclear accident on 11 March, 2011 that led to worldwide discussions about the security of nuclear power plants and energy policy issues. Germany imposed a three month moratorium on announced extensions for existing nuclear power plants and shut down 7 of its 17 power plants within days after the accident. Afterwards, the government announced that all existing power plants will be phased out by 2022. Italy had already closed down all its nuclear power plants after the Chernobyl accident, the last in 1990. However, the government planned to construct a new nuclear power plant and it was rejected in a referendum that took place in June 2011, just after the Fukushima incident (Jorant, 2011). In Switzerland, the Federal Council decided to suspend the approvals process for new nuclear reactors and, subsequently, decided to make the ban on new nuclear reactors permanent. Furthermore, it was decided that the country's five existing nuclear reactors would continue producing electricity until they are gradually phased out with no replacements. The implications of a switch in electricity generation from nuclear to other sources are important for countries like Germany and Switzerland that are heavily reliant on nuclear energy.[1]

Following the decision to phase out nuclear energy, the Swiss Federal Office of Energy (SFOE) developed an energy strategy, the *Energy Strategy 2050*. This strategy sees utilities as key players for reducing electricity consumption due to their direct contact with end-customers. With this in mind the Federal Council proposed, within the initial package of measures, mandatory efficiency goals at a national level for utilities that

[1] In 2011 almost 40% of Switzerland's electricity was produced from nuclear energy. The end-use consumption of electricity was 58.6 TWh of which 30.6% was consumed by households (SFOE, 2013).

sell more than 30 GWh as a way to reduce electricity consumption. This could be combined, in the future, with a white certificates scheme.[2] The World Energy Outlook (International Energy Agency, 2009) emphasizes the huge potential of energy efficiency (EE) measures which are viewed by many as "low-hanging fruit" due to their low marginal cost.

Promoting energy efficiency is a part of demand-side management efforts that are often undertaken by utilities and the government. Demand-side management (DSM) refers to the *"planning, implementing, and monitoring activities of electric utilities that are designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand"* (Energy Information Administration, 1999). Utility DSM programs began in the late 1970s as a response to the energy crises. They were begun primarily by utilities on the west coast of the USA before gradually spreading to other regions of the USA, as well as to British Columbia, Ontario and other provinces in Canada. In recent years DSM has spread to Australia and several countries in Europe, Latin America and Asia, although DSM efforts outside of North America till the 1990s have been limited (Nadel and Geller, 1996).

The original intention of DSM programs was to change the pattern of electricity demand to modify the load faced by a utility. It was subsequently modified to take into account the programs undertaken by utilities to promote energy efficiency. DSM, therefore, incorporates energy efficiency, energy conservation, and load management (Carley, 2012). There are various ways in which utilities and federal and local governments have carried out these objectives. They include, among other things, policies like appliance standards, financial incentive programs, information campaigns and voluntary programs (Gillingham et al., 2006).[3]

While there is a substantial literature on the development of DSM in the US and its impact on electricity demand, little is known about DSM efforts in other countries. There is a lack of a systematic analysis of DSM efforts in Switzerland given the importance accorded to energy efficiency in *Energy Strategy 2050*. Therefore, we have two research questions. First, do utility DSM programs in Switzerland have an impact on residential electricity consumption? Second, what is the magnitude of this impact, if any? To answer these two questions we designed and carried out a survey on Swiss electric utilities to obtain data on DSM efforts between 2006 and 2012 and use the variation within utilities and over time to identify the impact and its magnitude. We also use the econometric results to calculate the cost of saving a kilowatt hour given the effectiveness of the DSM programs. We follow previous studies in identifying the impact of DSM programs by correlating differences in the per household residential electricity consumption with the variation in DSM expenditures within Swiss utilities over time. Unlike most studies, we also check for the robustness of our approach by using an instrumental variables approach to account for any potential endogeneity problems

[2]A white certificates scheme works like a CO_2 emission trading scheme. To meet the reduction target a firm or utility can either perform its own reduction measures or buy certificates on the market. If the utility reduces by more than its efficiency goal, it can sell white certificates on the market. This policy ensures that the measures are performed where the marginal cost of reduction is the lowest. Until now, Denmark, France, Great Britain, Italy and the Flemish part of Belgium have introduced mandatory efficiency goals for the utilities, however only France and Italy also have an additional white certificates trading system (SFOE, 2012).

[3]For a detailed description of the history of utility-sponsored DSM programs in the US please refer to Eto (1996), Nadel and Geller (1996), and Nadel (2000).

arising out of measurement errors or simultaneity issues. We also try to attenuate any sample selection issues by using a Heckman-type model in the instrumental variables approach.

This paper contributes to the public policy debate about the degree to which DSM programs can reduce the demand for electricity in the residential sector as well as influence the adoption of energy efficiency measures. While we correlate changes in electricity consumption with changes in spending in DSM programs or with the presence of DSM programs, we can only infer that energy efficiency measures were adopted by households through the impact on the household's electricity consumption. A second major contribution of this paper is that, to our knowledge, this is the first econometric estimation of aggregate DSM efforts in a European country. Another contribution is that we construct a scorecard to measure the energy efficiency activities of individual utilities and correlate changes in the scorecard to to changes in the residential electricity consumption. Our scorecard is similar to the state energy efficiency scorecard published by the American Council for an Energy-Efficient Economy that measures the commitment of states to promote energy efficiency.

The structure of the paper is as follows. In the next section we provide a brief overview of demand-side management efforts in Switzerland. We then describe the existing literature on evaluating DSM activities in section 3. In section 4 we provide a description of the survey performed on some Swiss utilities, describe the construction of an energy efficiency score and describes the utilities in our survey and their DSM activities. The variables used in our model and their sources are described in section 5. Our identification strategy and estimating equation are provided in section 6 while the results of the econometric estimation are presented in section 7. We perform some robustness checks in section 8. We discuss some policy implications in section 9 while the final section has concluding remarks.

2 DSM in Switzerland

Switzerland is a federal state consisting of 26 cantons and responsibilities are divided between the federal government, cantonal governments and municipalities. In this institutional context, Swiss energy policy is defined and implemented at all the three levels, federal, cantonal, and municipal. Moreover, local utilities also play an important role especially for the definition of the implementation of DSM instruments. It was only in 1990 that the energy policy was embedded into the Federal constitution. Swiss residents voted for the energy article in September 1990, giving the Federal government a mandate to promote the economical and efficient use of energy and renewable energy (SFOE, 2007). Following that, in January 1999, the Energy Act (EnG) and energy regulation (EnV) came into force (Swiss Confederation, 2014). Their goal was to ensure an economic and sustainable provision of energy and the promotion of local and renewable energy sources. Following that, the Federal Councillor Adolf Ogi started a program called "*Energie 2000*" that ran between 1990 and 2000. The program was relaunched in 2001 by Federal Councillor Moritz Leuenberger under the name "*EnergieSchweiz*". The activities of *EnergieSchweiz* aim at raising awareness, information and education, networking and promotion of projects in the fields of renewable energies and energy efficiency. The program works in partnership with the cantons, communities and partners from industry, environmental and consumer organizations, and private sector agencies (SFOE, 2014). Other energy efficiency measures introduced by the national government include appliance standards (SFOE, 2014) and energy labels (Sammer, 2007). For the industry, the government introduced two measures: voluntary targets (EnAW, 2010) and competitive tenders (SFOE, 2012).

As previously mentioned, DSM instruments are mostly defined and implemented at the local level. In Switzerland, 681 utility companies (as of May 2014) are involved in the production, distribution and supply of electricity.[4] These utilities are of different sizes ranging from small municipal utilities supplying single communities to international operating companies. In contrast to other European countries, there are two DSM measures that Swiss utilities have applied for several decades: ripple control and time-of-use pricing (TOU). Ripple control is a traditional instrument to control load in order to keep the electric network stable. Basically it is a superimposed higher-frequency signal that is put on the standard power signal (50 Hz). Loads can be switched off and on in this way, e.g. for public street lamps, electric boilers and heaters (SFOE, 2009). In addition, ripple control is used to switch from peak to off-peak hours in the traditional metering system. Most Swiss utilities apply a TOU pricing for residential customers, where prices vary according to the time of the day with higher prices during the day as compared to the night. The difference between peak and off-peak prices vary between 50 and 100% (SFOE, 2009). There are also utilities that price differently in winter and summer. But this approach has been losing popularity in recent years.

In 1989, residents of Zürich voted for a more rational use of energy. Subsequently, the public utility installed a fund that promotes measures energy saving measures and green investments (ewz, 2003). In 1998, in the canton of Basel-Stadt, the parliament voted for a new energy law that was pioneering. It allowed the canton to raise a tax on electricity that is redistributed equally among the residents and companies (SFOE, 2003). Zürich and Basel are two early examples where DSM measures were introduced by utilities in Switzerland. In recent years, several utilities introduced energy efficiency measures such as rental of smart meters, awareness campaigns and funding help for efficient appliances. However, there has been no policy framework on utility-centered energy efficiency at the national level till now.

3 DSM literature

The empirical literature on the effectiveness of demand side management (DSM) programs in the US is extensive. Table 1 provides an overview of the empirical analyses of DSM, almost exclusively in the US. Early analyses concentrated on estimating its cost-effectiveness measured in terms of the cost of kWh saved

[4] http://www.elcom.admin.ch/themen/00002/00097/index.html.

compared to the cost of producing it. For example, Joskow and Marron (1992) and Eto et al. (1996) find that these programs were both cost-effective and also effective in reducing energy consumption. There are also several other qualitative studies that show that DSM programs are cost-effective (Eto et al., 2000; Nadel, 1992; Nadel and Geller, 1996). The first empirical analyses attempt to measure the accuracy of self-reported DSM savings of the utilities and draw conclusions on the effectiveness of DSM programs.

The literature on evaluation of DMS programs outside of the US and especially the empirical estimation of the effectiveness of DSM measures is very scarce. Dulleck and Kaufmann (2004) focus on information programs in Ireland and find that while the short-run demand behavior does not change significantly, the long-run demand changes by a great amount.[5] They conclude that information programs reduce electricity demand by around 7%. Another DSM study has been done for Canada by Rivers and Jaccard (2011). Rivers and Jaccard (2011) apply a partial adjustment model with bias-corrected estimators, based on Kiviet (1995), and conclude that DSM expenditure has only a marginal effect on electricity consumption in Canada.

To the best of our knowledge, these are the only two empirical studies conducted outside of the US. This leaves a major gap in research on the effectiveness of European energy efficiency measures in the residential electricity sector. Moreover, all of the above-mentioned studies, except for Carley (2012) and Horowitz (2004), treat the policy variable as exogenous. This may bias results since unobserved factors that influence the residential electricity demand may also influence the state's decision on whether or not to introduce a policy leading to a simultaneity problem. We try to overcome this problem by using an instrumental variables (IV) approach. In addition, similar to Carley (2012), we use different versions of policy variables: DSM expenditure per customer, a dummy for positive DSM spending and a score that measures the DSM effort of a utility. We can then verify the robustness of our estimates.

While there is a substantial literature on the development of DSM in the US and its impact on electricity demand, little is known about DSM efforts in Switzerland and its effectiveness. There is no policy framework on utility-centred energy efficiency at a national level. In 2011, two environmental organizations, the World Wide Fund for Nature (WWF) and Pro Natura, developed a rating system for the ecological comparison of Swiss utilities. Vettori et al. (2014) assess the extent to which the utilities promote energy efficiency and renewable energy using data on 24 utilities. Blumer et al. (2014) use data on 114 utilities and a two-step cluster analysis to identify three different clusters of Swiss utilities regarding their activity in implementing DSM programs. In addition they use analysis of variance to find that the clusters differ significantly on utility characteristics such as size, share of production, number of large clients, and the level of activity in implementing EE programs.

[5] While this study is also European, our analysis is based on an aggregate DSM measure as opposed to the specific nature of DSM program, *viz.* information programs, studied by Dulleck and Kaufmann (2004)

Table 1: Estimated DSM effects in the literature

Source	DSM Policy Variable	Effect	Model
Parfomak and Lave (1996)	Reported Conservation (GWh)	99.4% of the reported conservation impacts are statistically observable in system level sales after accounting for economic and weather effects.	Weighted least squares (WLS) estimators
Loughran and Kulick (2004)	1. Dummy if utility has positive DSM expenditure 2. DSM expenditure	DSM expenditures lowered mean electricity sales by 0.3 to 0.4 percent. Larger effect for a sample of utilities reporting positive DSM expenditures in every year (0.6 to 1.2 percent). Utilities themselves estimated effect between 1.8 and 2.3 percent. Authors think the difference is because utilities generally do not fully control for selection bias.	First difference fixed effects approach
Dulleck and Kaufmann (2004)	Information program value (0-1)	Providing customers with information reduced overall electricity demand by roughly 7%	Monthly time series
Horowitz (2004)	DSM savings per dollar state gross commercial product (which are endogenous) therefore instruments: 1. DSM instrument with non-declining DSM savings by replacing with the latest higher values 2. DSM instrument is estimated with a Tobit model using population and supply costs as explaining variables	Electric utility demand side management programs were responsible for reducing commercial sector electricity intensity in 2001 by 1.9% relative to the 1989 level.	Dynamic GLS-FE model
Horowitz (2007)	Reported accumulated (1992-2003) electricity savings attributable to DSM programs to categorize utilities in four different quartiles of different commitment to EE policies.	Those states that have moderate to strong commitment to energy efficiency programs reduce electricity intensity relative to what it would have been with weak program commitment; in the residential sector by 4.4%	Difference-in-differences approach
Auffhammer et al. (2008)	DSM expenditure	Reported utility DSM savings may be more accurate than Loughran and Kulick (2004) claim. Supports Parfomak and Lave (1996).	Loughran and Kulick (2004) model and data plus better test statistic and nonparametric bootstrap confidence intervals

Continued on next page

Table 1 – continued from previous page

Source	DSM Policy Variable	Effect	Model
Berry (2008)	1. ACEEE efficiency program score 2. Utility efficiency program spending score and 3. Other efficiency program score	The higher the utility efficiency program expenditures per capita and the greater the range of other efficiency programs offered, the greater is the reduction in the growth of electricity sales. A one-point increase in the efficiency program score is associated with about a 3.2% decrease in the growth of electricity sales over the 5-year study period.	OLS regression of difference
Rivers and Jaccard (2011)	DSM expenditure per capita	DSM expenditures by Canadian electric utilities have had only a marginal effect on electricity sales	Partial adjustment model (to correct for the inertia) with bias corrected estimators (by Kiviet (1995))
Arimura et al. (2012)	DSM spending per customer, lagged DSM spending (as well as their polynomials) as instruments.	They found that DSM expenditures have resulted in an annual average of 0.9 percent electricity savings at an average cost of 5 cents per kWh of electricity savings.	Basic approach of Loughran and Kulick (2004) plus address possible endogeneity in spending (by using a nonlinear GMM approach)
Carley (2012)	1. DSM policy effort (ACEEE score) 2. Public benefit funds spendings 3. Dummy for the state having an energy efficiency portfolio standard 4. Dummy for the state offering a performance incentive	State-run DSM efforts contribute to electricity savings across the country. Public benefit funds coupled with performance incentives are found to encourage utility participation in DSM programs. Energy efficiency portfolio standards and performance incentives effectively promote electricity savings, but public benefit funds without the support of other DSM policies are not significant drivers of either DSM program participation or total DSM electricity savings.	Two-step Heckman method

4 Survey

In order to perform a qualitative analysis of utility DSM efforts in Switzerland as well as an empirical analysis on the impact of DSM on electricity consumption we collected data on the measures introduced by Swiss electric utilities using a survey. For this purpose, we sent out questionnaires by e-mail to 105 utilities in Switzerland between April and November, 2013.[6] We mailed a questionnaire to the 50 largest utilities and to a random sample of 55 mid-sized utilities. The objective of the survey was to gather information on the electricity delivered to residential customers as well as to quantify any efforts made by utilities on demand-side measures to reduce electricity consumption. To achieve this objective we split the questionnaire into two parts. The first part covered questions about the consumption of residential customers, number of customers, electricity tariffs and utility characteristics. In the second part of the questionnaire we asked questions on DSM activities.

Table 2 shows the response rates to the survey, differentiating between the three major language areas in Switzerland.[7] The overall response rate of our survey was almost 42%. While the overall response rate was quite high, taking into account sufficiently completed answers resulted in a lower response rate of close to 30%. However, these 30 utilities account for almost half of the electricity delivered to households with around 45% of residential electricity sold in 2011. Most of the utilities, around 80%, are located in the German-speaking part of Switzerland while the rest of the utilities are divided almost equally between the French-speaking and Italian-speaking parts, 10% and a little over 10%, respectively.

The utilities surveyed were asked to fill in the respective data for 2006 until 2012. This means that we have a panel data set. The main advantage of using panel data is that we can control for unobserved heterogeneity of the utilities. However, we have an unbalanced panel dataset since some of the utilities were unable to provide information for the first few years. For our primary variable of interest, electricity consumption, there are 184 observations in total for the 30 utilities over 7 years.

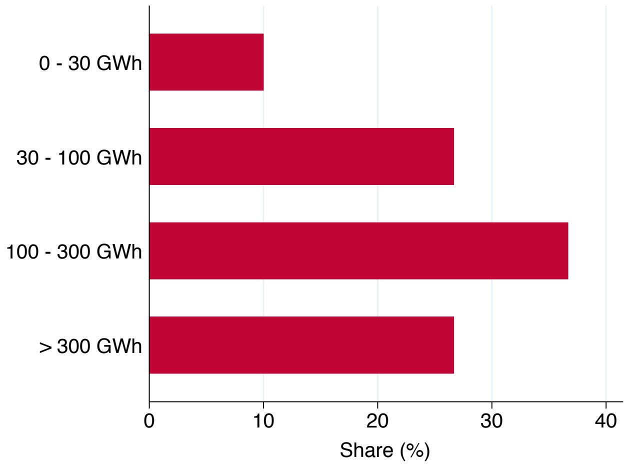
Table 2: Survey response rates

Region	Surveys sent	Responses with data	Responses without data	Overall response rate	Useable response rate
German	81	23	9	39.51%	28.40%
French	14	3	5	57.14%	21.43%
Italian	10	4	0	40.00%	40.00%
Total	**105**	**30**	**14**	**41.90%**	**28.57%**

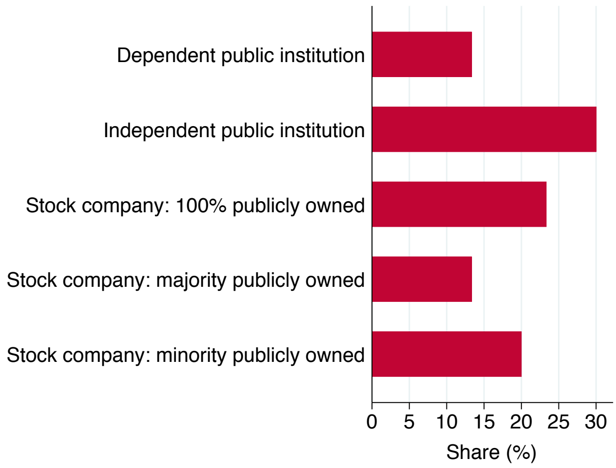
In Switzerland, electricity utilities are quite diverse in terms of their organization and ownership, size and field of activity. There are different ways to measure the size of a utility. Different proxies for the size of a utility could be, e.g., the sales revenue, the number of employees or the quantity of electricity delivered.

[6]While there are over 600 utilities in Switzerland, we restricted our survey due to constraints on time and resources.

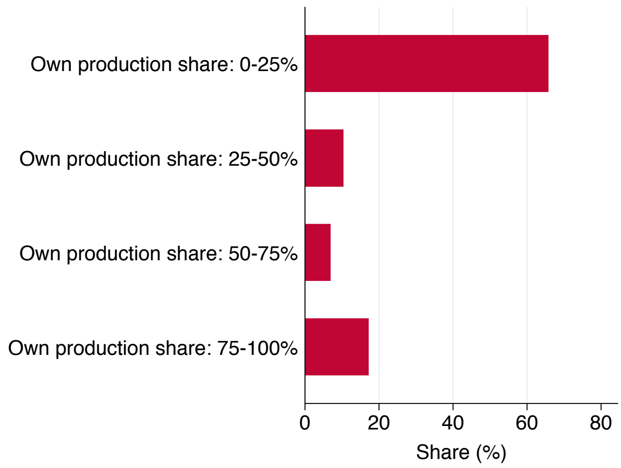
[7]For simplicity, we consider utilities located in the Romansh-speaking areas to be part of the German-speaking region.



(a) Size of utilities by electricity supplied to residential customers in 2012



(b) Legal forms of the surveyed utilities



(c) Shares of own production

Figure 1: Utility characteristics

Figure 1a presents four groups according to the utilities' supply of electricity to their residential customers in 2012. The graph shows that the majority of utilities supply between 100 and 300 gigawatt hours (GWh).

Another feature of Swiss electricity utilities is its legal form. We distinguish between five legal forms: (1) dependent public institution, (2) independent public institution, (3) publicly owned stock company, (4) stock company with a majority of public ownership and, (5) stock company with a minority of public ownership. Figure 1b shows the distribution of our surveyed utilities across the different legal forms. The graph shows that a third of the utilities are independent public institutions. Together with dependent public institutions they constitute about 45% of the sampled utilities. The other three categories are stock companies with different degrees of public ownership.

Utilities can be active in production, transmission and distribution of electricity. As we focus on utilities with residential end-use consumers, the utilities in the sample are mostly distribution companies. Nonetheless, some of the utilities also generate their own electricity. Figure 1c shows the shares of electricity produced by a utility itself. The graph shows that more than 60% of the utilities in the survey produce less than 25% of their electricity sold. This indicates that the utilities in the sample are more focused on the distribution side. Only a minority, close to 20%, produces more than three quarters of their supply to residential customers.

4.1 Funding activities

In order to measure the utilities' activity in DSM a popular method is to use the monetary effort for their programs. We summarize the DSM expenditures between 2006 and 2012 for the 30 surveyed utilities in table 3. DSM expenditure is measured as the annual expenditure on all energy efficiency measures directed at residential customers. A utility spent, on average, CHF 2.86 per residential customer during the survey period. The variation between the utilities is large as shown by the range and standard deviation. There are 14 utilities that have DSM in all the years, from 2006 to 2012. There are 11 further utilities that changed from having no DSM to having some DSM spending over the seven year period. There are 5 utilities that did not report any DSM spending in our study period. The maximum amount spent is almost 31 CHF per customer in a year. This variation can also be seen in figure 2, where we plot electricity consumption per customer against DSM expenditure per customer. Note that figure 2 includes all the surveyed 30 utilities and not only utilities with positive spending. We can see that there is a clear bunching around zero DSM expenditure and only a few utilities spend a large amount, per customer, on DSM measures.[8] Figure 3 provides a detailed analysis where the spending by individual utility is plotted separately. Apart from observing the evolution

[8]We have also estimated robust regression models that are variants on linear regression models that downplays the influence of outliers. The results suggest that outliers do not cause a problem and the coefficients from the robust regression models are, in general, very similar to our standard regression models.

of individual utility DSM spending over time, the graphs show that we can exploit the variation in DSM activities within utilities and across utilities over time to make an econometric estimation of the impact of DSM activities on electricity consumption.

In any case, we need to note that DSM expenditure may be measured with measurement error. Because of accounting purposes it is not possible for some utilities to tell the exact amount spent on such activities. Therefore, some utilities have only provide rough estimates of this variable. For this reason, we create two indicator variables that, we think, measure the funding activities in a more robust way. Firstly, we use a binary variable for positive spending where the cut-off for the switch from zero to one is spending greater than zero. Secondly, we use a similar dummy with a cut-off at the first quartile of DSM expenditure per customer. Figure 4 shows a box-plot of the positive spending binary variable against the consumption per customer from 2006 to 2012, whereas figure 5 displays the same for the second binary variable. As before, the graphs show us that we can exploit the variation in the binary DSM variable within utilities and across utilities over time to make an econometric estimation of the impact of DSM activities on electricity consumption.

Table 3: Summary statistics - Funding activities (in CHF)

Variable	Mean	Std. Dev.	Min.	Max.	N
Expenditures on all DSM measures	313128.75	1048718.63	0	5900000	210
Expenditures on funding	98089.47	336516.3	0	2951717	210
Expenditures on all DSM measures per customer	2.86	6.13	0	30.83	201
Expenditures on funding per customer	1.28	3.49	0	30.14	185

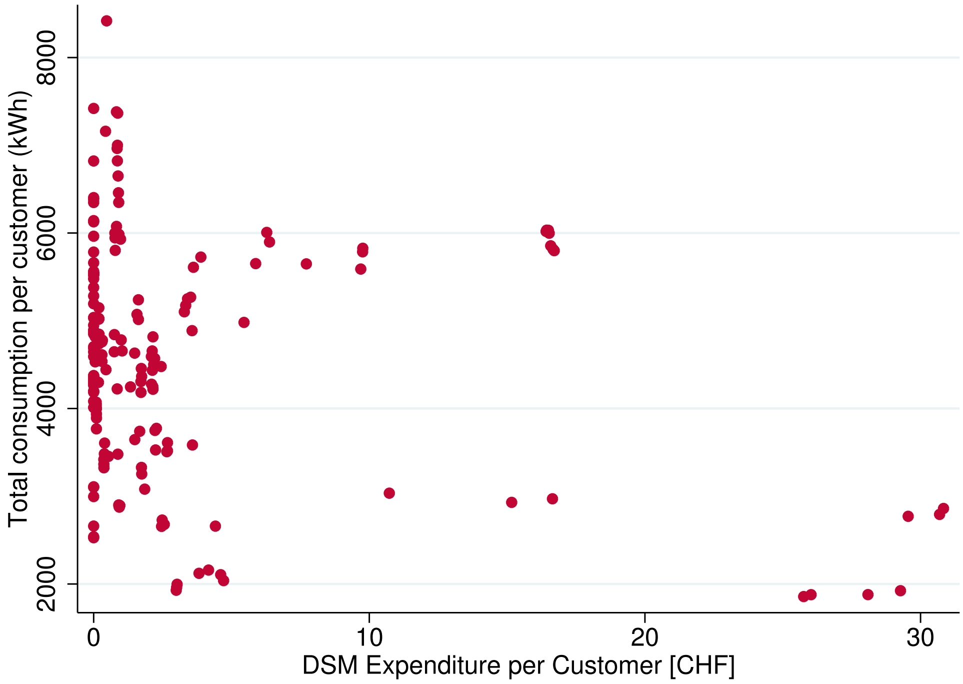


Figure 2: Electricity consumption per customer versus DSM expenditure per customer

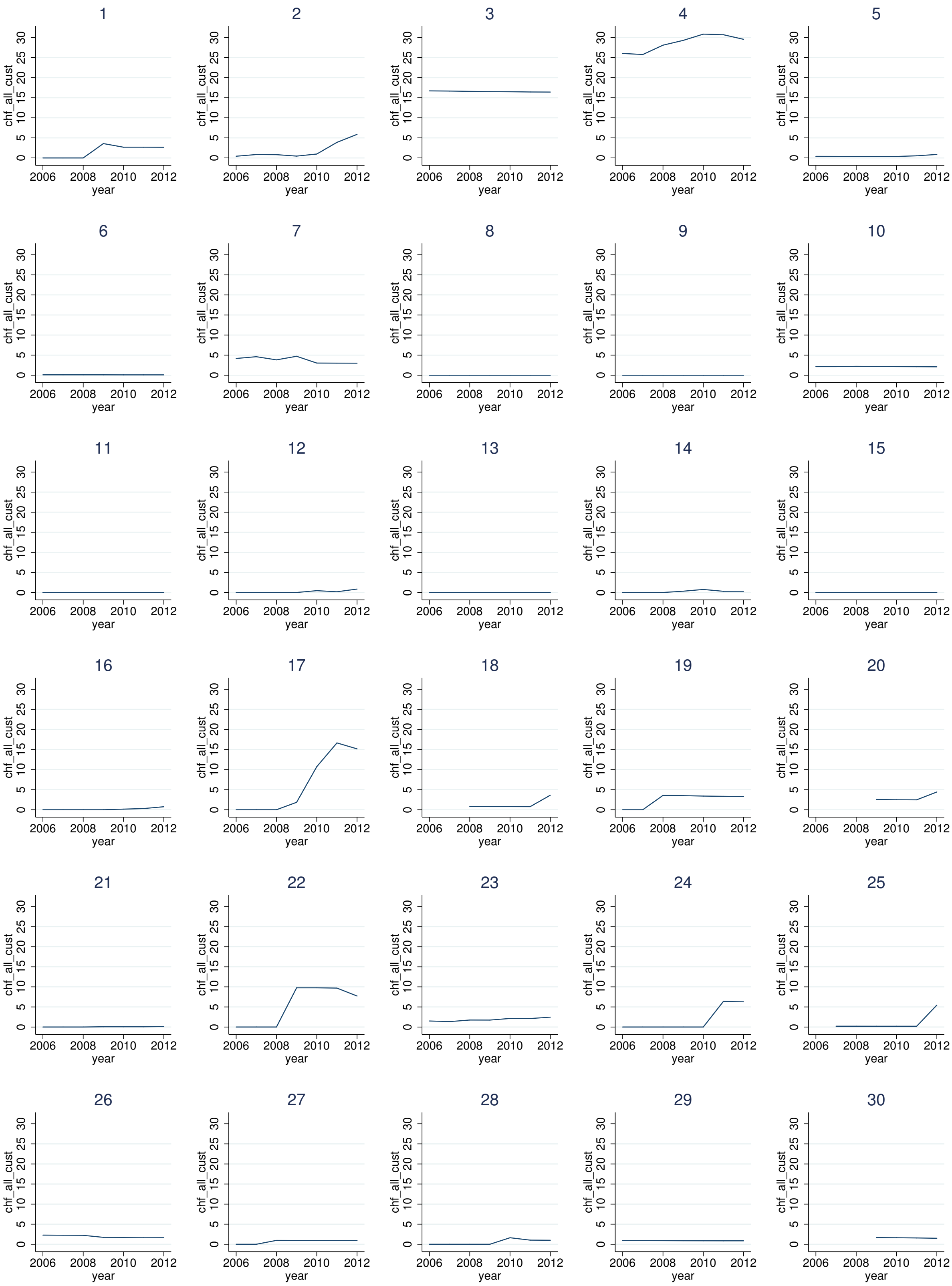


Figure 3: DSM Expenditure per customer for sampled utilities (2006–2012)

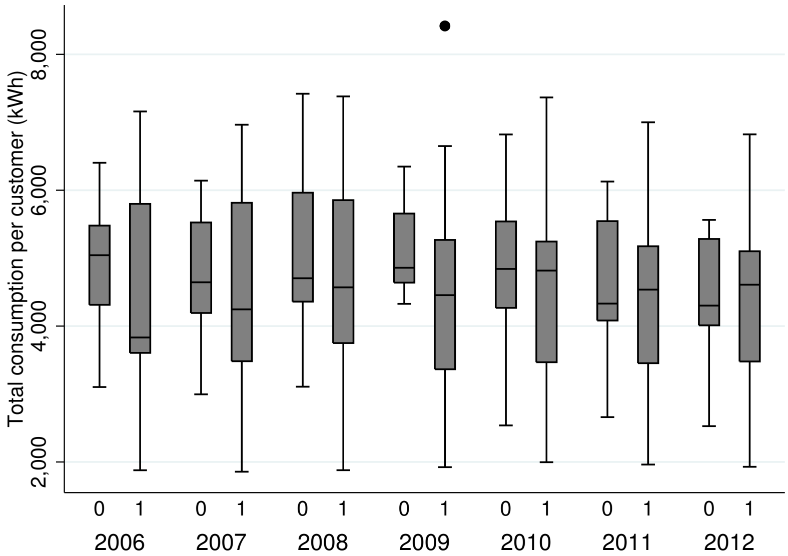


Figure 4: Electricity consumption per customer versus positive DSM spending (2006–2012)

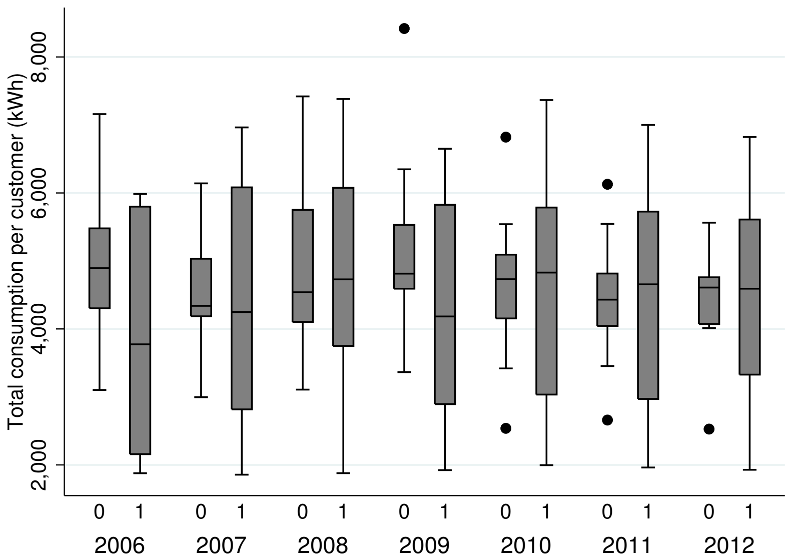


Figure 5: Electricity consumption per customer versus 1st Quartile positive DSM spending (2006–2012)

4.2 Energy efficiency score

In order to aggregate all the different utilities' activities in DSM it is possible to build an index. For example, Berry (2008) and Carley (2012) use the ACEEE scorecard to evaluate the effectiveness of DSM in the US. The ACEEE scorecard is an energy efficiency index that the American Council for an Energy-Efficient Economy (ACEEE) calculated for the first time in 2006. It has now become an annual benchmark of the progress of US state energy efficiency policies and programs. It considers six policy areas, one of which is utility and public benefits programs and policies. Within this sub-score program budget and savings, energy efficiency resource standard and regulation type is considered as criteria (ACEEE, 2007).

Using information from the second part of the survey, we develop an energy efficiency score that measures a utility's commitment to promote energy efficiency among their residential customers. For this purpose, we use the reports from Vettori et al. (2011, 2014) as a basis. In contrast to those studies, we consider only the energy efficiency policies that are directed only at residential customers and do not consider the commercial and industrial customers. However, we can calculate the EE score for all years between 2006 and 2012 and also analyse the dynamics of our score. We cover five fields of action, *viz.*, utility's strategy, tariff design, consulting offers, replacement of appliances and spending on financial programs. We assign an equal weight of 20% to each of these EE strategies.

	Criteria	0	1	2	3	4	Weights
1	**Strategy**						**20%**
	Does the utility have a strategy/ public mandate and defined goals for energy efficiency?	None		yes, but not quantified	yes, quantified	yes with fund	20%
2	**Tariff design**						**20%**
	Fixed tariff	yes, fixed fee				No fixed fee	5%
	Electricity purchased by regressive, linear or progressive rate	regressive rate		linear rate		progressive rate	5%
	Tariff for interruptable appliances for residential loads: Demand Shift	No				Yes	5%
	Tariff measures to decrease the consumption	None		for part of the customers (e.g. efficiency bonus)		incentive tax	5%
3	**Consulting**						**20%**
	Information supply and supply of consulting for residential customers	None	1 measure	2 - 3 measures	4 - 5 measures	6 measures	20%
4	**Programs for efficient appliances and equipment**						**20%**
	Does the utility promote the conversion of existing electric storage heaters and electric water heaters to energy efficient technologies?	None, no information		consulting, no financial measures		consulting, and financial measures	10%
	Incentives for the replacement of inefficient appliances. Does the utility support the purchase of energy efficient appliances?	None, no information		consulting, no financial measures		consulting, and financial measures	10%
5	**Spending on programs**						**20%**
	What was the expenditure (in CHF) for financial support, as measured by the electricity sales in utility area?	no financial support	>0-0,5 Fr/MWh per year	0,5-0,75 Fr/MWh per year	0,75-1 Fr/MWh per year	>1 Fr/MWh per year	20%

Figure 6: EE Score Calculation

Figure 6 shows how the EE score was calculated using the different criteria and their corresponding

Table 4: Summary statistics - EE Score

Variable	Mean	Std. Dev.	Min.	Max.	N
EE Score	1.21	0.88	0	3.5	210

weights. The overall score ranges from 0 to 4, with 0 being the worst, in terms of energy efficiency efforts, and 4 being the best. Table 4 presents the summary statistics of the score, with utilities obtaining an average score of 1.21 out of a maximum of 4. The maximum EE score reached by one of the surveyed utilities is 3.5. To obtain a better picture of the relation between the EE score and spending on EE measures, we present figure 7 in which the logarithm of positive EE spending is plotted against the EE score. The graph shows that there is a positive correlation between EE spending and the EE score with higher EE spending being reflected, on average, with a higher EE score.

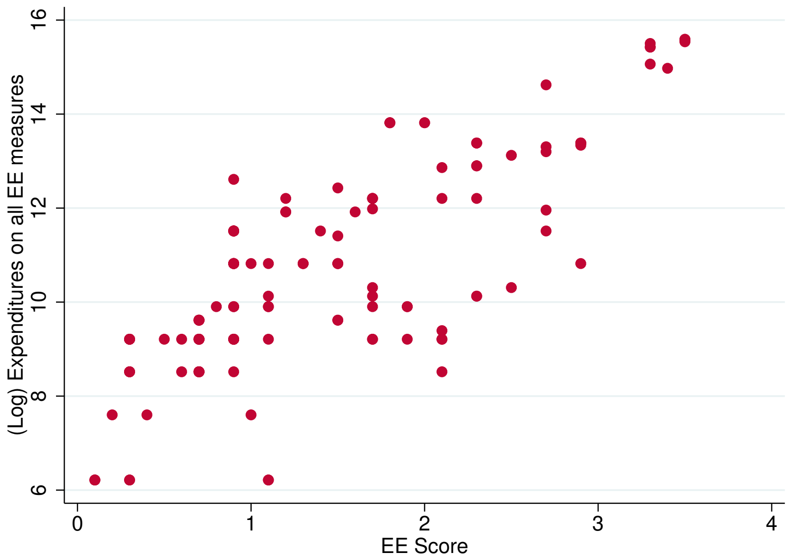


Figure 7: (Log) Expenditure on EE versus EE score

Figure 8 plots the logarithm of the electricity consumption per customer against the EE score. The EE score for each utility is averaged over two periods, one from 2006 to 2009 (indicated by the blue dots), and another from 2010 to 2012 (indicated by the red dots). The general picture shows a negative correlation between electricity consumption and the EE score, meaning that higher EE scores seem to be associated with utilities that have a lower electricity consumption.

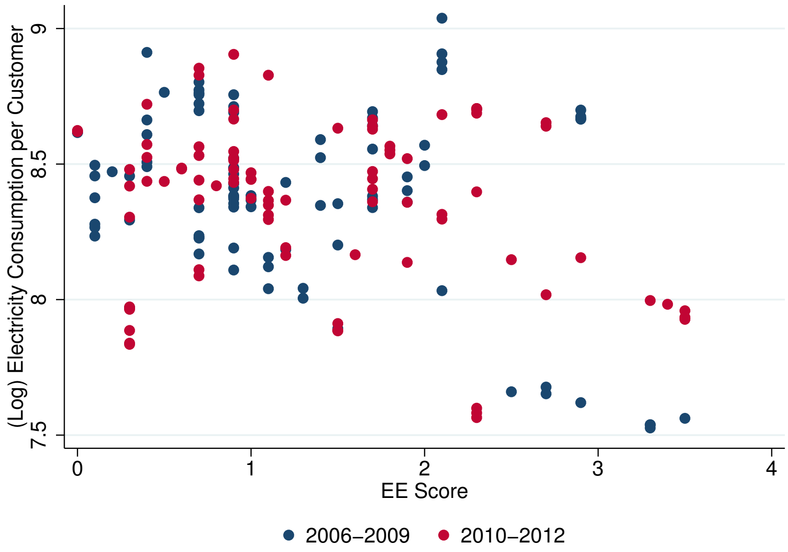


Figure 8: (Log) Per customer electricity consumption versus EE score

5 Data

We use three main sources of data. The first source is our survey from which we obtain utility characteristics, electricity consumption and price data as well as the DSM measures. Demographic data like income and political variables are from the Bundesamt für Statistik (BFS).[9] The final source is MeteoSchweiz from where we obtain information on heating and cooling degree days.

Table 5 shows the summary statistics of all the variables used. Most Swiss utilities have two kinds of tariffs for customers with a time-of-use scheme and a single tariff scheme. Customers with a time-of-use scheme pay a different price for electricity depending on the time of day with a higher rate during the day and a lower rate at night. Customers with a single tariff scheme pay a single price for electricity regardless of the time of day. To take this into account we weight the average price by using the number of customers in each tariff scheme. Based on the information from residential electricity tariffs, we calculate a weighted average electricity price for each utility and year.[10]

Demographic data is from the BFS. We use the average taxable income as a measure of the income of a household. Electricity demand also depends on the household size and we calculate this by dividing the population of the area served by a utility by the number of customers serviced by that particular utility to get an average size of a household in the area serviced by the utility. We also obtain a political measure in the service area of a utility by calculating the share of left-wing parties. This variable is used as an instrument as part of the robustness checks described in section 8. We also use heating and cooling degree days, collected

[9] The Bundesamt für Statistik is Switzerland's Federal Statistical Office.
[10] Details are provided in the Appendix.

from MeteoSchweiz, as a measure of the effect of weather variables on the demand for electricity.

The primary independent variable of interest is a measure of demand-side management programs. We calculate this in several ways. The first way is through an indicator variable that takes the value 1 if the utility has had any DSM spending in the year and zero, otherwise. The second way is also by using an indicator variable. However, in this case, we assign a value 1 to the DSM variable if the DSM spending lies at or above the first quartile of positive DSM spending. The third and fourth measures are by using the reported DSM spending by a utility and taking the natural logarithm of it, respectively. The fifth and last measures are by using the energy efficiency score calculated as in section 4.2 with the level value and the natural logarithm of the value, respectively.

Table 5: Summary statistics

Variable	**Mean**	**SD**	**Min.**	**Max.**	**N**
Total consumption per customer (in kWh)	4547.52	1311.02	1856.77	8418.08	182
Average price (in Rappen/kWh)	20.91	3.75	13.16	28.96	182
Average taxable income per taxpayer (in CHF)	69127.31	9894.18	56006.00	104537.19	210
Household Size: Population/Customers	1.86	0.55	0.76	4.24	185
Heating degree days	3567.52	904.93	2130.16	6452.90	210
Cooling degree days	137.99	90.15	0	442.12	210
Positive DSM expenditure dummy	0.66	0.47	0	1	210
DSM expenditure: 1.Quartile dummy	0.51	0.50	0	1	210
DSM expenditure per customer (in CHF)	2.86	6.13	0	30.83	201
EE Score	1.21	0.88	0	3.50	210
Dummy for stock company	0.55	0.50	0	1	210
Dummy for share of own production: 0-25%	0.66	0.48	0	1	204

Note: 1 CHF (Swiss Franc) = 100 Rappen.

All these measures have their respective advantages over one another. The advantage of the binary first and second measures over the continuous third and fourth measures is that they do not suffer from measurement error as the latter two measures since they are self-reported. The advantage of the continuous measures over the binary measures is that they provide a measure of the intensity of DSM activities and not just an indication of whether a utility engages in DSM or not. The advantage of the EE score is that it captures, in an index, the various DSM activities. However, the disadvantage is that it cannot capture the effectiveness of a particular DSM activity and cannot be expressed in monetary terms.

6 Empirical strategy

Our primary identification strategy to estimate the effectiveness of DSM efforts in Swiss utilities is to use the variation in DSM measures within utilities over time and across utilities. In effect, we are using the method of difference-in-differences to obtain this estimate. Difference-in-differences (DD) is a method used to determine causal relationships and its basic idea is to identify a policy intervention or treatment by comparing the difference in the outcomes before and after the intervention for the treated groups with the difference for the untreated groups. It is, therefore, crucial to have observations from the treated and untreated units both before and after the policy intervention.

In our analysis, we consider utilities that have implemented DSM as the treated units. There are 14 utilities that have DSM in all the years, from 2006 to 2012, and are considered to be in the treatment group. There are 11 further utilities that changed from having no DSM to having some DSM spending over the seven year period. On the other hand, there are 5 utilities that did not report any DSM spending in our study period. Due to the fact some utilities are changing from having no DSM to having DSM the number of utilities that belong to the treatment group is changing over time.

There are two key identification assumptions in the DD approach. The first is that the trend in the outcome variable are similar for both the treatment and control groups in the absence of treatment, referred to as the parallel (or common) trend assumption. The violation of this assumption means that we cannot attribute the effect of the outcome solely to the policy intervention. The second assumption is that that the assignment of a unit to the treatment group is exogenous. This may be violated if there is selection based on unobservable characteristics of the units or if the policy intervention is affected by the outcome. Therefore, we later perform various robustness checks to ensure that we do not need to be concerned with regard to these issues.

The simplest formulation in our framework is

$$\ln E_{it} = \beta_0 + \beta_1 DSM_{it} + \lambda_i + \delta_t + \epsilon_{it}, \quad (1)$$

where the subscripts i and t are the indices for an individual utility and time, respectively, E_{it} is the electricity consumption per customer (in kWh), DSM_{it} is the DSM policy variable of utility i in year t, λ_i is the utility fixed effect to control for any unobserved heterogeneity, δ_t is a year fixed effect common to all utilities, and ϵ_{it} is the usual idiosyncratic error term. Our coefficient of interest is β_1 since it captures the effect of the DSM measures on electricity consumption. In addition to this basic model, we can extend it to further include other observable characteristics that can be used to control for any other factors that might influence the electricity consumption per customer. We can, therefore, reformulate equation (1) as

$$\ln E_{it} = \beta_0 + \beta_1 DSM_{it} + \beta_2 p_{it}^E + \beta_3 Y_{it} + \beta_4 HS_{it} + \beta_5 HDD_{it} + \beta_6 CDD_{it} + \lambda_i + \delta_t + \epsilon_{it}, \quad (2)$$

where the additional variables p_{it}^E, Y_{it}, HS_{it}, HDD_{it}, and CDD_{it} refer to the electricity price, average taxable income per taxpayer, average household size calculated as the the population divided by the number of customers, heating degree days, and cooling degree days, respectively for the area serviced by utility i in year t.[11] There exists a variant of equation (2) where the DSM_{it} variable may include DSM effort lagged by one or more time periods. Several studies have explored this possibility, including Loughran and Kulick (2004), Rivers and Jaccard (2011) and Arimura et al. (2012). We considered this extension in our model but did not obtain any effect of the lagged DSM variable on the electricity consumption in the current period. However, the short time span of our data (7 years), could be an issue and it may be an avenue worth pursuing in the future with richer time-series data.

Our specification, equation (2), is in semi-log form since the continuous DSM measure contains zeros and the logarithm of zero is undefined.[12]

7 Results and discussion

The results of estimating equation (2) are in table 6. Columns (1) and (2) are the results from estimating equation (2) with indicator variables as our variable of interest, DSM_{it}. In column (1), the indicator variable takes the value 1 when a utility has spending on energy efficiency greater than zero and takes the value 0, otherwise. In column (2), the indicator variable takes the value 1 when a utility has spending on energy efficiency greater than the first quartile of positive EE spending and takes the value 0, otherwise. Column (3) estimates equation (2) with a continuous measure of DSM measures, the DSM expenditure per customer. Column (4) estimates equation (2) using the EE score.

Our results from columns (1) and (2) indicate that spending on EE programmes has a moderate, but statistically significant, effect on the electricity consumption per customer. Positive EE spending reduces electricity consumption per customer by around 4.5% in column (1) and by around 6% in column (2).[13] Our estimates from column (3) indicate that when we use the continuous measure of EE spending the results confirm the negative and statistically significant impact. Increasing per customer EE spending by CHF 1 in column (3) leads to a reduction in electricity consumption by around 0.5%. Assuming that a household, on average, consumes 4600 kWh of electricity per year, a reduction in electricity consumption of 0.5% is around 23 kWh per year per Swiss franc of DSM spending. Therefore, the cost of saving one kilowatt hour

[11] Income and heating and cooling degree days have been scaled to ensure that the results are easier to read.

[12] We have also performed the regressions by using a linear transformation of the DSM variable to ensure that the logarithm is defined and using a log-log model. The results are similar.

[13] The percentage change is calculated by using $100[e^{\beta_1} - 1]$ where β_1 is the coefficient of the DSM measure in equation (2).

is around CHF 0.04.[14] In other words, increasing per customer spending on EE in column (3) by 10% leads to a reduction in electricity consumption by around 0.14% when evaluated at the mean of DSM spending.[15]

The results with the EE score also indicate a statistically significant impact of utility DSM efforts on reducing per customer electricity demand. Column (4) in table 6 shows that an increase in the EE score by one point leads to a reduction in electricity consumption by around 3.2%. Evaluating the elasticity at the mean EE score, we find that a 1% increase in the EE score reduces per customer residential electricity consumption by around 0.04%.

The coefficients of several other explanatory variables in table 6 are statistically insignificant. The only variables that show consistent significance statistically are electricity price and household size. The price variable shows an elasticity, evaluated at the mean of the average price, ranging between –0.38 and –0.34 so the results are quite stable. The estimates obtained in this chapter are based on a static model of electricity consumption. The elasticity for household size is around 0.12 which implies that increasing the household size by 1% increases electricity consumption by around 0.12%. The coefficients for the other explanatory variables are statistically insignificant probably due to the fact that there is not much within-variation of those variables. Since our panel is relatively short in terms of the number of years, we expect these socio-demographic and weather variables not to exhibit much variation and, therefore, is captured by the utility fixed effects. Several explanatory variables are not statistically significant but that is not a problem since we are more interested in the coefficient of the policy intervention variable, DSM, in our DD model.

[14]This is obtained by dividing the cost, CHF 1, with the electricity saved, 23 kWh.

[15]We should note that the estimated impact of the DSM programmes obtained in the model with the binary DSM measure and in the model with the continuous DSM measure cannot be directly compared due to the discrete nature of the former measure and the continuous nature of the latter measure.

Table 6: FE Models of (log) residential electricity demand per customer

	(1)	(2)	(3)	(4)
Positive DSM expenditure	-0.047^a			
	(0.017)			
DSM expenditure: 1.Quartile		-0.058^b		
		(0.025)		
DSM expenditure per Customer			-0.005^b	
			(0.002)	
EE score				-0.030^b
				(0.014)
Average price	-0.018^a	-0.016^a	-0.018^a	-0.018^a
	(0.006)	(0.006)	(0.006)	(0.006)
Taxable income per taxpayer	0.004	0.003	0.005	0.003
	(0.005)	(0.005)	(0.005)	(0.005)
Household size	0.066^c	0.063^c	0.064^c	0.062
	(0.039)	(0.035)	(0.037)	(0.038)
Heating degree days	-0.009	-0.010	-0.008	-0.008
	(0.009)	(0.009)	(0.009)	(0.009)
Cooling degree days	-0.020	-0.038	-0.038	-0.027
	(0.031)	(0.031)	(0.031)	(0.030)
Utility Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	182	182	182	182
Adjusted R^2	0.954	0.955	0.954	0.954

Robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.
Income and heating and cooling degree days have been scaled.

8 Robustness checks

The advantage of DD estimation is that both group-specific and time-specific effects are accounted for by taking the time changes in the means of the outcome variable for both the treatment and control groups. However, as with any methodology, we need to be careful in implementing this method. The DD identification, as mentioned previously, depends on the assumption that the treatment and control groups exhibit parallel trends and to test this we perform some robustness checks.

To check for the parallel trends assumption we perform some placebo tests. These are done in several ways. In all the placebo tests we exclude utilities that had EE programmes throughout the time period in our survey. The only issue in our placebo tests is the low number of observations in our regressions and we should be careful in interpreting our results. However, considering the relatively small initial dataset we cannot perform the robustness checks without this caveat. First, we consider utilities that did not have EE spending in years 1, 2 and 3 but positive spending in years 4, 5, 6 and 7.[16] We assign a value 1 to the DSM indicator variable to those utilities in year 3. The results from this regression are presented in table

[16] We consider here, and in what follows, years 1, 2, 3, 4, 5, 6 and 7 to correspond to our surveyed years 2006, 2007, 2008, 2009, 2010, 2011 and 2012, respectively.

7. We also perform a similar regression for the continuous DSM spending variable.[17] The results from this regression are in column (2) of table 7. If the parallel trends assumption would be violated we would expect our coefficients of interest, the "Pseudo" variables to be significant. However, they are statistically insignificant in all the columns.

Second, as in the previous case, we again consider utilities that did not have EE spending in years 1, 2 and 3 but positive spending in years 4, 5, 6 and 7. However, this time we assign a value 1 to the DSM indicator variable to those utilities in years 2 and 3. The results from this regression are presented in table 8. We also carry out a similar regression for the continuous DSM spending variables. The results from this regression are in column (2) of table 8. If the parallel trends assumption would be violated we would expect our coefficients of interest, the "Pseudo" variables to be significant. However, they are statistically insignificant in all the columns.

Third, we consider utilities that did not have EE spending in years 1, 2, 3 and 4 but positive spending in years 5, 6 and 7. We assign a value 1 to the DSM indicator variable to those utilities in year 4. The results from this regression are presented in table 9. We also carry out a similar regression for the continuous DSM spending variables. The results from this regression are in column (2) of table 9. If the parallel trends assumption would be violated we would expect our coefficients of interest, the "Pseudo" variables to be significant. However, they are statistically insignificant in all the columns.

In the fourth, and final, placebo test we again consider utilities that did not have EE spending in years 1, 2, 3 and 4 but positive spending in years 5, 6 and 7. This time we assign a value 1 to the DSM indicator variable to those utilities in years 3 and 4. The results from this regression are presented in table 10. We also estimate a similar regression for the continuous DSM spending variables. The results from this regression are presented in column (2) of table 10. If the parallel trends assumption would be violated we would expect our coefficients of interest, the "Pseudo" variables to be significant. However, they are statistically insignificant in all the columns.

As mentioned before, due to the low number of observations in each placebo regression, we need to be careful in making any conclusions, but the lack of statistical significance for our relevant policy variables in the placebo tests indicates that the parallel trends assumption is not violated. Therefore, our original fixed effects results in table 6 appear to be robust.

[17] In this regression, as well as in subsequent placebo tests for the continuous variable, we assign a random positive value to those utilities that had positive EE spending in future years.

Table 7: FE Models of (log) residential electricity demand per customer

	(1)	(2)
Pseudo DSM dummy	-0.135	
	(0.090)	
Pseudo DSM expenditure per customer		-0.005
		(0.004)
Average price	0.063	0.045
	(0.049)	(0.053)
Taxable income per taxpayer	0.004	0.009
	(0.010)	(0.014)
Household size	1.727	1.745
	(1.349)	(1.357)
Heating degree days	0.045	0.032
	(0.056)	(0.059)
Cooling degree days	-0.267	-0.224
	(0.169)	(0.184)
Utility Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	27	27
Adjusted R^2	0.905	0.894

Robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.
Income and heating and cooling degree days have been scaled.

Table 8: FE Models of (log) residential electricity demand per customer

	(1)	(2)
Pseudo DSM dummy	-0.124	
	(0.094)	
Pseudo DSM expenditure per customer		-0.002
		(0.003)
Average price	0.043	0.024
	(0.042)	(0.047)
Taxable income per taxpayer	0.006	-0.004
	(0.010)	(0.009)
Household size	1.144	1.062
	(1.085)	(1.168)
Heating degree days	0.031	0.010
	(0.050)	(0.061)
Cooling degree days	-0.292	-0.162
	(0.195)	(0.171)
Utility Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	27	27
Adjusted R^2	0.895	0.872

Robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.
Income and heating and cooling degree days have been scaled.

Table 9: FE Models of (log) residential electricity demand per customer

	(1)	(2)
Pseudo DSM dummy	-0.097	
	(0.098)	
Pseudo DSM expenditure per customer		-0.005
		(0.005)
Average price	-0.006	0.003
	(0.019)	(0.011)
Taxable income per taxpayer	-0.002	-0.002
	(0.012)	(0.012)
Household size	-0.008	-0.071
	(1.101)	(1.043)
Heating degree days	-0.002	0.001
	(0.055)	(0.055)
Cooling degree days	-0.145	-0.166
	(0.169)	(0.181)
Utility Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	26	26
Adjusted R^2	0.778	0.779

Robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.
Income and heating and cooling degree days have been scaled.

Table 10: FE Models of (log) residential electricity demand per customer

	(1)	(2)
Pseudo DSM dummy	-0.122	
	(0.099)	
Pseudo DSM expenditure per customer		-0.007
		(0.007)
Average price	-0.005	-0.013
	(0.018)	(0.023)
Taxable income per taxpayer	0.004	0.010
	(0.011)	(0.016)
Household size	-0.182	-0.211
	(0.975)	(0.927)
Heating degree days	0.021	0.024
	(0.053)	(0.056)
Cooling degree days	-0.205	-0.206
	(0.168)	(0.179)
Utility Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	26	26
Adjusted R^2	0.810	0.807

Robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.
Income and heating and cooling degree days have been scaled.

DD estimation requires that the policy changes are not endogenous themselves. Our placebo tests showed that this may not be a major concern for us. However, we use the method of instrumental variables as another robustness check. An instrument should satisfy the conditions for relevance and exogeneity. It should, therefore, be correlated with the potentially endogenous EE spending variables variable but not with the error term. A weakness of using an instrumental variables procedure is the difficulty of finding valid and convincing instruments. A potential solution is to use utility characteristics that may influence the decision to implement EE programmes but will not directly affect the residential electricity consumption.

One of the problems with using instrumental variables in a fixed effects short-panel data framework is the potential low variation of those variables over time. This is especially true of utility characteristics that exhibit very little variation over time. The instrumental variables we consider are the legal form of a utility and a measure of the share of the total electricity sold by a utility that is produced by itself. These two variables satisfy the condition for instrument relevance since, as we argue below, both firm characteristics are possible determinants of DSM. They also satisfy the exogeneity condition since neither are possible direct determinants of residential electricity demand and the effect will be seen only indirectly through DSM.

The legal form of a utility is obtained from our survey with five different kinds of legal forms, as given by Figure 1b. The legal form is constructed as a dummy variable with a utility being a stock company or not. It does not show any within-utility variation over our survey period and, therefore, a traditional fixed effects model with instrumental variables will not work. There is some evidence in the DSM literature that the ownership of a utility may be a factor in the implementation of DSM initiatives. However, there is conflicting evidence on the direction of DSM initiatives taken by utilities based on the ownership. Hopper et al. (2009) shows that the energy-saving goals of investor-owned utilities are higher while Carley (2012) finds that investor-owned and cooperative utilities are more likely to have DSM programmes than municipal utilities. On the other hand, Vojdani (2008) states that energy conservation is a low priority for investor-owned utilities in the US. Cabrera et al. (2012) argue that DSM programs are used as tools to obtain certain political goals such as an energy reduction plan and that publicly owned utilities are more active in such a situation.

The share of electricity sold by a utility that is produced by itself may also have an impact on the implementation of DSM programs. This can manifest itself through the cost of purchasing electricity with utilities that generate only a small share of their own electricity needing to purchase electricity at a higher cost to fulfil the demand of their customers. Therefore, these utilities may find it cheaper to engage in DSM activities than in purchasing electricity in the market. On the other hand, Blumer et al. (2014) reason that utilities that generate a substantial fraction of their own electricity may have an incentive to promote DSM since this increases the amount of electricity that they can sell to other utilities.

The presence of a possible endogenous binary policy variable indicates a situation described in Heckman (1978). Therefore, we use a probit model to model the nonlinear binary policy variable. The instrumental variable is used in this probit stage along with the other explanatory variables. We then use the prediction of the policy variable from this stage as an instrument for the endogenous binary policy variable in a fixed effects instrumental variables regression model. This is a consistent estimation method that has been proposed by Amemiya (1978), Heckman (1978) and Lee (1979).[18] The instrumental variable is the excluded

[18] Wooldridge (2002, p. 939) provides a description of this method.

instrument in this model. We refer to this Heckman-type selection approach, in subsequent descriptions, as the "nonlinear" approach.[19] In our specification, we use two instrumental variables, *viz.* legal form of a utility and a measure of the share of the total electricity sold by a utility that is produced by itself, in the nonlinear probit first stage.

The results of the selection model, modelled as a probit, are provided in table 11 where we observe that the probability of DSM decreases when a utility is a stock company while it increases as the own share of electricity production is low. The effects are statistically significant in both columns (1) and (2). The predicted probabilities from this stage are then used as instruments in a two-stage least squares model and the first-stage results of this estimation are provided in table 12. While the coefficient for the predicted probability is statistically significant in column (1), it is not significant in column (2), which indicates that the instrument is very weak and we expect the second-stage results to be imprecisely estimated.

The final results of these estimation procedures are provided in table 13. Column (1) corresponds to instrumental variables estimation for column (1) in table 6 with the non-linear approach. The potentially endogenous DSM binary variable is the positive DSM spending. Column (2) corresponds to the DSM binary variable where the cut-off for assigning a value of unity is the first quartile of DSM spending. Our results show that estimates for the effect of DSM spending on per customer residential electricity consumption is very high compared to the normal DD fixed effects results in table 6. However, it is reassuring to observe that the effects are negative and significant, except in column (2). The estimate of the DSM coefficient in column (2) exhibits a very high standard error and the F-statistic from the first stage also indicate that the nonlinear procedure in this instance may have some issues, as we expected from the statistically insignificant coefficient of the predicted probability in table 12. The F-statistic in column (1) also indicates that our instruments, while valid, may be weak since the value of the F-statistic is less than 10, the generally acceptable cut-off for the strength of instruments.

[19] We also performed the estimations using the instrumental variables in a standard fixed effects framework but, as expected, we encountered a problem of weak instruments due to the low variability of the instruments that led to problems of identification.

Table 11: Probit stage of nonlinear estimation

	(1)	(2)
Average price	-0.053	0.006
	(0.034)	(0.033)
Taxable income per taxpayer	0.005	0.011
	(0.012)	(0.011)
Household size	-0.032	0.384[c]
	(0.234)	(0.226)
Heating degree days	-0.016	-0.036
	(0.025)	(0.023)
Cooling degree days	-0.552[b]	-0.907[a]
	(0.228)	(0.251)
Dummy for stock company	-0.971[a]	-1.346[a]
	(0.256)	(0.249)
Dummy for share of own production: 0-25%	0.839[a]	0.480[c]
	(0.263)	(0.251)
Intercept	2.289	1.000
	(1.879)	(1.850)
Observations	182	182

Robust standard errors in parentheses.
[a], [b], [c]: Significant at the 1%, 5% and 10% levels, respectively.

Table 12: First stage of IV/2SLS estimation

	(1)	(2)
Average price	-0.007	0.015
	(0.021)	(0.018)
Taxable income per taxpayer	-0.022	-0.043[b]
	(0.018)	(0.020)
Household size	0.092[c]	-0.006
	(0.052)	(0.157)
Heating degree days	-0.001	-0.029
	(0.026)	(0.026)
Cooling degree days	0.250[c]	-0.183
	(0.136)	(0.168)
Probability(Positive DSM expenditure)	0.885[b]	0.065
	(0.386)	(0.458)
Observations	182	182

Standard errors in parentheses.
[a], [b], [c]: Significant at the 1%, 5% and 10% levels, respectively.
[d] Used in the probit stage.
[e] Estimated in the probit stage.

Table 13: FE Models of (log) residential electricity demand per customer

	(1)	(2)
Positive DSM expenditure	-0.171[c]	
	(0.089)	
DSM expenditure: 1.Quartile		-1.900
		(12.645)
Average price	-0.021[a]	0.011
	(0.006)	(0.197)
Taxable income per taxpayer	0.002	-0.076
	(0.005)	(0.547)
Household size	0.074[c]	0.064
	(0.040)	(0.257)
Heating degree days	-0.010	-0.063
	(0.009)	(0.365)
Cooling degree days	-0.003	-0.405
	(0.037)	(2.555)
Utility Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	182	182
First Stage *F*-statistic	5.253	0.020

Robust standard errors in parentheses.
[a], [b], [c]: Significant at the 1%, 5% and 10% levels, respectively.

The previous part provides a description of a possible way to account for an endogenous binary policy variable. However, we also have continuous dependent variables, DSM expenditure and EE score, that may also be endogenous. A way to solve the problem of instruments with low within-variation for the continuous endogenous variables is to use OLS, without individual fixed effects, in the first stage. This will reduce the problem of low within-variation of the instrumental variables. As this is not a standard procedure available in Stata, we estimate the IV manually by using the predicted values of the first stage in the second stage. However, this method produces incorrect standard errors (Wooldridge, 2012) and, therefore, we bootstrap the standard errors. The results are displayed in table 14.

Table 14: Bootstrapped IV, First stage OLS, $N = 10000$

	Estimate	**Std. Err.**	***t*-stat**	***p*-value**
DSM expenditure per customer	-0.025	0.014	-1.836	0 .034
EE score	-0.194	0.100	-1.944	0.027

Note: The estimate is the mean of the variable of interest from 10000 replications.

The results in tables 14 show that DSM expenditure per customer reduce residential electricity consumption and while the estimated coefficient is higher compared to our results in table 6 the signs of the coefficients are the same. The comparison between table 14 and table 6 for the EE score shows that the impacts are the same with the expected negative sign but, as with the DSM expenditure per customer variable, magnitude of the impact reported in table 14 is much higher than that reported in table 6.

A summary of the results for our variable of interest, the DSM variable in its various forms, are provided in table 15.

Table 15: Summary of results for DSM variables

Variable	**DD**	**Nonlinear**	**Bootstrapped IV**
Positive DSM expenditure	-0.047	-0.171	
DSM expenditure: 1. Quartile	-0.058	-1.900	
DSM expenditure per customer	-0.005		-0.025
EE score	-0.030		-0.194

9 Policy implications

We now perform a simple counterfactual exercise, using the results from our econometric estimation of the impact of DSM initiatives from column (3) in table 6, to obtain a rough estimate of the cost of DSM programmes for a utility.[20] This is done to get an idea of the approximate range within which the costs of DSM may lie. To perform the counterfactual exercise we first estimate the electricity consumed per customer in the absence of any DSM programme. Using equation (2), we assign zero to the value of the DSM_{it} variable. Therefore, assuming that $DSM_{it} = 0$ we get

$$\widehat{\ln E_{it}} = \beta_0 + \beta_2 p^E_{it} + \beta_3 Y_{it} + \beta_4 HS_{it} + \beta_5 \cdot HDD_{it} + \beta_6 CDD_{it} + \lambda_i + \delta_t, \tag{3}$$

where $\widehat{\ln E_{it}}$ is the (log) electricity consumed per customer in the absence of DSM. We convert the logarithmic value to the level value $\widetilde{E_{it}}$ hereafter.

Since the estimate of the "DSM Expenditure per Customer" coefficient is negative, an increase in this variable will lead to a reduction in the electricity consumed per customer. Therefore, the estimated electricity consumed in the presence of DSM, $\widetilde{E_{it}}$ will be lower than in the absence of DSM. The reduction in the electricity consumed may be attributed to the effectiveness of the DSM programmes. The per customer impact of the DSM programmes is, therefore

$$\Delta E_{it} = \widehat{E_{it}} - \widetilde{E_{it}} \tag{4}$$

for utility i in year t. Summing the $\Delta E_{i,t}$ for all utilities over all years and taking into account the number of customers, we obtain the total electicity saving from DSM programmes:

$$\text{Total } E \text{ Saved} = \sum_{i,t} (\Delta E_{it} * \text{No. of customers}_{i,t}). \tag{5}$$

[20] A counterfactual exercise is a calculation performed to obtain a scenario of what may have happened in the absence of a policy. This is then compared with the estimated effect of having the policy in place to enable us to make a cost-benefit analysis.

The cost of the DSM programmes is obtained by multiplying the "DSM Expenditure per Customer" variable with the number of customers for utility i in year t and summing over all these values, i.e.

$$\text{Total } DSM \text{ Cost} = \sum_{i,t}(DSM_{it} * \text{No. of customers}_{it}). \quad (6)$$

Now, the only calculation remaining is to divide the total DSM cost, equation (6), by the total electricity saved due to the DSM programmes, equation (5), to get an estimate of the cost to utilities of reducing a unit of electricity by implementing DSM programmes:

$$\text{Cost of a kilowatt hour} = \frac{\text{Total } DSM \text{ Cost}}{\text{Total } E \text{ Saved}} \quad (7)$$

We calculate the cost of saving a kilowatt hour by using the estimated coefficient of "DSM Expenditure per Customer" and find it to be around CHF 0.04. The average cost of producing and distributing electricity in Switzerland is around CHF 0.18 per kilowatt hour.[21] It should be noted that these costs from the VSE are based on current production and distribution capacities. It is very likely that these costs may be higher in the future with the construction of new capacity. We should recognise, however, that the cost of DSM programmes calculated are very rough estimates due to our small sample and the fact that the DSM efforts reported in our survey may suffer from measurement error. The range of estimated cost, based on one standard deviation away from the point estimate, is from a low of CHF 0.03 to a high of CHF 0.09. Another potential caveat is that we do not consider any possible positive external benefits from not having to produce an additional unit of electricity or any possible negative externalities from generating electricity. If there *are* any positive external benefits from not producing electricity or any possible negative externalities from generating electricity, our costs that we have calculated will be overestimated.

10 Conclusion

In this paper we use the results of a survey carried out on 30 Swiss utilities to, firstly, provide a description of current demand-side management practices in Switzerland and, secondly, carry out an econometric analysis of the impact of such practices on the demand for per customer residential electricity demand. We find that while a lot of utilities have some kind of DSM programmes in place, the intensity of such programmes is somewhat lacking when compared to a country like the US. The average DSM spending per customer in the US is around CHF 9 per customer while it is less than CHF 3 per customer for Switzerland.[22] The difference, in terms of the maximum per customer DSM spending, is also very large with CHF 190 in the US compared

[21] VSE website, accessed 10 April, 2015.

[22] The figure for per customer DSM spending in the US is from Arimura et al. (2012). They report an average DSM spending per customer of US$ 9.41 between 1989 and 2006. We have converted the amount, and subsequent US dollar amounts, to Swiss Francs by using an exchange rate of US$ 1 = CHF 0.97.

to CHF 31 in Switzerland. However, the amount of electricity generated in the US is substantially higher than in Switzerland while the consumption per capita and per household are also much higher. Therefore, if we consider the expenditure on all DSM measures as well as energy efficiency funding per MWh consumed in Switzerland the value is almost CHF 1 for the former and around CHF 0.32 for the latter. This compares to CHF 1.8 on all DSM measures per MWh consumed and CHF 1.2 on energy efficiency spending per MWh consumed in the US. These figures indicate that utility efforts on DSM in the US are substantially higher than similar efforts in Switzerland.[23] We also find significant variation within Swiss utilities with some utilities having a very high spending. Another finding of our analysis is that Swiss utilities tend to focus more on communicating to its consumers about energy efficiency, with many utilities involved in providing information and having public relation campaigns as opposed to financial incentives and energy audits. There are, however, a few utilities that have invested much more in DSM. Using information from our survey, we also calculate an energy efficiency score for each of the surveyed utilities from 2006 to 2012. This has not been performed before for DSM measures on residential customers for Swiss utilities. We find that, while some utilities at the higher end of DSM efforts have a relatively high score, we believe that there is a lot of scope for improvement to increase DSM efforts.

The results of the econometric impact of DSM measures on residential electricity consumption indicate that, while the impact appears to be statistically significant, the size is small. There may be two possible hypotheses for this. The first is that the lack of intensity of DSM efforts may not have a large effect on electricity consumption. It may be effective for utilities to make more intensive efforts in energy efficiency programmes due to the low cost of energy efficiency (Goldman et al., 2014). The second explanation is that there may not be much scope for Swiss households to reduce their electricity consumption. The majority of Swiss households live in multiple family houses. Therefore, we may expect the presence of a principal-agent type of problem with the landlord or the tenant not investing in energy-efficient products because neither reaps the full benefits of that investment. Therefore, it may be more strategic for utilities and policy makers to target owners instead of tenants with energy efficiency programmes. However, these are merely hypotheses and it is important to test these possible explanations in future research.

Using the results of the econometric estimation we perform a simple counterfactual exercise to obtain an estimate of the cost of saving a unit of electricity that would have been produced in the absence of DSM programmes. We find that, on average, the cost of saving a kilowatt hour is around CHF 0.04. This is a rough estimate and should be treated with caution due to our relatively small sample of utilities and the possible measurement error of the DSM spending variable. The range of our estimate for this cost using the point estimate and one standard deviation above and below this point estimate is from a low of CHF 0.03 to a high of CHF 0.09 and compared to this the current cost of producing and distributing electricity

[23] We should note, however, that the figures for the US are for total spending on DSM and energy efficiency. The figures for spending by the residential sector are not available.

in Switzerland (CHF 0.18/kWh) lies above this range. Our costs may be overestimated since there could be positive external benefits by not having to produce an additional unit of electricity. Given our findings, it appears that DSM programmes may be a valuable option for Switzerland to pursue its goals in *Energy Strategy 2050*.

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Appendix

Electricity price

Based on the information from residential electricity tariffs, we calculate a weighted average electricity price for each utility and year as

$$
\begin{aligned}
P_{average} = & \frac{customer_{tou}}{customer_{total}} \cdot \frac{E_{peak} \cdot MP_{peak} + E_{off-peak} \cdot MP_{off-peak} + FixedFee_{tou}}{E_{tou}} \\
& + \left(1 - \frac{customer_{tou}}{customer_{total}}\right) \cdot \frac{E_{single} \cdot MP_{single} + FixedFee_{single}}{E_{single}},
\end{aligned} \tag{8}
$$

where E_{peak} is the peak period consumption per customer with a TOU tariff, $E_{off-peak}$ is the off-peak period consumption per customer with a TOU tariff, E_{single} is the consumption of a customer with a single tariff, MP_{peak} is the marginal price of electricity in peak periods, $MP_{off-peak}$ is the marginal price of electricity in off-peak periods, MP_{single} is the marginal price of electricity for customers with a single tariff system, $customer_{total}$ is the total number of customers of a particular utility, $customer_{tou}$ is the number of customers of a particular utility that have a TOU scheme, $customer_{single}$ is the number of customers of a particular utility that have a single tariff system, and $FixedFee$ is the fixed fee with subscripts tou and $single$ denoting the tariff scheme to which a customer belongs.

Energy efficiency score calculation

The **first field of action** deals with the strategy of the utilities and asks whether the utility has either a public mandate for promoting energy efficiency or a corporate strategy. If it has either of these, we ask whether there are defined efficiency goals or an energy efficiency fund. Some utilities transfer a fixed amount of their revenues or a fixed amount of the electricity price to a fund. From this fund they finance energy efficiency measures, research or renewable projects. The **second field of action**, tariff design, covers four sub-criteria: presence of a fixed fee, tariff linearity, interruptible load tariff, and tariff measures. Ito (2014) states that if households respond to average electricity prices rather than to marginal prices the monthly fixed fee removes the incentive to households to save electricity. There is evidence in the literature that shows that residential consumers are more concerned about the average price (e.g., Shin (1985) and Borenstein (2009)). Utilities may also have different tariffs for smaller and larger customers or block tariffs. This results in increasing (progressive), linear or decreasing (regressive) tariff structures. California and Italy introduced progressive tariffs for their residential customers in the 1970s (Dehmel, 2011; Tews, 2011). In Switzerland, on the other hand, many utilities have an interruptible load tariff in order to switch off large users (e.g. the electric boiler) during peak hours. This helps to shift the peak demand to off-peak demand hours. Tariff measures may take the form of an efficiency bonus that rewards customers with rebates for reaching saving goals, or a tax that gets refunded to the households in equal parts.

The **third field of action** is consulting offers by a utility. We aggregate the various offers into six categories of measures: information (leaflets, web pages, etc.); public relations (fairs, etc.); rental of smart meters; information on the bill; energy advice centers; and energy audits. Since some utilities in Switzerland help their customers with the replacement of old and inefficient electricity heating systems and home appliances, we analyse this in the **fourth field of action** of the score. These programs for efficient appliances can either provide customers with information or financial means. The **fifth, and last, field of action** deals with actual spending on such measures. We use spending for financial programs per MWh sold to residential customers as an indicator.

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