An Evaluation of the Impact of Energy Efficiency Policies on Residential Electricity Demand in Switzerland

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Deutsche Zusammenfassung

Nach dem Atomunfall am 11. März 2011 in Fukushima hat der Bundesrat beschlossen, die Genehmigungsverfahren für neue Kernkraftwerke in der Schweiz auszusetzen. Der Bundesrat hat anschliessend entschieden, auf den Neubau von Kernkraftwerken dauerhaft zu verzichten. Darüber hinaus wurde festgelegt, dass die fünf bestehenden Kernreaktoren des Landes weiter betrieben werden können bis sie nach und nach ohne Ersatz am Ende ihrer sicherheitstechnischen Laufzeit stillgelegt werden. Die Implikationen einer solchen Entscheidung sind für ein Land wie die Schweiz weitreichend, da die Stromversorgung zu einem grossen Teil von der Kernkraft abhängt. Aus diesem Grund hat der Bundesrat die *Energiestrategie 2050* ausgearbeitet.

Die *Energiestrategie 2050* legt die Energie-Zukunft für die Schweiz ganz klar fest: "Der Bundesrat setzt in erster Linie auf eine konsequente Erschliessung der vorhandenen Energieeffizienzpotenziale und in zweiter Linie auf eine ausgewogene Ausschöpfung der vorhandenen Potenziale der Wasserkraft und der neuen erneuerbaren Energien. In einer zweiten Etappe der Energiestrategie will der Bundesrat das bestehende Fördersystem durch ein Lenkungssystem ablösen." Die *Energiestrategie 2050* versteht die Elektrizitätsversorgungsunternehmen (EVU) als wichtige Akteure für die Reduktion des Stromverbrauchs, da sie direkten Kontakt mit den Endkunden haben. Vor diesem Hintergrund hat der Bundesrat innerhalb des ersten Massnahmenpakets vorgeschlagen, verbindliche Effizienzziele für jene Versorgungsunternehmen festzusetzen, deren Versorgungsleistung 30 GWh übersteigt. Zudem sieht das Lenkungssystem, welches in der zweiten Etappe das bestehende Fördersystem ersetzen soll, eine Energiesteuer vor, welche einen Anreiz für einen verantwortungsvolleren Umgang mit den Ressourcen und für die Stabilisierung des Stromkonsums bis 2050 setzen soll.

Um effektive energiepolitische Instrumente zu entwerfen und einzuführen, ist es wichtig, dass politische Entscheidungsträger und Stromversorgungsunternehmen über Informationen verfügen, wie Konsumenten auf eine Preiserhöhung reagieren, und dass sie die Wirkung von aktuellen und vergangenen Energieffizienzmassnahmen kennen. Ziel dieses Projektes ist es, einerseits die Preiselastizität von Konsumenten in Bezug auf den Strompreis zu schätzen und andererseits die Energieffizienzmassnahmen von Schweizer Stromversorgern zu evaluieren.

Im ersten Teil des Projektes schätzen wir die kurz- und langfristige Strompreiselastizitäten von Schweizer Haushalten unter Verwendung einer Haushaltsumfrage und mit Hilfe eines Haushaltsgeräteindex sowie unter Berücksichtigung von Energiedienstleistungen. Wir berechnen den Geräteindex durch die Aggregation der wichtigsten Haupthaushaltsgeräte. Dieser Index benutzen wir um den Einfluss des Gerätebestands auf den Stromkonsum zu messen. Zudem berücksichtigen wir auch Energiedienstleistungen (wie zum Beispiel die Anzahl gekochter Mahlzeiten oder die Anzahl Waschmaschinenladungen) in unserer Schätzung. Für die Schätzung verwenden wir die Methode der Instrumentenvariablen um potentiellen Endogenitätsproblemen des Durchschnittspreises und des Geräteindex vorzubeugen und um so eine robuste Schätzung der Preiselastizität zu erhalten. Unsere Schätzungen ergeben eine kurzfristige Preiselastizität von -0.4 und eine langfristige Preiselastizität von -0.4 bis -0.6. Die kurz- und langfristigen Schätzungen sind vergleichbar mit anderen ähnlichen Studien für die Schweiz. Zudem erhalten wir ähnliche Resultate, wenn wir die in so einer Schätzung üblichen Haushaltscharakteristika durch die Variablen zu den Energiedienstleistungen ersetzen.

Im zweiten Teil des Projekts schätzen wir die kurz- und langfristige Elastizität des Strombedarfs auf der aggregierten Ebene unter Verwendung einer Umfrage, die auf einem Sample von 30 Schweizer Stromversorgern basiert und Daten von 2006 bis 2012 abfragt. Es handelt sich hierbei um einen unbalancierten Paneldatensatz. Unter Verwendung der Daten zu Haushaltsstromverbrauch, Stromtarifen, mittlerer Haushaltsgrösse, mittlerem steuerbarem Einkommen und zu Wetterfaktoren schätzen wir ein dynamisches Stromnachfragemodell. Während bei der Verwendung des Durchschnittsstrompreises in der Schätzung mit disaggregierten Haushaltsdaten ein Endogenitätsproblem auftreten kann, ist dies im Falle von aggregierten Daten weniger der Fall. Dies aus dem Grund weil wir in diesem Sample viele verschiedene Preislevel und Tarife an vielen verschiedenen Orten haben, was das Problem der möglichen Endogenität des Durchschnittsstrompreises mildert. Wir benutzen eine Korrektur des Least Squares Dummy Variablen-Schätzers, um die mögliche Endogenität der zeitverzögerten abhängigen Variable in einem dynamischen Nachfragemodell zu berücksichtigen. Wir erhalten eine kurzfristige Preiselastizität von etwa -0.3 und eine langfristige Preiselastizität von rund -0.6. Die kurzfristigen Ergebnisse sind vergleichbar mit den meisten anderen ähnlichen Studien für die Schweiz, aber höher als in ausländischen Studien. Die langfristigen Resultate sind hingegen tiefer als vergleichbare Studien aus dem Ausland.

Im dritten Teil des Projektes verwenden wir dieselben Umfragedaten wie im zweiten Teil des Projekts, um den Effekt von Demand-Side Management (DSM) Aktivitäten auf den Stromverbrauch zu schätzen. Dazu verwenden wir einerseits die Ausgaben für DSM-Programme und andererseits einen Energieeffizienz-Score. Mit Hilfe der Variation der DSM-Aktivitäten unter den Stromversorgern und über die Zeit versuchen wir die Wirkung dieser Programme zu identifizieren. Wenn wir die Ausgaben für DSM-Programme heranziehen, finden wir bei einer 10% Erhöhung der Ausgaben für DSM einem Rückgang von 0.14% des Verbrauchs. Um die Robustheit dieses Resultats zu checken, schätzen wir zusätzlich ein Model mit einer binären Variable, welche die An– oder Abwesenheit eines DSM-Programms misst. Auch hier finden wir einen signifikanten und negativen Effekt (Rückgang des Stromverbrauches). Um potentielle Endogenitätsprobleme des politischen Instruments zu testen führen wir verschiedene Robustheitschecks durch. Aus diesem dritten Teil können wir folgern, dass aktuelle DSM Aktivitäten in der Schweiz zwar einen statistisch signifikanten aber moderaten Effekt auf den Stromverbrauch von Haushalten haben.

Unsere ökonometrischen Schätzungen zeigen, dass aus der Sicht der politischen Entscheidungsträger, eine Preispolitik auf kurze Sicht einen kleinen Effekt auf die Stromnachfrage haben könnte. Auf lange Sicht hingegen haben wir eine höhere Preissensibilität festgestellt, was zeigt, dass die Haushalte langfristig auf eine Preispolitik reagieren. Es kann sein, dass der Effekt dennoch nicht so gross wie erforderlich ist, weshalb ein Instrumenten-Mix verwendet werden sollte, um die langfristige Stromnachfrage von Haushalten zu beeinflussen.

Die Dringlichkeit der *Energiestrategie 2050* unterstreicht die Notwendigkeit geeigneter politischer Instrumente um die Hindernisse des Wechsels von Atomstrom auf erneuerbare Energien abzufedern. Angesichts der fehlenden aktuellen Studien hinsichtlich der Abschätzung der Stromnachfrage-Preiselastizität in der Schweiz, insbesondere für Nicht-Haushalts-Konsumenten, ist es wichtig, dass in allen Sektoren weitere Forschungsprojekte durchgeführt werden, um zuverlässige Schätzungen bezüglich der Preissensibilität der Konsumenten zu bekommen. Diese ökonometrischen Abschätzungen des Strombedarfs können sowohl bei der Prognose der zukünftigen Stromnachfrage als auch bei der Planung von Produktions-, Übertragungs- und Verteilungskapazitäten behilflich sein. Zudem liefern unsere Schätzungen eine dringend benötigte neue Datenbasis für die Schweiz, welche zukünftigen Forschern aktuelle Strompreiselastizitäten von Schweizer Haushalten zur Verfügung stellt.

In unserer Analyse von DSM-Aktivitäten von Schweizer Stromversorgern zeigt sich, dass viele Stromversorger zwar auf irgendeine Art im DSM-Bereich aktiv sind, die Intensität aber vergleichsweise gering ist, wenn man die Situation mit den USA vergleicht. Wir fanden aber auch innerhalb der Schweiz eine relativ grosse Variation, wobei es einige Versorger mit grossen Ausgaben im DSM-Bereich gibt. Zudem stellen wir fest, dass in der Kommunikation das Thema Energieeffizienz im Vordergrund steht, wobei viele der Schweizer Versorger eher PR-Kampagnen und Bereitstellung von Information zum Thema Energieeffizienz einsetzen als finanzielle Anreize oder Energie-Audits. Es gibt aber auch einige wenige Versorger, die im DSM-Bereich viel investieren. Bei der Berechnung des Energieeffizienz-Scores über die Jahre 2006 bis 2012 beobachten wir einen ähnlichen Effekt. Es gibt einige wenige Versorger am oberen Ende, für den Rest gibt es, so glauben wir, ein grosses Potential.

Aus dem ökonometrischen Teil dieser Analyse können wir folgern, dass aktuelle DSM-Aktivitäten in der Schweiz einen statistisch signifikanten Effekt auf den Stromverbrauch von Haushalten haben. Mit der Hilfe der Resultate aus der ökonometerischen Schätzung mit der kontinuierlichen Variable für die Ausgaben für DSM-Programme schätzen wir durch eine simple kontrafaktische Überlegung die Kosten einer gesparten Einheit Strom, die in Abwesenheit des DSM Programms produziert worden wäre. Wir erhalten durchschnittliche Kosten von 0.04 CHF für eine eingesparte Kilowattstunde. Hier muss man betonen, dass es sich nur um eine grobe Abschätzung handelt, und mit Vorsicht in Betracht gezogen werden muss, da unsere Stichprobe relativ klein ist, und wir möglicherweise Messfehler der DSM-Ausgaben nicht ausschliessen können. Die Bandbreite für diese Kosten liegt zwischen 0.03 CHF und 0.09 CHF, die Kosten für die Produktion und Verteilung von Elektrizität in der Schweiz liegen jedoch über dieser Bandbreite. Angesichts unserer Ergebnisse scheint es, dass DSM Programme eine wertvolle Option für die Schweiz sein kann um die Ziele der *Energiestrategie 2050* zu verfolgen.

Abschliessend empfehlen wir in Zukunft regelmässig detailliertere Informationen über die Versorgungsunternehmen und ihre DSM Anstrengungen zu sammeln. Dies wird es den Forschern ermöglichen die Daten zu analysieren um anschliessend Regulatoren, politischen Entscheidungsträger und andere Interessenten über den Fortschritt *Energiestrategie 2050* der zu informieren.

Résumé français

A la suite de l'accident nucléaire de Fukushima du 11 mars 2011, le Conseil fédéral a décidé de suspendre les procédures d'autorisation pour les nouvelles centrales nucléaires en Suisse. Il a ensuite décidé de renoncer durablement à la construction de nouvelles installations. Les cinq réacteurs nucléaires actuellement en service en Suisse pourront continuer d'être exploités jusqu'à ce qu'ils soient progressivement mis hors service, sans être remplacés, à la fin de la durée conforme aux critères techniques de sécurité. Une telle décision entraîne des conséquences importantes pour un pays comme la Suisse où l'approvisionnement en électricité dépend en grande partie de l'énergie nucléaire. C'est pourquoi le Conseil fédéral a élaboré la *Stratégie énergétique 2050*.

La *Stratégie énergétique 2050* définit clairement les contours de l'avenir énergétique de la Suisse: "Le Conseil fédéral table en priorité sur une intégration systématique des potentiels d'efficacité

énergétique existants. Il mise ensuite sur l'exploitation adéquate des potentiels existants en matière de force hydraulique et d'énergies renouvelables. Dans une seconde étape, il souhaite remplacer le système d'encouragement existant par un système incitatif." La *Stratégie énergétique 2050* considère que les entreprises d'approvisionnement en électricité (EAE) – qui sont en contact direct avec les clients finaux – ont un rôle important à jouer en termes de réduction de la consommation électrique. Dans ce contexte, le Conseil fédéral a proposé, dans le premier volet de la stratégie, de fixer des objectifs d'efficacité contraignants pour les entreprises dont la puissance dépasse 30 GWh. En outre, le système d'incitation, destiné à remplacer le système d'encouragement existant, prévoit une taxe sur l'énergie qui doit favoriser une utilisation responsable des ressources et la stabilisation de la consommation d'électricité d'ici à 2050. Si l'on souhaite élaborer et mettre en œuvre des instruments de politique énergétique efficaces, il importe que les décideurs politiques et les entreprises d'approvisionnement en électricité disposent d'informations sur la manière dont les consommateurs réagissent aux augmentations de prix et sur les effets des mesures d'efficacité énergétique actuelles ou passées. L'objectif de ce projet consiste, d'une part, à estimer l'élasticité-prix des consommateurs par rapport au prix de l'électricité et, d'autre part, à évaluer les mesures d'efficacité énergétique prises par les fournisseurs d'électricité suisses.

La première partie du projet vise à définir les élasticités-prix à court et à long terme qui caractérisent les ménages suisses. Nous nous fondons pour ce faire sur un sondage effectué auprès des ménages, un inventaire des appareils ménagers et les prestations énergétiques en tant que telles. L'inventaire des appareils résulte de l'agrégation d'informations concernant les appareils ménagers les plus importants. Cet inventaire nous permet de mesurer l'influence des appareils sur la consommation d'électricité. Par ailleurs, nous prenons en compte les prestations énergétiques (nombre de repas cuisinés ou nombre de cycles de lavage, p. ex.). Dans notre estimation, nous appliquons la méthode des variables instrumentales afin de prévenir les problèmes liés à l'endogénéité du prix moyen et de l'inventaire des appareils, et nous obtenons ainsi une solide appréciation de l'élasticité-prix. Notre étude montre que l'élasticité prix à court terme est d'environ -0.4 alors qu'à long terme elle est comprise entre -0.4 et -0.6. Ces estimations à court et long terme correspondent à celles trouvées dans les études précédentes sur la Suisse. Nous obtenons également des résultats similaires en utilisant comme variable explicative la quantité de services énergétiques consommée par les ménages.

La seconde partie du projet évalue l'élasticité à court et à long terme de la demande en électricité, au niveau agrégé, sur la base d'un échantillonnage de 30 fournisseurs d'électricité suisses et de données couvrant la période de 2006 à 2012. Il s'agit ici d'une base de données de panel non équilibrée. Les données sur la consommation d'électricité des ménages, les tarifs d'électricité, la taille moyenne des ménages, le revenu imposable moyen et des facteurs météorologiques nous permettent de conclure à un modèle dynamique de demande d'électricité. Alors que l'utilisation du prix de l'électricité moyen dans l'estimation effectuée sur la base des données désagrégées sur les ménages peut présenter des problèmes d'endogénéité, cela est moins probable avec des données agrégées parce qu'un tel échantillonnage comprend plusieurs niveaux de prix différents et des tarifs pratiqués en de nombreux endroits différents, ce qui atténue le problème de la possible endogénéité du prix de l'électricité moyen. Nous procédons à une correction de l'estimation des variables fictives des moindres carrés, de manière à prendre en compte la possible endogénéité de la variable dépendante retardée dans un modèle de demande dynamique. Nos résultats indiquent que la demande d'électricité est inélastique à court et long terme. L'élasticité prix est à court terme d'environ -0.3 alors qu'elle est d'environ -0.6 à long terme. L'élasticité prix à court terme correspond à celle obtenue dans les études précédentes sur la Suisse. En comparaison avec les élasticités obtenues dans les études portant sur l'étranger, l'élasticité à court terme est plus grande alors que l'élasticité à long terme est plus faible.

Dans la troisième partie du projet, nous utilisons les mêmes données de sondage que dans la seconde partie pour mesurer l'effet d'activités de gestion de la demande (Demand-Side Management, ci-après DSM) sur la consommation d'électricité. Nous utilisons pour cela, d'une part, les dépenses consenties pour les programmes DSM et, d'autre part, une note d'efficacité énergétique. En nous aidant de la variation des activités DSM enregistrées en fonction des fournisseurs d'électricité et au cours du temps, nous essayons d'identifier l'impact de ces programmes. Ainsi, une augmentation de 10% des dépenses pour les programmes DSM correspond un recul à de 0,14% de la consommation. Afin de vérifier la robustesse de ce résultat, nous faisons en outre appel à un modèle utilisant une variable binaire qui mesure les effets de la présence ou de l'absence d'un programme DSM. Nous aboutissons, ici également, à un résultat négatif significatif (recul de la consommation). Nous procédons à plusieurs tests de robustesse afin d'identifier les problèmes potentiels d'endogénéité de l'instrument politique. Il résulte de cette troisième partie que les activités DSM menées actuellement en Suisse, bien que significatives sur le plan statistique, ont un effet modéré sur la consommation des ménages.

Nos estimations économétriques indiquent aux décideurs politiques qu'une politique de prix ne devrait avoir qu'un faible impact à court terme. Sur la durée en revanche, nous avons constaté une sensibilité aux prix plus élevée, ce qui illustre que les ménages réagissent à long terme à une politique des prix. Il est toutefois probable que l'effet ne soit pas aussi important que souhaité, raison pour laquelle une combinaison d'instruments devrait être nécessaire si l'on veut influencer durablement la demande des ménages.

L'importance de la *Stratégie énergétique 2050* illustre la nécessité de disposer d'instruments politiques appropriés pour surmonter les difficultés qu'implique le passage de l'électricité nucléaire aux énergies renouvelables. Etant donné le peu d'études récentes concernant l'élasticité prix de la demande d'électricité en Suisse, en particulier concernant les consommateurs hors ménages, il est primordial d'approfondir les recherches sur ce sujet. Il serait important de poursuivre l'analyse sur tous les secteurs et pour tous les types de consommateurs, ménages et hors ménages, afin d'estimer correctement la réactivité des consommateurs face aux variations de prix. Ces analyses économétriques des besoins en électricité peuvent être utiles lorsqu'il s'agit de prévoir la demande d'électricité ou de planifier les capacités de production, de transport et de distribution. Nos estimations constituent une nouvelle base de données indispensable pour la Suisse, qui fournit aux futurs chercheurs des données actuelles sur les différentes élasticités-prix des ménages helvétiques.

Notre analyse montre en outre qu'en Suisse, même si de nombreux fournisseurs d'électricité mènent diverses activités de DSM, l'intensité de ces mesures est restreinte en comparaison de la situation aux Etats-Unis. Nous avons aussi constaté des variations plutôt importantes au sein de la Suisse, quelques fournisseurs consacrant des dépenses importantes au domaine du DSM. Nous observons par ailleurs que le thème de l'efficacité énergétique occupe l'avant-scène de la communication: même si quelques fournisseurs suisses, peu nombreux, investissent des moyens conséquents dans le domaine du DSM, nombreux sont ceux qui préfèrent organiser des campagnes de promotion et d'information sur le thème de l'efficacité énergétique plutôt que mettre en place des incitations financières ou des audits énergétiques. Les calculs de la note d'efficacité énergétique sur les années 2006 à 2012 reflètent la même tendance. Peu de fournisseurs obtiennent des résultats excellents, et il reste un potentiel important à exploiter pour la majorité d'entre eux.

La partie économétrique montre que les activités de DSM actuellement menés en Suisse ont un effet statistiquement significatif sur la consommation d'électricité des ménages. A l'aide des résultats de l'estimation économétrique, qui s'appuie sur la variable continue des dépenses consacrées aux programmes DSM, nous effectuons une analyse comparative simple pour estimer les coûts d'une unité de courant économisée qui aurait été produite en l'absence du programme DSM. Le coût d'un kilowattheure économisé revient à 0,04 CHF. Il convient de souligner ici qu'il ne s'agit que d'une estimation approximative qui doit être considérée avec prudence étant donné que notre échantillonnage est relativement restreint et que des erreurs de mesure des dépenses consacrées aux DSM ne peuvent pas être exclues. Ces coûts se situent dans une fourchette allant de 0,03 CHF à 0,09 CHF alors que les coûts de production et de distribution de l'électricité en Suisse sont à un niveau plus élevé. Selon notre étude, il apparaît que les programmes de DSM constituent une option intéressante afin d'atteindre les objectifs de la *Stratégie énergétique 2050*.

Pour conclure, nous recommandons de réunir régulièrement des informations détaillées sur les entreprises d'approvisionnement et leurs activités dans le domaine des DSM. Les chercheurs pourront ainsi analyser ces données de manière à informer les régulateurs, les décideurs politiques et d'autres acteurs intéressés sur les progrès de la *Stratégie énergétique 2050*.

English summary

Following the Fukushima Daiichi nuclear accident on 11 March, 2011 the Swiss Federal Council decided to suspend the approvals process for new nuclear reactors in Switzerland. The Council 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 a country like Switzerland which is, at the moment, heavily reliant on its nuclear reactors. The Federal Council has, therefore, developed a long-term energy policy, *Energy Strategy 2050*.

The *Energy Strategy 2050* sets out the future for Switzerland very clearly by stating that it "is focusing on increased energy efficiency, the expansion of hydropower and use of new renewable energy, and in a second step the Council wants to replace the existing promotion system with a steering mechanism". The *Energy Strategy 2050* sees the utilities as key players for reducing electricity consumption because they have direct contact with end-customers. With this in mind the Federal Council has proposed, within the initial package of measures, mandatory efficiency goals for the utilities that sell more than 30 GWh as one way to reduce electricity consumption. The *Energy Strategy 2050* also includes, in a later phase, a possible ecological tax reform. This will introduce an energy tax to provide an incentive for a more responsible use of resources and the stabilisation of electricity consumption by 2050.

In order to design and implement effective energy policy measures it is important for policy makers and utilities to have information on the response of consumers to an increase in electricity prices

as well as on the impact of current and past energy efficiency programmes on the electricity demand. The overarching goal of this project is to provide more information on the price elasticity of residential electricity demand and to evaluate demand-side management programmes introduced by some Swiss utilities.

In the first part of the project we estimate the long- and short-run price elasticities of residential electricity consumption in Switzerland from a household survey by constructing an index of the stock of household appliances as well as by using energy services. We create the index by aggregating the information on the major household appliances. The index is used to estimate the impact of appliances on residential electricity demand. Furthermore, we also use energy services (like number of cooked meals or number of washing cycles) to estimate the electricity demand. We adopt an instrumental variables approach to obtain consistent estimates of the price elasticity to account for potential endogeneity concerns with the average price as well as the appliance index. Our results indicate that the price elasticity in the short-run is around -0.4 while in the long-run it ranges between -0.4 and -0.6. The short- and long-run estimates are similar to comparable studies for Switzerland. We also find that estimates of the electricity demand when we substitute the usual residential characteristics with energy services are very similar.

In the second part of the project we estimate the short- and long-run elasticity of electricity demand at the aggregate level from a recent survey carried out on a sample of Swiss utilities. Using information on residential electricity consumption, electricity prices, average household size, average taxable income and weather factors from an unbalanced panel dataset of 30 utilities covering 7 years from 2006 till 2012 we estimate a dynamic model of electricity consumption. While the average price of electricity we calculate may suffer from a problem of endogeneity, as when using disaggregated data, the fact that we use aggregate data means that the potential for the price to be endogenous with consumption is mitigated by the presence of many different pricing levels and schemes at different locales. We use a correction for the least squares dummy variable method to account for the endogeneity of the lagged dependent variable in a dynamic electricity demand model. Our results indicate that the price elasticity of electricity is inelastic, both in the short- and long-run. We estimate the short-run price elasticity to be about -0.3 while the long-run price elasticity is about -0.6. The short-run estimates are similar to most comparable studies for Switzerland but higher than other countries while the long-run estimates are lower than comparable studies for other countries.

In the third part of the project we use data from a survey conducted on 30 Swiss utilities from 2006 to 2012 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 programmes. If we consider the amount of monetary spending, a continuous measure, a 10% increase in DSM spending causes around a 0.14% reduction in per customer residential electricity consumption. To check for the robustness of this result we also consider a binary variable to denote the presence or absence of these programmes and find that they reduce per customer residential electricity consumption. We then conduct several robustness checks for potential endogeneity issues of the policies and conclude that current DSM practices in Switzerland, while statistically significant, have a moderate effect.

Our estimates indicate that, from the point of view of policy makers, pricing policy as an instrument may have a small impact in the short run. However, since the estimates of the long-run price elasticity of electricity consumption are generally higher this indicates that households will be influenced by pricing policy even though the impact may not be as substantial as needed and a combination of policies may be necessary to affect long-term electricity demand.

The importance of *Energy Strategy 2050* emphasises the need to have appropriate energy policies in place to mitigate the difficulties of a switch away from nuclear energy to other sources of electricity. Given the lack of recent studies in the estimation of the price elasticity of electricity demand in Switzerland, especially for non-residential consumers, it is important that further research is carried out in all sectors, residential and non-residential, to obtain reliable estimates of the responsiveness of customers to price changes. In terms of other implications for policy, the estimates provide policy makers and utility companies with estimates needed for forecasting electricity demand and enable them to plan for generation, transmission and distribution capacities. Our estimates are also a much-needed update for Switzerland and will provide future researchers with current values of price elasticities for residential electricity demand.

In our analysis of DSM programmes by Swiss electric utilities we find that while a lot of utilities have some kind of DSM programmes in place, the intensity of such programmes is lacking when compared to a country like the US. 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. We also calculate an energy efficiency score for each of the surveyed utilities from 2006 to 2012. We observe 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 analysis of current DSM activities in Switzerland on residential electricity consumption indicate that the impact appears to be statistically significant. Using the results of the econometric estimation we perform a simple counterfactual exercise, with the continuous monetary spending DSM variable, 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 is from a low of CHF 0.03 to CHF 0.09 while the current cost of producing and distributing electricity in Switzerland is higher than this range. Given our findings, it appears that DSM programmes may be a valuable option as Switzerland pursues its goals in *Energy Strategy 2050*.

Finally, our suggestion is to gather information on utilities and their DSM efforts on a regular basis. This will enable researchers to analyse the data and then inform regulators, policy makers and interested parties on the progress made in *Energy Strategy 2050*.

1 Introduction

The Fukushima Daiichi nuclear accident on 11 March, 2011 led to worldwide discussions about the security of nuclear power plants and energy policy issues. In Germany, the chancellor Angela Merkel imposed a moratorium for three months on announced extensions for existing nuclear power plants and shut down seven 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 has 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. The referendum for this took place in June 2011, just after the Fukushima incident, and a majority voted against this plan (Jorant, 2011). In Switzerland the Federal Council decided to suspend the approvals process for new nuclear reactors. The Council 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.[1] The implications of a switch in electricity generation from nuclear to other sources are important for a country like Switzerland which is, at the moment, heavily reliant on its nuclear reactors. 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, 2013a).

Even before the Fukushima incident the way forward for Switzerland in terms of its energy and climate policies had been discussed since 2004 when work started on *Energy Perspectives 2035* by the Swiss Federal Office of Energy. The results of this research led to the introduction of the Swiss Electricity Supply Law (StromVG) in 2007 as well as the start of liberalisation in the Swiss electricity market. The Swiss Federal Council and Swiss Parliament also discussed and worked on new energy policies. The Fukushima incident led to further debate on the future direction of Swiss energy policies. The Federal Council proposed the *Energy Strategy 2050* that sets out the future for Switzerland very clearly by stating that it "is focusing on increased energy efficiency, the expansion of hydropower and use of new renewable energy, and in a second step the Council wants to replace the existing promotion system with a steering mechanism." With regard to the focus on energy efficiency, the *Energy Strategy 2050* includes an initial package of measures with mandatory efficiency goals for utilities and, in a later phase, a possible ecological tax reform.

The proposal in the *Energy Strategy 2050* to include mandatory efficiency goals for utilities underlines the need to analyse existing policy instruments to promote energy efficiency. These instruments may be either market based or non-market based. Examples of market based instruments are rebates and taxes while non-market based usually involve information campaigns, eco-labelling and appliance standards. These policy instruments are usually considered to be a part of demand-side management (DSM) initiatives undertaken by governments and local utilities. 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).

In Switzerland, local utilities play an important role in the implementation of DSM programmes. The proposal in the *Energy Strategy 2050* to include mandatory efficiency goals for utilities underlines the need to analyse existing DSM initiatives in Switzerland and evaluate the effectiveness of such

[1] This decision is not final yet because it has not gone through the parliament yet and there is a possibility of a referendum.

programmes using econometric techniques. The other proposal in the *Energy Strategy 2050* for a possible ecological tax reform has, as its basis, a plan to introduce an energy tax to provide incentives for a more responsible use of resources and to stabilise the consumption of electricity by 2050.[2] To be able to find out the effectiveness of an energy tax on electricity consumption it is important to obtain credible estimates of the responsiveness of electricity demand to its price. These estimates will also provide policy makers and utility companies with estimates needed for forecasting electricity demand and enable them to plan for generation, transmission and distribution capacities.

Although DSM includes load management and energy efficiency programmes, we consider only energy efficiency and conservation measures but not load management programmes for our econometric estimation. However, we consider both energy efficiency and conservation measures as well as load management programmes in Switzerland for our descriptive analysis.

The overarching objectives of this project are to provide more information on the price elasticity of residential electricity demand and to evaluate energy efficiency programmes introduced by some Swiss utilities. The specific objectives of this research project are the following:

1. Estimate the residential demand for electricity by using aggregated and disaggregated data
2. Estimate the short- and long-run price elasticities of residential electricity consumption using different approaches and data sets
3. Provide a descriptive analysis of demand-side management programmes of Swiss utilities and evaluate their impact on residential electricity consumption using data from a survey conducted on Swiss utility companies

Using the specific objectives as a guide, we divide our project into the following four chapters that reflect the purpose of our project:

In chapter 2 ("Estimating Residential Electricity Demand: New Empirical Evidence Using Household Data") we use disaggregated data to analyse the impact of electricity price and stock of household appliances on residential electricity demand. The disaggregated data is from a survey conducted by the Verband Schweizer Elektrizitätsunternehmen (VSE) in 2005 and 2011. Five major utility companies were surveyed in each year and 2,074 households participated. The survey includes details about electricity consumption, the stock of electrical appliances in residences, the age of the major appliances and their usage, measured in hours, per day. This chapter is adapted from Boogen et al. (2014).

In chapter 3 ("Dynamic Models of Residential Electricity Demand") we use aggregated data to estimate the short- and long-run residential electricity demand using a dynamic model of electricity demand. The aggregated data is a panel data from 30 utilities over a period from 2006 to 2012 that uses information from a survey conducted by ourselves. We obtained data on the number of households in the residential sector, electricity prices, household electricity demand and various energy efficiency measures and their annual expenditures on such measures.

In chapter 4 ("Demand-Side Management by Electric Utilities: Analysing its Impact on Residential Electricity Demand") we use aggregated data, from the same survey as in chapter 3, to provide a descriptive analysis as well as analyse the impact of energy efficiency policies and spending on residential electricity demand. We exploit the variation within utilities and across time in EE policies

[2] This issue is is in consultation (Vernehmlassung) until June 2015 and comes into the Swiss parliament later.

of Swiss electricity companies to identify the impact of such policies. Using the results of the econometric estimation we calculate the cost to a utility of not producing a kilowatt hour attributed to the impact of DSM programmes and compare it to the current average cost of producing and distributing electricity.

The final chapter, chapter 5, offers concluding remarks, provides some policy implications of the project and some recommendations for the future of Swiss energy policy.

2 Estimating Residential Electricity Demand: New Empirical Evidence Using Household Data

2.1 Introduction

In order to find out the effectiveness of an energy tax on electricity consumption it is important to obtain credible estimates of the responsiveness of electricity demand to its price. In this chapter, we ask three research questions. Firstly, what is the price elasticity of residential electricity consumption? This will enable the design of appropriate pricing policies by utilities and the regulatory authorities to reduce electricity consumption as well as provide a way to forecast demand and plan for generating capacity in the future. Secondly, how does the stock of electrical appliances affect the consumption of residential electricity? This will enable us to obtain a more precise estimate of the price elasticity. Finally, what is the impact of using energy services, such as the number of meals cooked at home and the amount of time spent using personal computers and watching television, on the electricity consumption of a household? How is the price elasticity of demand for electricity affected if we use such measures instead of the usual method of approximating energy services with household and socio-demographic characteristics?

To answer these questions we use data from a survey of Swiss households served by seven electric utility companies and conducted by the Verband Schweizerischen Elektrizitätsunternehmen (VSE) in 2005 and 2011.[3] The survey contains information on a household's stock of appliances, the usage behaviour, and various socio-demographic characteristics. The survey also reports the electricity consumption of each household in the previous billing cycle.[4] We find that Swiss households are price inelastic in electricity and the price elasticity in the short-run is around -0.4 while in the long-run it ranges between -0.4 and -0.6. These results can be used by policy makers and utility companies to design instruments to reduce and modify electricity consumption.

The rest of the chapter is organised as follows. In the next section we provide an overview of residential electricity demand in Switzerland while section 2.3 describes previous literature on estimating electricity demand using disaggregate data. We present the motivation for using a modified model of household production to derive a model for estimating electricity demand and a description of our empirical strategy in section 2.4. Section 2.5 describes the household survey as well as other sources of data. The penultimate section, section 2.6, presents the results of our empirical specifications while the final section has concluding remarks.

2.2 Residential Electricity Demand in Switzerland

In Switzerland, 718 utility companies (as of September 2012) are involved in the production, distribution and supply of electricity (ElCom, 2013). These utilities are very heterogeneous, ranging in size from small municipal utilities to international operating companies. In 2011 these utilities sold 17.9 TWh to their residential customers. The mean household consumption was 5,167 kWh and the mean per capita consumption was 2,268 kWh (SFOE, 2013a). We compare these values to those of its neighbours (Austria, France, Germany and Italy), the EU average and the US in Table 1, and find that while Italy, Germany and the EU (on average) use less electricity, both per household and per

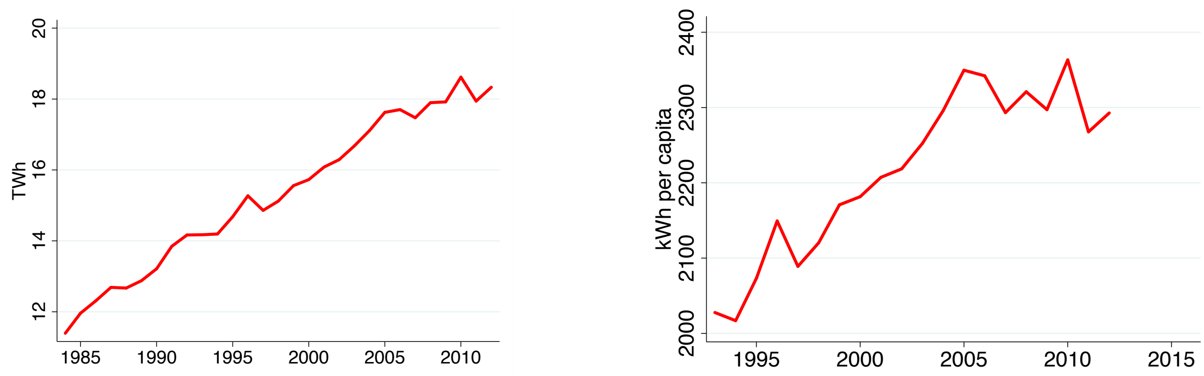
[3] The VSE is the Swiss Association of Electric Utilities.

[4] The billing cycle is one year so the electricity consumption reported is the electricity consumed in the previous year.

Table 1: Selected electricity consumption (in kWh)

	Per Capita	Per Household
Switzerland	2,268	5,167
Germany	1,714	3,454
France	2,277	4,977
Austria	2,212	4,931
Italy	1,153	2,735
European Union	1,611	3,888
USA	4,569	11,789

Source: World Energy Council (2013)



(a) Total Demand from 1984-2012.

(b) Per Capita Demand from 1993-2012.

Figure 1: Residential electricity demand in Switzerland (*Source*: SFOE 2013a)

capita, France and Austria are similar. Only US households consume a lot more with about double the consumption of Swiss households. If we consider the trend of Swiss electricity consumption over the years we see, in Figure 1, that it is growing at a steady rate but the per capita consumption has flattened out from 2005.

2.3 Previous Work

There are a number of studies that estimate long- and short-run price elasticities for residential electricity demand using aggregated as well as disaggregated data.[5] Using one or the other type of data has its advantages as well as disadvantages. Therefore, in this report we will use both types of data. We use a household survey, i.e. data at the disaggregated level, in this chapter to estimate the residential electricity demand. Chapter 3 uses aggregate data at the utility level to estimate the electricity demand. Both approaches encounter similar issues in terms of the possible endogeneity of the electricity price, obtaining a measure of the stock of household appliances and information on the activities for which electricity is used. One of the objectives of estimating electricity demand is to ensure that these issues are minimised as much as possible and, therefore, using aggregated or disaggregated can help in achieving this. Using data at a disaggregated level can add great detail to the knowledge of consumer response due to the heterogeneity of residential consumers.

[5]Refer to section 3.2 for studies using aggregated data.

As noted by Dubin and McFadden (1984), using disaggregated data avoids misspecification error caused by aggregation bias from using aggregate electricity consumption and prices. Table 2 provides an overview of some selected estimated price elasticities for electricity using disaggregated data in the literature. For example, Reiss and White (2005) use a sample of about 1,300 Californian households from the Residential Energy Consumption Survey (RECS) in 1993 and 1997 to estimate price and income elasticity using marginal price and a set of appliances. They find considerable amount of heterogeneity in the estimated elasticities across income and other demographic characteristics. Yoo et al. (2007) use survey data from 380 households in Seoul and a bivariate model to account for sample selection. They find significant sample selection bias and also find that a plasma TV or an air conditioner has a significant positive impact in residential consumption. However, the electricity demand estimated by using the average price appears to be price (-0.25) and income inelastic (0.06).

On the other hand, Alberini et al. (2011) find a much higher price response by residential consumers (-0.74 in the short-run to -0.81 in the long-run). They use a mix of panel data and multi-year cross-section household-level data from over 70,000 households in the 50 largest metropolitan areas in the United States from 1997 to 2007. To correct for a possible measurement problem the average electricity price is instrumented with state-level electricity and gas prices or lagged electricity prices. In contrast to Reiss and White (2005), they find no evidence of significantly different price elasticities for households with electric and gas heating systems. Fell et al. (2014) use monthly data from a consumer expenditure survey collected between 2006 and 2008 to estimate the price elasticity. Using expenditure data and state-level average electricity prices to compute the quantity of electricity consumed they have two possible sources of endogeneity that they solve with a GMM approach. They estimate an own price elasticity of around -0.5 which is at the higher end for cross-sectional studies.

There are only a few previous studies in Switzerland using disaggregated data. Table 2 also provides an overview of disaggregated studies within Switzerland. Among the first studies using disaggregated data are those by Dennerlein and Flaig (1987) and Dennerlein (1990). Dennerlein and Flaig (1987) use pooled cross-section data of almost 6,000 households collected with an expenditure survey from 1975 to 1984. This survey also includes information about the ownership of some appliances. They estimate the electricity demand as well as two separate discrete choice (probit) models for the ownership of electric stoves and TVs. Moreover, they also control for the ownership of electric stoves, electric water and space heating and TVs and find short-run elasticities between -0.2 and -0.4 and long-run elasticities of between -0.4 and -0.6. Dennerlein (1990) uses the same database but from 1977 to 1986 and finds slightly higher short-run (-0.5) and long-run (-0.7) elasticities using average prices. However, both these studies may suffer from potential simultaneity issues because the choice of appliances may depend on the consumption of electricity.

Zweifel et al. (1997) use data from around 1,300 households from different years (1989–92) and group them in three different pools depending on whether households have a single-tariff structure, a time-of-use structure and a time-of-use structure by choice. These households are customers of utilities that have either both structures or a time-of-use scheme. For the first group, the price elasticity is very small and not significant. But for the second and third groups the elasticities, estimated by OLS, are significant and -0.66 and -0.59, respectively. Excluding the city of Zürich in the third group reduces the elasticity to -0.42. However, the variation of electricity price in this study is based on only three utility companies and is, therefore, low. Since the 1990s there has been no study using disaggregated data in Switzerland to estimate the price elasticity of residential electricity demand and this chapter provides an update using a unique household survey.

Table 2: Selected price elasticities using disaggregated data in the literature

Author(s)		**Short-run**	**Long-run**
International			
Tiwari (2000)	Mumbai, India	-0.61 to -0.84	
Halvorsen and Larsen (2001)	Norway	-0.433	-0.442
Reiss and White (2005)	California, USA	-0.39	
Yoo et al. (2007)	Seoul, South Korea	-0.25	
Alberini et al. (2011)	USA	-0.74	-0.81
Fell et al. (2014)	USA	-0.5	
Switzerland			
Dennerlein and Flaig (1987)		-0.2 to -0.4	-0.4 to -0.6
Dennerlein (1990)		-0.5	-0.7
Zweifel et al. (1997)		-0.42 to -0.66	

All the studies mentioned above use individual appliance dummy variables to control for the effect of appliances. To the best of our knowledge, Garbacz (1984) and Tiwari (2000) are the only studies that use the concept of an appliance index. Garbacz (1984) develops a three-equation model with an electricity demand equation, an appliance stock equation and an equation for the electricity price. However, his appliance index is based on typical usage of the individual appliances in kWh and not a measure of typical capacity. Tiwari (2000) calculates the index using the average power requirement of individual appliances. He uses a survey of 6,000 households between 1987 and 1988 from the Bombay Metropolitan Regional Development Authority (BMRDA). He estimates the residential electricity demand using average electricity price, income, dwelling characteristics, household characteristics and an appliance index. The appliance index is composed of the average power of a television, iron, video and tape recorder, radio and refrigerator owned by the household relative to the maximum power available. He estimates the short-run price and income elasticities to be -0.70 and 0.34, respectively. However, the study ignores the possible endogeneity problem caused by using the average electricity price as well as the simultaneity bias caused by using an appliance index.

This chapter contributes to the existing literature in several ways. Firstly, we use a unique survey of households conducted in Switzerland that includes extensive information about a household's stock of appliances. Secondly, we use an instrumental variables approach to account for the possible endogeneity of the average price of electricity as well as the stock of household appliances. Thirdly, our theoretical model is based on household production theory that posits electricity demand as being a derived demand for energy services. We estimate our model using information collected from the survey that includes, e.g., the number of meals cooked and washing done by a household. Estimating the electricity demand using energy services has, to the best of our knowledge, not been done before and this aspect is a significant contribution to the existing literature. Finally, we use an appliance index as an aggregate measure of the household's stock of appliances. This is more precise than using dummy variables since we are able to incorporate vintage and size among other characteristics. Also, given that the stock of appliances suffers from a potential endogeneity problem, we do not need to include multiple instruments. As is well-known in the applied econometrics literature, using many instruments for many endogenous variables could, potentially, lead to a problem of weak instruments.[6]

2.4 Model and Empirical Strategy

The residential demand for electricity is considered to be a derived demand since electricity is consumed to provide us with services, e.g. an electric heater providing warmth. We ultimately derive equations for the long- and short-run residential electricity demands by using a simplified version of household production theory whereby households combine electricity and capital goods to obtain energy services.[7] Solving the optimisation procedure we obtain the demand function for electricity, E, as being determined by the prices of electricity and capital as well as the energy services consumed by a household:

$$\begin{aligned} E^* &= E(P^E, P^K, S^*(P^E, P^K, M, Z)) && \text{(1a)} \\ &= E(P^E, P^K, M, Z), && \text{(1b)} \end{aligned}$$

where P^E and P^K are the prices of electricity and capital, respectively, S is the amount of energy services consumed, M is the household income and Z is a matrix of socio-demographic and residential characteristics. Equation (1a) indicates that electricity consumption depends on the electricity price, prices of the stock of appliances and the equilibrium amount of energy services consumed. This implies that, if we can obtain measures of the price variables and the quantity of energy services consumed, we will be able to estimate the electricity demand. Typically, the amount of energy services, as in equation (1a), are not measured and are, instead, approximated by including residential and socio-demographic characteristics. Therefore, we can also use equation (1b) to estimate the electricity demand. This represents electricity consumption as a function of electricity price, price of the stock of appliances and household income. It is also a function of other household characteristics.

The demand function for household appliances, or capital, K is also determined by the prices of electricity and capital as well as the energy services consumed by a household:

$$\begin{aligned} K^* &= K(P^E, P^K, S^*(P^E, P^K, M, Z)) && \text{(2a)} \\ &= K(P^E, P^K, M, Z). && \text{(2b)} \end{aligned}$$

[6]We consider 11 appliances and, therefore, we would have needed to find at least 11 instrumental variables. This would have led to the problem of weak instruments being extremely severe.

[7]See Deaton and Muellbauer (1980) for a description of household production theory and Dubin (1985), Flaig (1990) and Filippini (1999) for an application to electricity demand analysis. Note that there is no labour input in this version of the household production model.

The equations for E^* and K^* represent the long-run equilibrium consumption amounts for a household. While it is empirically possible to estimate equations (1b) and (2b) simultaneously, researchers limit themselves to estimating equation (1b). Since we are interested in estimating residential electricity demand we will focus our analysis on estimating E^*.[8]

Equation (1b) is a static model in the sense that the adjustment of electricity consumption is instantaneous if there is a change in any of the determinants of electricity consumption. It also reflects the fact that the rate of utilisation and the stock of appliances are adjusted instantaneously when there are changes in prices or income. However, the instantaneous adjustment of the stock of appliances may be a relatively strong assumption. For this reason, it is important to estimate the electricity demand with a short-run perspective in which the stock of appliances cannot be adjusted while it can be in the long run.

With the above discussion in mind, we now present the short- and long-run electricity demand models used in our study. The short-run electricity demand equations corresponding to (1a) and (1b), respectively, can be written as

$$E^{SR} = E^{SR}(P^E, K, S^*(P^E, K, M, Z)) \tag{3a}$$
$$= E^{SR}(P^E, K, M, Z), \tag{3b}$$

where K denotes a given stock of appliances and the superscript SR refers to the short run. Capital stock is assumed to be fixed in the short run. One way to measure a household's stock of appliances is to construct an index by using the capacity of the major appliances owned by the household. Tiwari (2000) uses this method to get an approximate measure of the appliance stock owned by a household.

In the long-run, however, the electricity demand equations corresponding to (1a) and (1b), respectively, can be written as

$$E^{LR} = E^{LR}(P^E, P^K, S^*(P^E, P^K, M, Z)) \tag{4a}$$
$$= E^{LR}(P^E, P^K, M, Z), \tag{4b}$$

where the superscript LR refers to the long run. Equations (4a) and (4b) indicate that the long-run electricity demand changes when the prices of electricity and appliance stock change. Obtaining an estimate of the price of the stock of appliances is key to estimating the long-run equilibrium of electricity consumption and one way is to calculate the price index of the appliance stock by using the capacity of the major appliances owned by the household (the index used in the short-run estimation). This is adjusted with the price of the corresponding appliance to determine the price index of the appliance stock.

Finding an estimate of the price of the stock of appliances is key to estimating the long-run equilibrium of electricity consumption, as denoted by equations (4a) and (4b). We can then estimate the short- and long-run price elasticity of electricity consumption by utilising stock and price information

[8]However, as described later, since we use a two-stage instrumental variable procedure to account for the potential endogeneity of the stock of appliances we are, in effect, estimating the demand for capital, as given by equation (2b). The results of this estimation are provided by the estimates in the first stage of the instrumental variable (IV) regression. The results of the first stages are provided in the Appendix since this part is not the focus of this chapter.

of the appliances, respectively. The previous discussion provides the motivation in terms of the explanatory variables for our econometric model specification. Using a log-log functional form, as is common in the literature, the long-run electricity demand function for household i can be written as

$$\text{ln}E_i^{LR} = \alpha_0 + \alpha_1 \text{ln}p_i^E + \alpha_2 \text{ln}p_i^K + S_i\delta^{LR} + \epsilon_i. \tag{5a}$$

$$\text{ln}E_i^{LR} = \alpha_0' + \alpha_1' \text{ln}p_i^E + \alpha_2' \text{ln}p_i^K + \alpha_3' \text{ln}M_i + Z_i\gamma^{LR} + \epsilon_i', \tag{5b}$$

where α_1 and α_1' are the parameters to be estimated for the price of electricity p_i^E, α_2 and α_2' are the parameters to be estimated for the price of household appliances p_i^K, δ^{LR} is a vector of parameters to be estimated for energy services S, α_3' is the the parameter to be estimated for household income M_i, γ^{LR} is a vector of parameters to be estimated for household characteristics Z_i, and ϵ_i and ϵ_i' are the usual error terms, assumed to be independently and identically distributed. An advantage of using a log-log specification is that the coefficient of electricity price, e.g., α_1, is easily interpreted as the price elasticity of electricity demand. This means that a one percent change in electricity price will cause an α_1% change in the electricity consumption, keeping all else the same.

The short-run electricity demand function for household i can be written as

$$\text{ln}E_i^{SR} = \beta_0 + \beta_1 \text{ln}p_i^E + \beta_2 K_i + S_i\delta^{SR} + \nu_i. \tag{6a}$$

$$\text{ln}E_i^{SR} = \beta_0' + \beta_1' \text{ln}p_i^E + \beta_2' K_i + \beta_3' \text{ln}M_i + Z_i\gamma^{SR} + \nu_i'. \tag{6b}$$

where, similar to before, β_1 and β_1' are the parameters to be estimated for the price of electricity p_i^E, β_2 and β_2' are the parameters to be estimated for the stock of household appliances K, δ^{SR} is a vector of parameters to be estimated for energy services S, α_3' is the the parameter to be estimated for household income M_i, γ^{SR} is a vector of parameters to be estimated for household characteristics Z_i, and ϵ_i and ϵ_i' are the usual error terms, assumed to be independently and identically distributed. In contrast to the long-run equations, the short-run equations include the household's stock of appliances instead of the price of appliances.[9]

The method to calculate the electricity price is crucial to estimate the price elasticity of electricity. While the literature on this is substantial, the main approaches can be divided into two strands. The first approach uses average prices while the second uses marginal prices. Nordin (1976) suggests using the marginal price (and subtract the fixed fee from the income). Shin (1985) uses the average price. The average price of electricity is obtained by dividing the electricity bill with the quantity of electricity consumed. In our case, we use the marginal price and fixed fee, if any, to calculate the electricity bill by multiplying the electricity consumption with the marginal price and then adding the fixed fee.

The advantage of using the marginal price over the average price is its exogeneity, i.e. the marginal price of electricity will affect electricity consumption but not the other way round. Since the average price is calculated by dividing spending on electricity, that usually includes a fixed fee, with the quantity consumed there exists the problem of simultaneous causality which leads to the

[9] An alternative approach is to estimate the long- and short-run price elasticities by using a partial adjustment model. Unfortunately, we cannot use this approach since we do not have panel data. See Alberini and Filippini (2011) and Blázquez et al. (2013) for applications.

average price being an endogenous explanatory variable. However, as has been discussed in the literature, the average price is probably more important than the marginal price since households are more concerned about their total electricity bill rather than the price of electricity at the margin (e.g., Shin (1985), Borenstein (2009) and Ito (2014)). We, therefore, use the average price in our analysis.[10] We use instrumental variables in two-stage least squares models to account for the potential endogeneity issues stemming from using the average price.

As mentioned before, the way we incorporate a household's stock of appliances will enable us to estimate the long- and short-run price elasticities of demand for electricity. In our analysis, we use an index of the stock of appliances to estimate the short-run price elasticity. The index is calculated by using the estimated capacities (in Watt) of a household's stock of major appliances. The appliance stock, however, may suffer from simultaneity bias since the choice of appliances may depend on the consumption of electricity (Dubin and McFadden, 1984). Therefore, the stock of appliances may be endogenous in the estimating equation and we use instrumental variables to account for this potential bias. An advantage of constructing an aggregate index of individual appliances instead of using the appliances individually is the avoidance of using multiple instrumental variables to account for the potential endogeneity of the appliances. Since we consider many appliances it is very difficult to find instruments for multiple endogenous variables due to the possibility of weak instruments that will produce inconsistent estimates. Collapsing the multiple appliances to a single measurable index means that we need to find at least one instrumental variable. We estimate the long-run price elasticity in two ways. Firstly, by calculating a rental price for each major appliance and secondly, by calculating a price index for the appliances, i.e. the price per estimated installed capacity.

In the rest of our analysis we estimate equations (5a) and (6a) as well as equations (6b) and (5b) where the parameters of interest are the long-run estimates of α_1 and α_1' and short-run estimates of β_1 and β_1', i.e. the price elasticities of residential electricity consumption in Switzerland. The goal is to estimate those elasticity parameters by taking into account the possible endogeneity of both the average price and the appliance index.

2.5 Data

The primary data come from a household survey organized by the Verband der Schweizerischen Elektrizitätsunternehmen (VSE) while we use secondary data from the Swiss Federal Electricity Commission (ElCom), the Swiss price supervisor ("Preisüberwacher"), Schweizerische Agentur für Energie Effizienz (SAFE) and comparis, a Swiss price comparison website. The data are described below while Table 4 provides the summary statistics of all the variables.

2.5.1 VSE Survey

We use data from a survey performed by the Verband der Schweizerischen Elektrizitätsunternehmen (VSE). It conducted two surveys on around 2,400 Swiss households served by 7 different utility companies. The first survey was conducted in 2005 and the second survey in 2011, both by telephone interviews. In both surveys data were collected from residential customers of five utilities for a total of 1,200 households. Three out of those five utilities were common to both the 2005 and the 2011 surveys but the households were not necessarily the same. Due to a confidentiality agreement, we

[10] We do not use marginal prices because of very low variation of these prices across the utilities in our sample.

are unable to list the names of the utility companies involved. However, these seven utilities account for around 25% of the residential electricity consumption in Switzerland. Variables collected include characteristics of houses (e.g., the number of rooms they live in), demographics of households (e.g., the gender and age group), the stock of appliances, rough characteristics of appliances (e.g. if older than 10 years), the usage of appliances (e.g., the hours switched on) and the annual electricity consumption of the household. We exclude households with a yearly consumption of less than 200 kWh and more than 30,000 kWh. This leaves us with 1,944 observations.

The survey reports the electricity consumption for the previous year. The household electricity consumption was not asked during the interview but was obtained from the last regular meter readings conducted by the respective utility company. Comparing the mean total consumption in kWh per household and per capita in our sample to the Swiss Electricity Statistics (SFOE, 2013a) shows that both values in our sample are lower. One possible explanation is that households with an electric heating systems are not part of our sample. Between 2000 and 2008 the share of electric heated homes in Switzerland decreased by 3.8%, but is still at a level of 6% (Prognos, 2008). The distribution of the electricity consumption for the utilities in 2005 and 2011 are provided in the kernel density plots in Figures 2 and 3, respectively. The upper graph in each figure is for the total electricity consumption and the lower graph is for its logarithmic transformation. Figure 3 shows that utilities 3 and 7 are quite different compared to utilities 1, 2, and 6. The customers of utilities 3 and 7 are all exclusively located in urban areas while the customers of utilities 1, 2, and 6 are distributed between rural and urban areas, as shown in Table 38 in the Appendix.[11] Figure 3 also shows that the electricity consumption in utility 1 in 2011 is very different compared to the other utilities. Therefore, in our analysis, we control for a household belonging to utility 1 in 2011. Table 3 shows the representativeness of our sample, comparing household income, number of rooms, abundance of children and household size to numbers from the Swiss Federal Statistical Office (BFS).[12] In our sample, the distribution of gross household income appears to be a little different from the distribution obtained from BFS. However, since our data has only income groups it is difficult to make an appropriate comparison. The number of rooms, household size and percentage of households with children are comparable to the whole of Switzerland. Therefore, we conclude that our sample is representative.

[11] We define urban as an area of agglomeration with more than 10,000 inhabitants.

[12] http://www.bfs.admin.ch/bfs/portal/de/index/themen.html

Table 3: Representativeness of our sample

Variable	**BFS**	**VSE**
Gross Household Income in CHF per month†		
1st Quintile	4880	3750
2nd Quintile	7173	5250
3rd Quintile	9702	7500
4th Quintile	13170	12000
Number of rooms		
1-2 rooms	17.96%	11.28%
3-5 rooms	71.06%	72.85%
6 rooms or more	10.97%	15.86%
Household size		
1-2 persons	68.91%	66.44%
3-4 persons	25.54%	27.77%
5 persons or more	5.56%	4.79%
Children	32.25%	29.85%

†:VSE incomes are calculated using the mid-point of the income groups
BFS: Bundesamt für Statistik is the Swiss Federal Statistical Office
VSE: Verband der Schweizerischen Elektrizitätsunternehmen is the Swiss Association of Electric Utilities

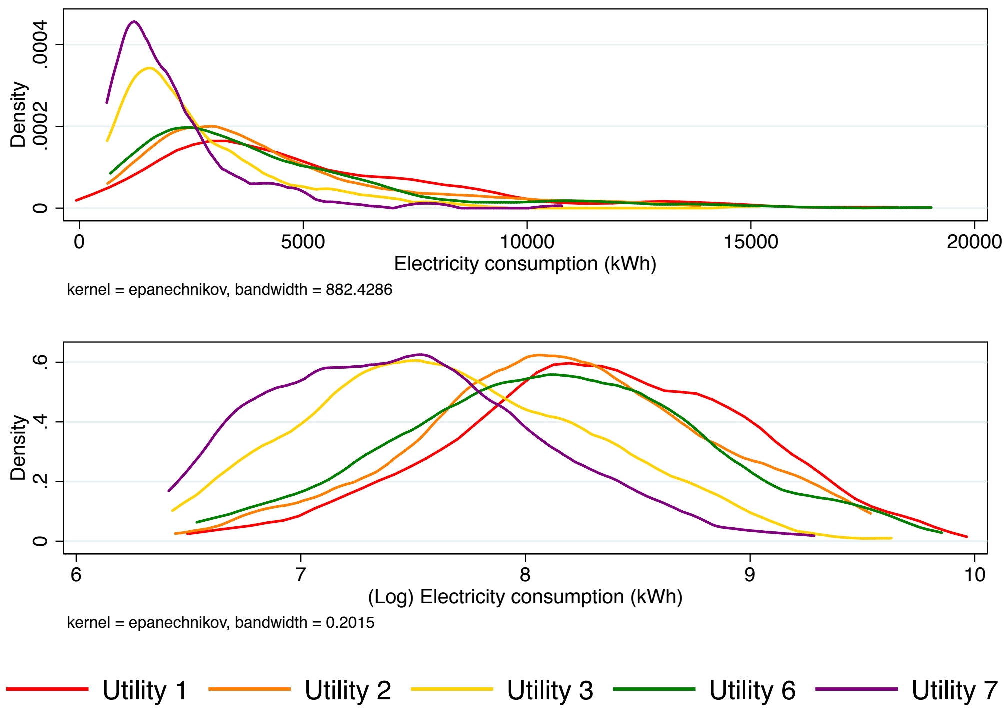


Figure 2: Kernel density plot for electricity consumption in 2005

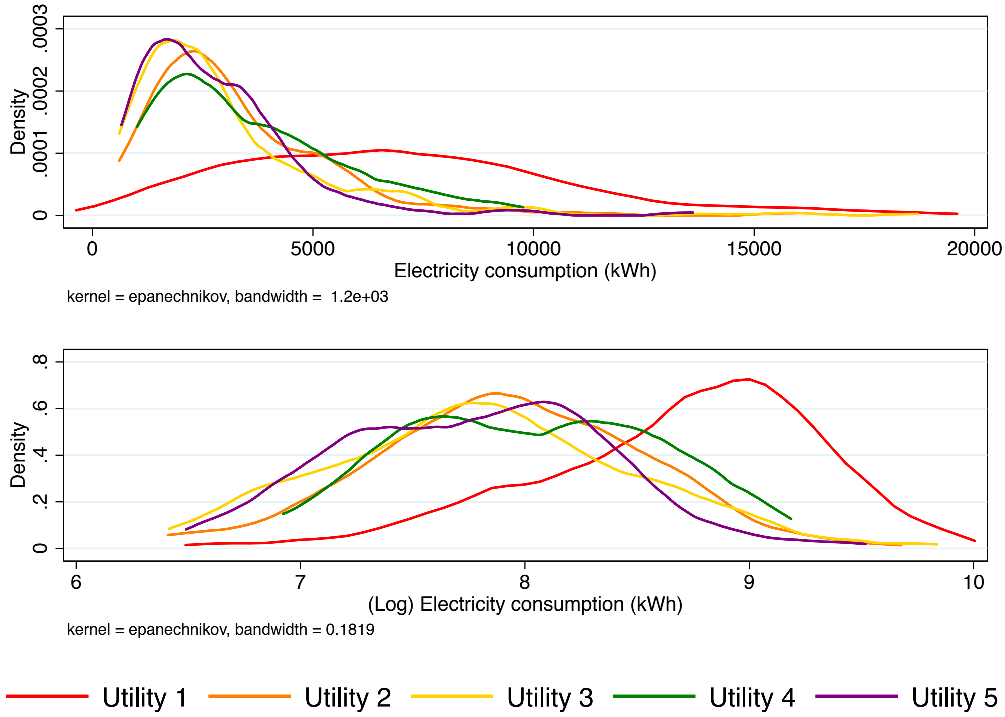


Figure 3: Kernel density plot for electricity consumption in 2011

Table 4: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Consumption & price					
Total consumption (in kWh)	3833.20	3123.27	247	29476	1944
Average price	17.28	5.73	2.83	62.8	1944
ElCom price	16.03	4.37	8.02	29.75	1844
Income groups					
Income group 1	0.09	0.29	0	1	1944
Income group 2	0.17	0.37	0	1	1944
Income group 3	0.23	0.42	0	1	1944
Income group 4	0.29	0.46	0	1	1944
Income group 5	0.18	0.38	0	1	1944
Income group 6	0.04	0.20	0	1	1944
Household characteristics					
Number of rooms	4.15	1.49	1	9	1944
Household size	2.38	1.22	1	8	1944
Single family housing dummy	0.34	0.47	0	1	1944
Tenant dummy	0.55	0.50	0	1	1944
Children dummy	0.31	0.46	0	1	1944
Retired dummy	0.32	0.47	0	1	1944
Share female	0.55	0.29	0	1	1944
Time-of-use dummy	0.77	0.42	0	1	1944
Urban dummy	0.60	0.49	0	1	1944
Dummy for utility 1 in 2011	0.08	0.27	0	1	1944
Year 2011 dummy	0.49	0.50	0	1	1944
Appliances					
Appliance Index (in Watt)	5191.88	2070.68	110	11605.1	1944
Freezer	0.55	0.50	0	1	1944
Electric boiler	0.32	0.46	0	1	1944
Clothes washer	0.55	0.50	0	1	1944
Dishwasher	0.72	0.45	0	1	1944
Electric stove	0.96	0.20	0	1	1944
Tumble dryer	0.58	0.49	0	1	1944
Micro wave oven	0.52	0.50	0	1	1944
Separate oven	0.37	0.48	0	1	1944
No. of fridges	1.14	0.38	1	3	1944
No. of TVs	1.35	0.72	0	7	1944
No. of PCs	1.34	1.14	0	9	1944
Appliance user costs					
Price per watt	0.44	0.40	0.14	7.24	1944
Price of freezer	121.53	17.56	88.55	139.56	1944
Price of electric boiler	81.80	16.61	58.39	156.80	1944
Price of clothes washer	348.81	29.98	312.30	382.01	1944
Price of dishwasher	281.01	26.96	238.94	329.60	1944
Price of electric stove	138.18	18.63	109.48	167.22	1944
Price of tumble dryer	178.56	49.85	124.92	231.53	1944
Price of micro wave oven	32.31	7.26	23.93	39.55	1944
Price of oven	133.65	8.12	124.09	142.14	1944
Price of fridge	154.83	45.17	83.28	231.53	1944

Continued on next page

Table 4 – continued from previous page

Variable	Mean	Std. Dev.	Min.	Max.	N
Price of TV	307.56	199.15	66.02	1598.12	1944
Price of PC	373.17	143.63	109.49	610.71	1944
Energy services					
No. of meals per day	2.39	1.03	0.14	13	1944
No. of hot water services per day	1.27	1.41	0	16.14	1944
No. of washing services per week	3.23	4.60	0	54	1944
Hours of entertainment per day	7.34	9.05	1	176	1944

2.5.2 Electricity Price

Apart from the survey, we also use electricity price data for 2004 from "Preisüberwacher" [13] and for 2010 from the Federal Electricity Commission (ElCom) as well as price data collected from VSE.[14] The *average price* of electricity is calculated by multiplying the electricity consumption of the household with the marginal price faced by the household, adding the fixed fee (if any) and dividing this total cost by the total electricity consumption.[15] This price variable is endogenous due to the presence of the fixed fee and therefore, we correct for its endogeneity by using an instrumental variables approach that will provide consistent estimates of the price elasticity. We need to find instrumental variables that will satisfy the relevance and exclusion criteria for instruments. In other words, the instrument should be correlated with the average price to satisfy the relevance condition but affect the electricity consumption only through its effect on average price to satisfy the exclusion criterion.

We consider the *ElCom price* (ElCom, 2013) as an instrument for the average price. The ElCom price is a weighted average price faced by a typical household with certain characteristics. It is calculated according to the consumption profile for each household type by taking into account summer and winter and four blocks during the day (6 a.m.– 12 p.m., 12 p.m.– 6 p.m., 6 p.m.– 10 p.m. and 10 p.m.– 6 a.m.). The way we construct the ElCom price for each household is to match a particular household with certain characteristics, as given in Table 5, with the ElCom price faced by a typical household with similar characteristics serviced by the respective utility. For example, if a household in our sample lives in a flat and consumes 2000 kWh of electricity per year then it belongs to ElCom household type H2 and is assigned the corresponding ElCom price. Since the ElCom price is an average price faced by a typical household with certain characteristics it does not directly affect the consumption of a particular household but has an influence on the average price faced by a household. Since it does not suffer from a potential endogeneity problem as in the calculated average price above we will use this price as an instrument for the average price.

[13] http://www.preisueberwacher.admin.ch/dokumentation/00073/00074/00203/index.html?lang=de

[14] We refer to the 2004 electricity prices as ElCom prices to maintain consistency. ElCom was founded only in 2009 and started collecting data from then onwards. The 2004 prices from the "Preisüberwacher" are collected using the same methodology as the ElCom prices in 2010. Marginal price data were collected with the help of VSE.

[15] While a household may choose to use a particular tariff structure, e.g. electricity from renewable sources, we do not have this information and so consider the most common tariff that is provided by the respective electric utility.

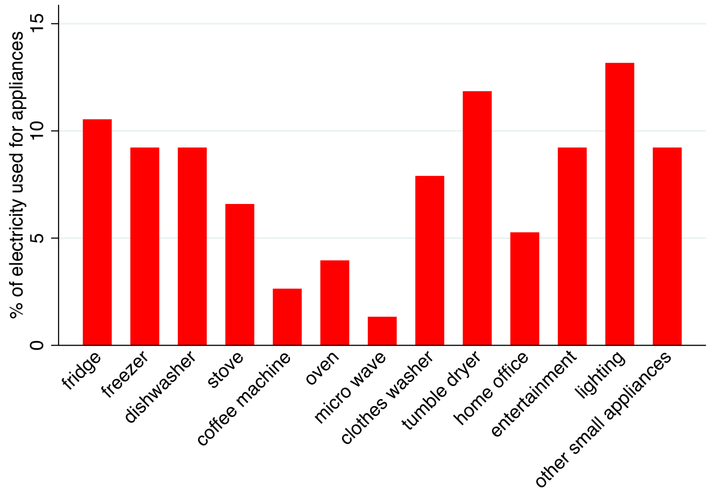


Figure 4: Share of electricity used by major household appliances (Source: SAFE)

Table 5: ElCom household types

Type	Electricity [kWh/year]	Other	Number	%
H1	0–1,600	Flat	366	18.83%
H2	1,600 – 2,500	Flat	347	17.85%
H3	2,500 – 4,500	Flat+boiler	95	4.89%
H4	2,500 – 4,500	Flat+no boiler	301	15.48%
H5	0–7,500	Single family housing	484	24.90%
H6	13,000 – 25,000	Single family housing	36	1.85%
H7	7,500 – 13,000	Single family housing	137	7.05%
H8	$>$ 4,500	Flat	78	4.01%
Not matched			100	5.14%

2.5.3 Appliances

The VSE survey contains information on a number of appliances owned by a household. Schleich and Mills (2011) state that the major household appliances use 35% of residential end-use consumption of electricity in the EU 15 states. Figure 4 shows the most abundant home appliances and their share of electricity consumption in Switzerland. Kitchen appliances are a big share with more than 40% of the electricity consumed. In this paper, we do not use the categories “other small appliances”, “lighting” and “coffee machine” since the capacities and prices are very diverse within these categories. This would make it challenging to estimate reference values. We use televisions (TVs) and personal computers (PCs) as representative of the categories “home office” and “entertainment”. Our analysis is restricted to 11 major appliances, namely, *refrigerators, freezers, electric stoves, electric ovens, microwaves, dishwashers, clothes washers, tumble dryers, electric boilers, television sets* and *personal computers*. We assume that a household possesses a tumble dryer and clothes washer only if their usage is reflected in its own electricity bill.

We construct an appliance index that aggregates the appliances owned by a household into one index that can be compared across the households in our survey. We do this by using a measure of the approximate power used by the major household appliances that we refer to as the "estimated capacity". The estimated capacity of the 11 major appliances is obtained by dividing the appliances into their vintage (older than 5 or 10 years) and size. The estimated capacity of an appliance is the average power used by the appliance while in use.[16] Electric boiler capacities are estimated by using the number of people in a particular household. See Table 6 for the detailed appliance characteristics used for the index. The advantage of using an appliance index is the relatively higher precision of the appliance capacity obtained when compared to using an aggregated count variable or individual appliance dummies. To the best of our knowledge, only a couple of studies have utilized such an appliance index. Garbacz (1984) develops a three-equation model with an electricity demand equation, an appliance stock equation and an equation for the electricity price. However, his appliance index is based on typical usage of the individual appliances in kWh and not a measure of typical capacity. Tiwari (2000), on the other hand, constructs an index based on average power requirement of the appliances.

We define the appliance index of household i (AI_i) as the sum of the estimated reference capacities, in Watt, of the 11 appliances:

$$AI_i = \sum_{k=1}^{11} \text{Estimated Capacity}_{i,k} \tag{7}$$

where k refers to appliance k. The estimated capacity is a function of the vintage, size and household size (only for electric boilers).

Following Diewert (1974) and Thomas (1987) we calculate the "user cost" of appliances that reflects the price of services obtained from a durable good even though it has been purchased by the household. Let us define this rental price or user cost of household appliances as P'_k. Thomas (1987, p. 26-27) defines the user cost as the difference between the purchase at the beginning of one period and the discounted price at the beginning of the next period after taking depreciation into account:

$$P'_{k,t} = P_{k,t} - \frac{(1-\delta_{lifetime})P_{k,t+1}}{1+r_{t,canton}} \tag{8}$$

where $P_{k,t}$ is the price of each appliance k [17], $\delta_{lifetime}$ is the annual rate of depreciation and $r_{t,canton}$ is the annual opportunity cost of capital. The interest rate $r_{t,canton}$ consists of cantonal mortgage interest rates.[18]

We can rewrite equation (8) as:

$$P'_{k,t} = ((\delta_{lifetime} \cdot P_{k,t+1}) + (r_{t,canton} \cdot P_{k,t}) + (P_{k,t} - P_{k,t+1})) \cdot \frac{1}{1+r_{t,canton}} \tag{9}$$

For simplicity, we assume that the initial value of the appliance is the same as in the next time period $(t+1)$, as there are no efficiency losses during the lifetime. This means that $P_{k,t} = P_{k,t+1}$.

[16] The estimated reference capacities (in terms of Watt) have been provided by Schweizerische Agentur für Energie Effizienz (SAFE).

[17] These price estimates were also provided to us by SAFE. Similar to the measurement of the capacities for the 11 major appliances, these price estimates are approximate prices of the corresponding appliances by dividing the appliances into their vintage and size.

[18] The interest rate values were provided by comparis, a Swiss price comparison website.

At the end of the appliance's lifetime the value will be zero instantly.[19] Therefore, we can simplify equation (9) to:

$$P'_k = (\delta_{lifetime} + r_{t,canton}) \cdot P_k \cdot \frac{1}{1 + r_{t,canton}} \tag{10}$$

Using the estimated capacity and price of the eleven appliance categories we can create a *price per installed capacity (in Watt)* for each household. We use this price per installed capacity in two ways. Firstly, as the price of appliance stock in the long-run estimation and, secondly, as an instrument for the household's stock of appliances in the short-run. The price per installed capacity is defined as:

$$PI_i = \frac{\sum_{k=1}^{11}(\text{Rental Price of Appliance}_{i,k})}{\sum_{k=1}^{11}(\text{Estimated Capacity}_{i,k})} = \frac{\sum_{k=1}^{11} P'_k}{AI_i}. \tag{11}$$

We choose this price index as an instrumental variable for estimating the short-run electricity demand. However, we use the neighbouring price index instead of a household's own price index. This is because we assert that the own price of a household's appliances will be directly correlated with the own electricity demand, thereby violating the exclusion restriction. We define a neighbour as the other households within the same utility but having the same single family housing status. So, for example, the neighbouring price index for a household that is in a multi-family house and is a customer of utility 2 will have the average of the rest of utility 2's households living in multi-family housing. The neighbouring price index will not affect a particular household's electricity demand, thereby satisfying the exclusion restriction. However, the neighbouring price index will affect a particular household's electricity demand through a spatial effect on its price index for appliances, thereby satisfying the relevance condition. This spatial effect can be caused by similar households being together. In our case, we have grouped the households by whether they are single family households or not.

Table 6 shows the appliance characteristics that we are able to incorporate into the appliance index. The fact that we are able to incorporate vintage and size among other characteristics makes our appliance index unique and more precise than a set of appliance dummies. Figure 5 displays the appliance index as a histogram. In the empirical analysis we use the appliance index because it incorporates the stock of appliances used in the production of energy services more precisely.

[19]There is also a simplified version of the user cost that assumes that the appliance is not sold in the next period but is kept till its value depreciates to zero. We have estimate our specifications using this version and the results remain unchanged.

Table 6: Characteristics of appliances

Appliance	Age class	Size class	Other characteristics
Refrigerator	10 years	Small/large	Freezer compartment/combined
Freezer	10 years	Small/large	Upright/deep
Dishwasher	10 years		
Stove	10 years		
Oven	10 years		
Microwave oven	10 years		
Clothes washer	10 years		
Tumble dryer	10 years		
Television	5 years	Small/middle/large	Flatscreen
Personal computer	5 years	Small/middle/large	Flatscreen, laptop/desktop
Electric boiler			Household size

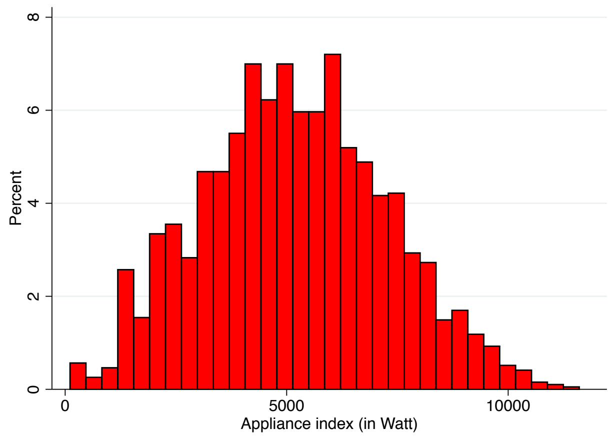


Figure 5: Histogram of appliance index

2.5.4 Energy Services

The VSE survey also contains information on some activities by households with regard to energy usage in the week prior to the survey being undertaken. We combine energy usage into four broad categories, viz. the amount of washing, the amount of meals cooked at home, the number of hours spent on entertainment and the amount of hot water services. We combine the usage of a clothes washer, tumble dryer and dehumidifier as representing the amount of washing. The amount of meals cooked at home is defined as the sum of breakfasts, lunches and dinners made at home. We obtain the number of hours spent on entertainment by adding the hours spent on a personal computer and on watching television. Hot water services are calculated by adding the number of showers and baths taken. Table 4 provides a summary of these variables. Lighting is also an important component of energy services. However, since we do not have information on the number of hours a household's lights are switched on we use the number of rooms as an approximation.

2.6 Estimation Results

We now present the results obtained by estimating models based on equations (5a), (5b), (6a) and (6b). The first set of results estimates short-run models using the appliance index while the second set estimates long-run models using the price index as calculated with equation (11) and then separately with the appliance user costs as estimated in equation (10). We first estimate the models using the set of household and socio-demographics and then estimate the models using energy services.

2.6.1 Short-Run Estimation Results

The results of the electricity demand estimation in the short run using the appliance index from equation (7) are shown in Table 7. In columns (1) and (2) we assume that the average electricity price and appliance stock are exogenous. The price elasticity for electricity is between –0.8 and –0.9. We test for the potential endogeneity of the average electricity price and the appliance index and find that the null hypothesis of these two regressors being exogenous may be rejected.[20] Therefore, we focus on columns (3) and (4) where both the average electricity price and the appliance index are assumed to be endogenous. The instruments we use are the ElCom prices for the own utility and the average price per installed capacity, by the single family housing status, of other households within the same utility. Since we have two endogenous variables the relevant statistic to test for weak instruments is the Cragg-Donald statistic (Cragg and Donald, 1993). Stock and Yogo (2002) calculate the critical value of the Cragg-Donald statistic for a model with two endogenous variables and two instruments and find it to be 7.03 at the 10% level of significance.[21] The Cragg-Donald statistic values reported in Table 7 exceed the critical value and we can, therefore, conclude that the instruments do not appear to be weak.

The difference between the two columns is that in column (3) we use equation (1b) where the household characteristics and socio-demographic variables are used to determine the electricity demand while in column (4) we use equation (1a) where energy services are used instead of socio-demographics. However, we also include certain residential characteristics in column (4), e.g. if the household lives in a single family house, if it resides in an urban area, and if it is a tenant in the residence. These characteristics are not captured by the energy services. We also include the number of rooms as a residential characteristic since our energy services variables do not include the effect of lighting on electricity consumption. We include a binary variable as an indicator for whether a household is a customer of utility 1 in 2011 since the electricity consumption in that particular utility in 2011 is quite different to the rest of the utilities in the survey as observed in Figure 3. We also have an indicator for the year in which the survey was carried out as well as an indicator for a time-of-use tariff structure.

The price elasticities are negative, as expected, and statistically significant. Instrumenting for the potential endogeneity bias of the average price and the appliance stock, we obtain a price elasticity of around -0.4. The coefficient for appliance stock is positive and significant across the two models and indicates that installing 10% more capacity (in Watt) will lead to a 7-8% increase in electricity

[20] We use the `endog()` option in Stata's `ivreg2` (Baum et al., 2010) command.

[21] The first stage results are reported in Table 39 in the Appendix. All the instruments are significant and have the expected signs. In the first stages for the endogenous appliance index models we find that the appliance stock is highly dependent on the income dummies, which are all positive and significant. Furthermore, the appliance index depends significantly on the electricity price.

consumption. Unfortunately, we cannot calculate the income elasticity since the VSE survey only reports income ranges for households. While the coefficients for the income dummies are negative in column (1) only one group is statistically significant at the 1% level of significance. This may be due to the income effect being captured by certain residential and household characteristics like the number of rooms and household size.[22]

Table 8 shows the expected sign of the coefficients related to the characteristics of households. Most coefficients of household characteristics, as presented in column (3) of Table 7, are significant and show the expected sign. Household size, number of rooms, single family housing status and dummy for children increase the electricity demand, as expected. Households residing in an urban area and those with a higher share of women reduce the estimated electricity demand, as expected. Results also indicate that households with a time-of-use (TOU) pricing scheme tend to use less electricity. However, the estimated coefficient is not statistically significant. The TOU tariff system is designed to shift some of the peak period consumption to the off-peak period. The part of peak period consumption that cannot be shifted to the off-peak period is consumed in the peak price period and therefore less electricity is consumed in the peak period due to the higher price.[23] Share of women may have a negative influence because either there are unobserved wealth effects (Brounen et al., 2012) or because women are more conscious towards environmental and energy related topics (Gaspar and Antunes, 2011). Tenants also tend to use less electricity. The strong statistical significance in household characteristics indicates a large degree of heterogeneity among households which indicates the need to use disaggregated data.

The results of the estimation in column (4) of Table 7 indicate the change in electricity demand due to a change in certain energy services. A unit increase in cooking a meal at home per day leads to an increase in electricity consumption by 4% while an hour more of entertainment per day increases electricity consumption by 1%. Using one more hot water service per day increases electricity consumption by 2%, though this coefficient is not statistically significant, while one more washing service per week increases electricity consumption by 1%, though this coefficient is also not statistically significant.

[22] The models have been estimated with only the price of electricity and income groups and the results, not presented here, show that the effect of the income groups is positive and significant. We have also performed a multicollinearity check after estimating the full model and find that the highest variance inflation factor is below 3.5. This indicates that multicollinearity is not an issue in our full model.

[23] In principle with the increase of local solar PV installations peak load is getting less relevant compared to residual load. However, for the observed time frame this impact is very low for the observed utilities.

Table 7: Regression of short-run (log) electricity demand

	(1)	(2)	(3)	(4)
(Log) Average price	-0.88^a	-0.82^a	-0.45^a	-0.40^a
	(0.08)	(0.08)	(0.08)	(0.08)
(Log) Appliance stock (in Watt)	0.27^a	0.21^a	0.75^a	0.67^a
	(0.03)	(0.03)	(0.20)	(0.19)
Income group 2	-0.01		-0.06	
	(0.05)		(0.06)	
Income group 3	-0.07		-0.17^b	
	(0.05)		(0.07)	
Income group 4	-0.14^b		-0.25^a	
	(0.05)		(0.08)	
Income group 5	-0.16^a		-0.30^a	
	(0.06)		(0.09)	
Income group 6	-0.13		-0.24^b	
	(0.08)		(0.11)	
(Log) Household size	0.26^a		0.21^a	
	(0.04)		(0.05)	
Children dummy	0.11^a		0.09^b	
	(0.04)		(0.05)	
Retired dummy	-0.08^a		-0.06^b	
	(0.03)		(0.03)	
Share of females	-0.16^a		-0.16^a	
	(0.04)		(0.05)	
Single family housing dummy	0.22^a	0.21^a	0.33^a	0.34^a
	(0.03)	(0.04)	(0.04)	(0.04)
Urban dummy	-0.23^a	-0.24^a	-0.10^a	-0.12^a
	(0.03)	(0.03)	(0.04)	(0.03)
Tenant dummy	-0.15^a	-0.11^a	-0.02	0.00
	(0.03)	(0.03)	(0.05)	(0.05)
(Log) No. of rooms	0.24^a	0.32^a	0.09	0.14^c
	(0.05)	(0.04)	(0.07)	(0.08)
No. of meals per day		0.04^a		0.04^b
		(0.01)		(0.01)
Hours of entertainment per day		0.01^a		0.01^a
		(0.00)		(0.00)
No. of hot water services per day		0.05^a		0.02
		(0.01)		(0.02)
No. of washing services per week		0.02^a		0.01
		(0.00)		(0.01)
Dummy for utility 1 in 2011	0.36^a	0.33^a	0.33^a	0.33^a
	(0.04)	(0.04)	(0.05)	(0.05)
Time-of-use dummy	-0.12^a	-0.11^a	0.03	0.04
	(0.04)	(0.04)	(0.05)	(0.04)
Year 2011 dummy	-0.03	0.03	0.06^c	0.07^b
	(0.03)	(0.03)	(0.03)	(0.03)
Intercept	8.05^a	7.94^a	2.74	2.83^c
	(0.38)	(0.38)	(1.68)	(1.61)
Observations	1,944	1,944	1,844	1,844
Adjusted R^2	0.54	0.53		
Cragg-Donald F-statistic			20.82	23.96
p-value of Endogeneity test			0.00	0.00

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 8: Household characteristics and their expected sign on electricity demand

Variable	Sign	Selected Reference
Number of rooms	$+$	Baker et al. (1989)
Household size	$+$	Baker et al. (1989)
Single family housing dummy	$+$	Brounen et al. (2012)
Tenant dummy	$+/-$	
Children dummy	$+$	Baker et al. (1989)
Share of females	$-$	Brounen et al. (2012)
Time of use dummy	$+/-$	
Urban dummy	$-$	Leahy and Lyons (2010)
Income	$+$	Economic theory in general

2.6.2 Long-Run Estimation Results

The long-run estimates of electricity demand are shown in Table 9. These models include the rental price of appliances. Columns (1) and (3) use the individual rental prices of the appliances whereas columns (2) and (4) use the price index of the appliances as calculated in equation (11). As in the short-run estimation we use household characteristics and socio-demographic variables in columns (1) and (2) while in columns (3) and (4) we use energy services instead of socio-demographics. One difference between the long-run and short-run models is that the appliance index in the latter is replaced by either the price of an aggregate measure of appliance stock or by the prices of individual appliances in the long-run models. Another difference is that all the long-run models are estimated using an instrumental variables approach to account for the endogeneity of the average price variable.

The price elasticities of residential electricity demand are negative, as expected, and statistically significant and range from a low of -0.4 to a high of -0.6. Using the rental prices of capital stock in columns (2) and (4), we find that an increase of 1% in the price per watt leads to a decrease in electricity consumption by around 1.1%.[24] The effect of income, as measured by the income groups, is statistically insignificant, except for income group 4 in column (1). The share of females in a household, being located in an urban area and being a tenant have negative and statistically significant effects on the electricity consumption. Increasing the household size, number of rooms and having children have positive and significant effects on the electricity consumption. Most coefficient estimates are very similar across the different models.

[24]We do not report the coefficients of the prices for individual appliances in the table. If we consider the rental prices of individual appliance only those of freezers and electric stoves are negative and significant. The rental price of personal computers is positive and significant in both models.

Table 9: Regression of long-run (log) electricity demand

	(1)	(2)	(3)	(4)
(Log) Average price	-0.63^a	-0.51^a	-0.55^a	-0.43^a
	(0.07)	(0.08)	(0.07)	(0.08)
(Log) Price of capital stock		-1.08^a		-1.11^a
		(0.33)		(0.37)
Income group 2	-0.01	0.02		
	(0.05)	(0.07)		
Income group 3	-0.06	-0.03		
	(0.05)	(0.07)		
Income group 4	-0.09^c	-0.05		
	(0.05)	(0.07)		
Income group 5	-0.08	-0.06		
	(0.06)	(0.07)		
Income group 6	-0.02	0.11		
	(0.08)	(0.10)		
(Log) Household size	0.38^b	0.33^a		
	(0.15)	(0.05)		
Children dummy	0.10^b	0.09^c		
	(0.04)	(0.05)		
Retired dummy	-0.06^c	-0.21^a		
	(0.03)	(0.06)		
Share of females	-0.17^a	-0.19^a		
	(0.04)	(0.06)		
Single family housing dummy	0.32^a	0.36^a	0.29^a	0.36^a
	(0.04)	(0.04)	(0.04)	(0.05)
Urban dummy	-0.18^a	-0.09^b	-0.18^a	-0.09^b
	(0.03)	(0.04)	(0.03)	(0.04)
Tenant dummy	-0.14^a	-0.07	-0.12^a	-0.02
	(0.03)	(0.05)	(0.03)	(0.06)
(Log) No. of rooms	0.26^a	0.25^a	0.22^a	0.40^a
	(0.05)	(0.06)	(0.04)	(0.06)
No. of meals per day			0.02^c	0.02
			(0.01)	(0.02)
Hours of entertainment per day			0.01^a	0.02^a
			(0.00)	(0.00)
No. of hot water services per day			0.03^b	0.04^b
			(0.01)	(0.02)
No. of washing services per week			0.02^a	0.02^a
			(0.00)	(0.00)
Dummy for utility 1 in 2011	0.38^a	0.35^a	0.35^a	0.31^a
	(0.05)	(0.05)	(0.05)	(0.06)
Time-of-use dummy	-0.04	0.02	-0.02	0.04
	(0.05)	(0.05)	(0.05)	(0.05)
Year 2011 dummy	0.28	0.03	0.24	0.06
	(0.25)	(0.04)	(0.25)	(0.04)
Intercept	-2.23	7.85^a	0.42	7.14^a
	(9.87)	(0.48)	(9.89)	(0.56)
Observations	1,844	1,844	1,844	1,844
F-statistic of first stage	2101.27		2138.71	
Cragg-Donald F-statistic	3048.29	12.28	3121.62	10.47
p-value of Endogeneity test	0.00	0.00	0.00	0.00

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

As in the case with the short-run estimation we test for the potential endogeneity of the average electricity price in columns (1) and (3) and the potential endogeneity of the average electricity price as well as the price of capital stock in columns (2) and (4). We find that the null hypothesis of the average electricity price being exogenous can be rejected. We also find that the null hypothesis of the average electricity price and the price of capital stock being exogenous can be rejected.[25] Since we have two endogenous variables the relevant statistic to test for weak instruments is the Cragg-Donald statistic (Cragg and Donald, 1993). The critical value of the Cragg-Donald statistic for a model with two endogenous variables and two instruments is 7.03 at the 10% level (Stock and Yogo, 2002). Our calculated statistic is statistically significant at the 10% level in both columns, (2) and (4).[26]

The results of the estimation in columns (3) and (4) of Table 9 using energy services instead of the usual household characteristics indicate the change in electricity demand due to a change in certain energy services. The results from the long-run estimation are very similar to the estimates obtained in the short-run electricity demand estimation. An increase in cooking a meal at home by one per day leads to an increase in electricity consumption by around 2%, though it is not statistically significant in column (4), while an hour more of entertainment per day increases electricity consumption by 1-2%. Using one more hot water service per day increases electricity consumption from 3-4% while one more washing service per week increases electricity consumption by 2%.

2.6.3 Discussion

If we compare the short-run models with exogenous and endogenous average price we see that instrumenting for average price reduces the elasticity from around -0.8 to around -0.4. This indicates that the price elasticity is overestimated when the endogeneity of average price is not corrected for.[27] This appears consistent with Vaage (2000) who mentions that ignoring the simultaneity of the appliance choice and usage may lead to a downward bias in the price elasticities of electricity demand.

If we compare the different ways of incorporating appliances into the short-run electricity demand estimation then using an appliance index is a superior approach to using individual appliance dummy variables since it avoids the problem of finding enough instruments in an instrumental variable approach. It is very difficult to find instruments for multiple endogenous variables due to the possibility of weak instruments that will produce inconsistent estimates. We can also distinguish vintage and size among other characteristics of the appliances with the index. This makes our approach using an appliance index unique and more precise than the traditional way of using a set of individual appliance dummies. Our results also indicate that using the appliance index produces very stable results.

A household's appliance stock is not fixed in the long run and therefore we expect the long-run electricity price elasticities to be higher than the short-run price elasticities. While in the short-run only the utilisation rate of the existing capital stock can be chosen, in the long run the level of capital stock can also be optimised. In some studies, elasticity estimates from cross-sectional studies are interpreted as being long-run values (Baltagi and Griffin, 1984). The assumption is that the majority

[25] As before, we use the `endog()` option in Stata's `ivreg2` (Baum et al., 2010) command.

[26] The first-stage results are reported in Table 41 in the Appendix. The instruments are significant and have the expected, positive, signs.

[27] We also correct for the possible endogeneity of the appliance index by using an instrument and find that the price elasticity increases very slightly. The results are not reported in this paper but can be obtained upon request.

of households in a cross-section are well adapted to their financial circumstances and the cross-section will represent a steady-state. Therefore, the estimated elasticities will represent long-run circumstances (Thomas, 1987). However, the long-run elasticities in this study are only slightly higher than the short-run estimates. This is possibly because the short-run estimates may be considered to be more medium-term due to the cross-sectional nature of the data and we do not directly observe any adjustment decisions. Halvorsen and Larsen (2001) use pooled cross-section data (five years) from the Norwegian Survey of Consumer Expenditure and also find negligible differences between estimated short- and long-run Cournot elasticities. They attribute this result to the fact that there is no substitute for electricity in the use of household appliances in Norway.

As previously mentioned, customers of utility 1 in 2011 appear to consume more electricity than customers served by other utilities in the sample as well as customers of utility 1 in 2005. One possible explanation for this may be that 54% of households served by utility 1 in 2011 have an electric boiler while the share for the rest of the sample is 20%. However, this should be captured by the appliance index since an electric boiler is part of the 11 major appliances that we use to construct the index. Another explanation may be the presence of some special appliances that we do not consider in the appliance index but consume a large amount of electricity, e.g. saunas, solarium and whirlpools. For the survey in 2011 we have information on these appliances. We find that households that are served by utility 1 tend to have more of these appliances installed. Furthermore, using data from the Swiss Federal Statistical Office (SFSO, 2011) we investigate the house size of the cantons covered in the sample and find three further possible causes of the difference. Firstly, the canton where utility 1 is located has a larger share of houses with more rooms. However, in our model we control for the number of rooms. Secondly, the canton has a larger share of houses with larger floor area. And finally, households in the canton tend to have higher shares within larger floor area categories conditional on the number of rooms. For example, if two houses have the same number of rooms, the house located in the canton served by utility 1 has a larger floor area. We should note that the electricity consumption in our data does not include heating services.

With this descriptive evidence and the fact that the consumption of utility 1 customers in 2011 is very different to utility customers in 2005 as our motivation, we perform robustness checks by excluding customers of utility 1 in 2011. We estimate our models without the households served by utility 1 in 2011. Table 10 presents the short-run estimates while Table 11 presents the long-run estimates.[28] The price elasticities are summarised in Table 12. We note that excluding households served by utility 1 in 2011 slightly reduces the price elasticity across all models.[29]

[28]The corresponding first-stage regression models are presented in Tables 40 and 42 in the Appendix.

[29]Another way to deal with this issue would be to estimate a latent class model in order to get different price elasticities for different latent groups. The reason for not doing so is that the endogeneity problem can not be solved when using a latent class model.

Table 10: Regression of short-run (log) electricity demand without utility 1 in 2011

	(1)	(2)	(3)	(4)
(Log) Average price	-0.82^a	-0.76^a	-0.37^a	-0.32^a
	(0.08)	(0.08)	(0.08)	(0.08)
(Log) Appliance stock (in Watt)	0.26^a	0.20^a	0.76^a	0.66^a
	(0.03)	(0.03)	(0.21)	(0.20)
Income group 2	0.00		-0.06	
	(0.05)		(0.06)	
Income group 3	-0.08		-0.19^a	
	(0.05)		(0.07)	
Income group 4	-0.14^a		-0.27^a	
	(0.05)		(0.08)	
Income group 5	-0.17^a		-0.33^a	
	(0.06)		(0.10)	
Income group 6	-0.14		-0.26^b	
	(0.08)		(0.11)	
(Log) Household size	0.25^a		0.20^a	
	(0.04)		(0.05)	
Children dummy	0.14^a		0.13^a	
	(0.04)		(0.05)	
Retired dummy	-0.08^b		-0.06^c	
	(0.03)		(0.03)	
Share of females	-0.16^a		-0.15^a	
	(0.05)		(0.05)	
Single family housing dummy	0.22^a	0.20^a	0.33^a	0.34^a
	(0.04)	(0.04)	(0.04)	(0.04)
Urban dummy	-0.24^a	-0.24^a	-0.10^b	-0.12^a
	(0.03)	(0.03)	(0.04)	(0.04)
Tenant dummy	-0.14^a	-0.11^a	-0.01	0.02
	(0.03)	(0.03)	(0.05)	(0.05)
(Log) No. of rooms	0.24^a	0.33^a	0.09	0.15^c
	(0.05)	(0.05)	(0.07)	(0.08)
No. of meals per day		0.04^a		0.04^a
		(0.01)		(0.01)
Hours of entertainment per day		0.01^a		0.01^a
		(0.00)		(0.00)
No. of hot water services per day		0.05^a		0.02
		(0.01)		(0.02)
No. of washing services per week		0.02^a		0.01
		(0.00)		(0.01)
Time-of-use dummy	-0.10^b	-0.09^b	0.06	0.08^c
	(0.04)	(0.04)	(0.05)	(0.05)
Year 2011 dummy	-0.02	0.03	0.06^c	0.06^c
	(0.03)	(0.03)	(0.03)	(0.03)
Intercept	7.90^a	7.83^a	2.41	2.66
	(0.39)	(0.39)	(1.78)	(1.70)
Observations	1,787	1,787	1,688	1,688
Adjusted R^2	0.50	0.49		
Cragg-Donald F-statistic			18.09	20.89
p-value of Endogeneity test			0.00	0.00

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 11: Regression of long-run (log) electricity demand without utility 1 in 2011

	(1)	(2)	(3)	(4)
(Log) Average price	-0.54^{a}	-0.43^{a}	-0.45^{a}	-0.34^{a}
	(0.08)	(0.08)	(0.07)	(0.09)
(Log) Price of capital stock		-1.12^{a}		-1.10^{a}
		(0.35)		(0.40)
Income group 2	-0.00	0.02		
	(0.05)	(0.07)		
Income group 3	-0.08	-0.05		
	(0.05)	(0.07)		
Income group 4	-0.11^{c}	-0.07		
	(0.05)	(0.07)		
Income group 5	-0.10	-0.09		
	(0.06)	(0.08)		
Income group 6	-0.04	0.09		
	(0.09)	(0.10)		
(Log) Household size	0.35^{b}	0.33^{a}		
	(0.16)	(0.06)		
Children dummy	0.13^{a}	0.13^{b}		
	(0.05)	(0.06)		
Retired dummy	-0.06^{c}	-0.21^{a}		
	(0.03)	(0.06)		
Share of females	-0.16^{a}	-0.18^{a}		
	(0.05)	(0.06)		
Single family housing dummy	0.33^{a}	0.36^{a}	0.29^{a}	0.35^{a}
	(0.04)	(0.05)	(0.04)	(0.05)
Urban dummy	-0.18^{a}	-0.08^{c}	-0.18^{a}	-0.09^{c}
	(0.03)	(0.05)	(0.03)	(0.05)
Tenant dummy	-0.12^{a}	-0.06	-0.10^{a}	-0.01
	(0.04)	(0.05)	(0.03)	(0.06)
(Log) No. of rooms	0.27^{a}	0.25^{a}	0.22^{a}	0.40^{a}
	(0.05)	(0.06)	(0.05)	(0.06)
No. of meals per day			0.02^{c}	0.03
			(0.01)	(0.02)
Hours of entertainment per day			0.01^{a}	0.02^{a}
			(0.00)	(0.00)
No. of hot water services per day			0.02	0.04^{b}
			(0.02)	(0.02)
No. of washing services per week			0.02^{a}	0.02^{a}
			(0.00)	(0.00)
Time-of-use dummy	0.01	0.06	0.03	0.08
	(0.05)	(0.05)	(0.05)	(0.05)
Year 2011 dummy	0.14	0.03	0.10	0.06
	(0.25)	(0.04)	(0.26)	(0.04)
Intercept	3.05	7.55^{a}	5.34	6.84^{a}
	(9.87)	(0.52)	(9.93)	(0.60)
Observations	1,688	1,688	1,688	1,688
F-statistic of first stage	2056.09		2083.19	
Cragg-Donald *F*-statistic	2852.19	10.34	2910.08	8.85
p-value of Endogeneity test	0.00	0.00	0.00	0.00

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 12: Estimated short- and long-run price elasticities

	Full sample	**Without utility 1 in 2011**
Short-Run		
Socio-demographics	-0.45	-0.37
Energy services	-0.40	-0.32
Long-Run		
Individual prices & socio-demographics	-0.63	-0.54
Price of Watt & socio-demographics	-0.51	-0.43
Individual prices & energy services	-0.55	-0.45
Price of Watt & energy services	-0.43	-0.34

2.7 Conclusion

In this chapter we estimate the price elasticity of residential electricity consumption in Switzerland using a unique household survey conducted in 2005 and 2011. The future direction of Swiss climate and energy policy has been the subject of much political debate. It is, therefore, important to obtain a measure of the responsiveness of Swiss households to changes in the price of electricity. This will enable policy makers and electric utility companies to design appropriate pricing policies to modify consumer behaviour. The previous estimate of price elasticity with household data in Switzerland was done in 1998 and our study is a much-needed update of this measure. Moreover, our study improves upon the previous studies by using an instrumental variables approach to correct for potential endogeneity concerns as well as using an aggregate measure of a household's stock of appliances.

We estimate the effect of the stock of household appliances on the consumption of electricity. Previous studies have not always considered household appliances and when they have, not always accounted for the possibility that the choice of appliances may be endogenous. We construct an appliance stock index to capture a household's stock of major appliances. This is a single index that avoids the problem of choosing multiple instruments that may lead to a problem of weak instruments. It also has the advantage of being a more precise measure of the appliance stock than using appliance indicator variables. We also estimate models of electricity demand based on household production theory that use energy services like the number of meals cooked at home and the amount of time spent using personal computers and watching television.

In our analysis we calculate the short- and long-run price elasticities using an instrumental variables approach to account for the fact that the price of electricity and the appliance stock may lead to simultaneous causality and, therefore, be endogenous. The price of electricity is endogenous since we use the average price obtained by multiplying the electricity consumption with the marginal price of electricity and adding the fixed fee component, if applicable. The stock of appliances may be endogenous since the choice of appliances may depend on the amount of electricity consumed.

We find that, after correcting for endogeneity, the long-run price elasticity of residential electricity consumption is, in some specifications, more elastic than -0.5 and ranges from -0.4 to -0.6 while the short-run estimate is less elastic than -0.5 and is around -0.4. Table 12 provides a summary of the estimated price elasticities using the different instrumental variables models. Our observation is in line with existing economic theory that the long-run elasticity should be more elastic than the short-run elasticity because households take into account the decision to adjust their stock of appliances. Therefore, they are more sensitive to price changes in the long-run. The price elasticity estimates for

Switzerland fall within the range of other studies made for other countries as well as previous studies for Switzerland that use disaggregated data and show that the response of Swiss households to electricity prices is inelastic. These results suggest that, in view of the recent proposal of the Federal Finance Administration to introduce a tax on electricity, an increase in electricity price may result in a moderate decrease in electricity consumption.

3 Dynamic Models of Residential Electricity Demand

3.1 Introduction

In this chapter, we estimate the short- and long-run elasticity of electricity demand using aggregated data. There are different approaches to estimating these elasticities. In the previous chapter, chapter 2, we used a household survey with information on appliances, residential characteristics and energy services consumed to estimate the price elasticities for electricity. In this chapter we use another approach to estimate the electricity demand. We adopt a partial adjustment model using aggregated data since we do not have information on household appliances. Since this chapter uses aggregated data it is complementary to the previous chapter, chapter 2, which estimates electricity demand at the household level. It is also complementary to other disaggregate studies that have been performed for other countries as well as Switzerland. In addition, these estimates will provide a measure of how an energy tax may affect the responsiveness of electricity consumption. In addition, this chapter will provide policy makers and utility companies with estimates needed for forecasting electricity demand and enable them to plan for generation, transmission and distribution capacities. To do this we use information from a recent survey carried out on a sample of Swiss utilities.[30] Using information on residential electricity consumption, electricity prices, household characteristics and weather factors, we estimate a dynamic model of electricity consumption. We find that the long-run elasticity of residential demand for electricity is inelastic and is around -0.6 for Switzerland. The short-run elasticity is more inelastic with a value of around -0.3.

This chapter contributes to the empirical literature on short- and long-run electricity demand by estimating the respective price elasticities using a new survey data at the utility level, i.e. at the aggregated level. Utilities in Switzerland have both time-of-use and single tariff schemes and our data uses information from both sets of customers to obtain the total electricity consumption and estimate the short- and long-run electricity demand. Our focus is on the total electricity demand because, in our sample, about 20% of residential electricity is consumed by households that have a single tariff scheme. Our analysis supplements that of Filippini (2011) which estimates the time-of-use electricity demand. Our survey is also larger than that of Filippini (2011). We use a correction introduced by Kiviet (1995) for the least squares dummy variable method to account for the endogeneity of the lagged dependent variable in a dynamic demand model using aggregated data. An advantage of aggregated data over disaggregated data is that we have the total electricity consumption of a utility without being restricted to a sample as is the case with a household survey. A significant contribution of this chapter is to provide an update of the short- and long-run price elasticity of household electricity consumption.

The structure of this chapter is as follows. In the next section we provide a brief overview of previous literature on the estimation of models of electricity demand using aggregated data. In section 3.3 we describe a model of electricity demand. The variables used in our model and their sources are described in section 3.4. Our estimating equation and results of the estimating procedure are provided in 3.5. The final section has concluding remarks.

[30]We use data from a survey carried out on a sample of Swiss utilities. This information is also used in chapter 4 and further details of the survey are provided in section 4.2.

3.2 Previous Work

There is a substantial literature that estimates the price responsiveness of residential electricity demand. It ranges from studies at the disaggregated level, e.g. using household surveys, to the aggregated level, e.g. at the state- or country-level. Most of the studies at the disaggregate level are cross-sectional in nature while those at the aggregate level exploit panel data or, alternatively, for single country studies, just the time-series aspect of the data.[31]

Among early works, Houthakker (1951) looks at electricity demand using domestic two-part tariffs in 1937-38 for 42 provincial towns in Great Britain. Fisher and Kaysen (1962) study residential and industrial electricity demand in the United States. They were the first to distinguish explicitly between short-run and long-run demand. A first wave of papers on residential electricity demand was published in the 1970s, as concerns on the limits of growth were emerging (e.g., Houthakker and Taylor (1970); Halvorsen (1975)).

There have been numerous studies on residential electricity demand estimation using various static and dynamic panel data approaches for different countries in the last 20 years. While most studies are on the United States (e.g. Silk and Joutz (1997); Maddala et al. (1997); Alberini and Filippini (2011)), some other countries such as Greece (Donatos and Mergos, 1991), Taiwan (Holtedahl and Joutz, 2004), Australia (Narayan and Smyth, 2005), Japan (Okajima and Okajima, 2013), and Spain (Blázquez et al., 2013) have also been studied. To obtain an overview of the huge amount of studies, Espey and Espey (2004) use a meta-analysis to quantitatively summarize 126 previous studies, from 1971 to 2000, of residential electricity demand to determine if there are factors that systematically affect estimated elasticities. In this study, price and income elasticities of residential demand for electricity from previous studies are used as the dependent variables, with data characteristics, model structure, and estimation technique as independent variables, using both least square estimation of a semi-log and maximum likelihood estimation of a gamma model. They find a mean price elasticity of -0.35 in the short-run, which increases to -0.85 in the long-run. These results show that in the short-run households are rather insensible to price changes, however in the long-run the demand clearly becomes more elastic.

In contrast, studies on residential electricity demand in Switzerland are rather rare. There have been some studies using disaggregated data while others have used aggregated data to estimate the electricity consumption (Carlevaro and Spierer, 1983; Spierer, 1988; Zweifel et al., 1997; Filippini, 1999, 2011).[32]

Carlevaro and Spierer (1983) analyse the end-use consumption of energy in Switzerland between 1960 and 1979 using a single-equation dynamic model. They disaggregate the consumption into three sectors (industry, transportation, and residential–commercial) and five energy sources (electricity, petroleum products, gas, coal, and wood). For electricity consumption they separate the residential and commercial users. In the electricity demand model for residential consumers degree days, number of households and consumption expenditure were used as independent variables. However, electricity price was not taken into the model explicitly.

Spierer (1988) estimates short and long run price elasticities as part of a large report from the expert group for energy scenarios ("Expertengruppe Energieszenarien"). This expert group was

[31] Heshmati (2012) provides an overview of the numerous studies.

[32] Please refer to section 2.3 for a survey of studies for Switzerland using disaggregated data (Dennerlein and Flaig, 1987; Dennerlein, 1990; Zweifel et al., 1997; Boogen et al., 2014).

formed after the incident in Chernobyl in 1986. Spierer (1988) uses data from 1960 to 1984 to analyse end-use consumption of energy in Switzerland in a similar way as in Carlevaro and Spierer (1983) . His results indicate a short-run own price elasticity of electricity of -0.19 and -0.5 in the long-run.

Zweifel et al. (1997) use data from 40 Swiss cities between 1987 and 1990 to explain the total electricity consumption. They use number of households in the city, average household size, heating degree days and a time-of-use status to explain electricity consumption. The price is incorporated in two ways: first, they use the stone price index to be able to include peak and off-peak marginal prices and the fixed fee was deducted from the income tax revenue per household. They estimate a price elasticity of -0.25 using an error correction model and -0.3 when using ordinary least squares.

Filippini (1999) estimates electricity demand using aggregate data for 40 Swiss cities over the period 1987 to 1990. The price elasticity is estimated to be -0.30, which shows a moderate responsiveness of electricity consumption to changes in prices. This result indicates a price-inelastic demand for electricity with lower price elasticity than those reported in previous studies. Filippini (2011) estimates the time-of-day residential demand for electricity in Switzerland. The estimated short-run own-price elasticities are -0.60 during the peak period and -0.79 during the off-peak period. The estimated long-run values are, as expected, higher than in the short-run with -0.71 during the peak period and -1.92 during the off-peak period. This indicates a high responsiveness of electricity consumption to changes in prices. However, as noted by Filippini (2011), the results should be treated carefully due to the small sample used for the analysis.

Table 13: Selected price elasticities in the literature.

Author(s)	**Region**	**Short-run**	**Long-run**
International			
Houthakker and Taylor (1970)	USA	-0.13	-1.89
Halvorsen (1975)	USA		-1.00 to -1.21
Prosser (1985)	OECD	-0.22	-0.37
Bentzen and Engsted (1993)	Denmark	-0.14	-0.47
Maddala et al. (1997)	USA	-0.18	-0.26
Fatai et al. (2003)	New Zealand	-0.18 to -0.24	-0.44 to -0.59
Kamerschen and Porter (2004)	USA	-0.85 to -0.92	
Holtedahl and Joutz (2004)	Taiwan	-0.15	
Liu (2004)	OECD	-0.030	-0.157
Narayan and Smyth (2005)	Australia	-0.26 to -0.27	-0.47 to -0.54
Alberini and Filippini (2011)	USA	-0.08 to -0.15	-0.43 to -0.73
Blázquez et al. (2013)	Spain	-0.07	-0.19
Switzerland			
Spierer (1988)		-0.19	-0.5
Zweifel et al. (1997)			-0.25 to -0.3
Filippini (1999)			-0.3

3.3 Dynamic Model of Electricity Demand

Household demand for electricity may be considered to be a derived demand since electricity is not consumed *per se* but to provide us with services, e.g. an electric heater providing warmth. Using the basic framework of household production theory we can derive the demand for electricity.[33] As shown by some papers that estimate electricity demand using the household production function, long-run electricity demand depends on the price of electricity, the price of appliances, the price of electricity substitutes, household income, and other factors like socio-demographic and residential characteristics. On the other hand, short-run electricity demand depends on all the above factors except for the price of appliances. In this case, we substitute the price of appliances with the actual stock of appliances due to the fact that household appliances cannot be replaced swiftly. Therefore, the demand for electricity depends on the stock of appliances owned by a household and a static model is not able to capture this long-run equilibrium.[34] The long-run equilibrium of a household's stock of appliances cannot be reached instantaneously and, in case the capital stock cannot be observed, we can use a partial adjustment model (Houthakker, 1980). This assumes that the change in actual electricity demand between two neighbouring periods, $t-1$ and t, is only some fraction, say λ, of the difference between the logarithm of actual electricity demand in time period $t-1$ and the logarithm of the long-run equilibrium electricity demand in time period t. We denote this partial adjustment model as

$$\text{ln}E_{i,t} - \text{ln}E_{i,t-1} = \lambda(\text{ln}E^*_{i,t} - \text{ln}E_{i,t-1}) \tag{12}$$

where E is the electricity demand, i denotes the utility, t is the time index and $E^*_{i,t}$ denotes the long-run equilibrium demand in time period t. The value of the adjustment factor, λ, lies between 0 and 1. Equation (12) implies that given an optimum, albeit unobservable, level of electricity demand, the demand will gradually converge to the optimal level between any two time periods. We can use this model of partial adjustment to specify dynamic models of electricity demand.

Following Alberini and Filippini (2011) we can express the desired electricity use as $E^*_{i,t} = \alpha P_E^{\eta} e^{(X\gamma)}$ where P_E is the price of electricity, η is the long-run price elasticity of electricity, X is a matrix of household and socio-demographic characteristics that influence household electricity consumption.[35] If we replace this equation in equation (12), rearrange it and insert a statistical error term, ε, we get

$$\text{ln}E_{i,t} = \lambda\text{ln}\alpha + \lambda\eta\text{ln}P_E + \lambda X\gamma + (1-\lambda)\text{ln}E_{i,t-1} + \varepsilon_{i,t}. \tag{13}$$

The short-run elasticity of electricity demand is denoted by the coefficient of the lnP_E term, $\lambda\eta$, while the long-run elasticity is obtained by dividing the estimate of $\lambda\eta$ by λ. We obtain λ from the estimates in our model by subtracting the estimated coefficient of the ln$E_{i,t-1}$ term from 1.

[33]There are numerous applications of household production to estimating the electricity demand. See, e.g., Dubin (1985), Flaig (1990), and Filippini (1999).

[34]There is some debate about the short- and long-run demand estimates with Baltagi and Griffin (1984) stating that a cross-sectional analysis is an indication of the long-run estimates since the majority of households in a cross-section are well adapted to their financial circumstances and the cross-section will represent a steady-state. Therefore, the estimated elasticities will represent long-run circumstances (Thomas, 1987).

[35]We exclude the utility-specific i subscript in the independent variables to avoid clutter in notation.

3.4 Data

We use aggregate electricity consumption data at the utility level from a survey carried out by us. We mailed a questionnaire to the 50 largest utilities in Switzerland and also to a random sample of 55 mid-sized utilities. Data from 30 utilities were, ultimately, usable. The questionnaire covered questions about the consumption of residential customers, number of customers, electricity tariffs and utility characteristics. 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.

Other sources of data are the Bundesamt für Statistik (BFS) and MeteoSchweiz. Weather information on heating and cooling degree days is from MeteoSchweiz and demographic information used to calculate the household size and a measure of income are from BFS. The variables used from these two sources and the summary statistics of those variables are presented in Table 14. Apart from these variables, we also need the price electricity. We calculate this for each utility in each year based on the information from residential electricity tariffs as

$$P_{average} = \frac{(FF_{tou} + MP_{peak} \cdot E_{peak} + MP_{off-peak} \cdot E_{off-peak}) + (FF_{single} + MP_{single} \cdot E_{single})}{E_{total}}, \tag{14}$$

where E_{peak} is the total peak period consumption of customers with a TOU tariff, $E_{off-peak}$ is the total off-peak period consumption of customers with a TOU tariff, E_{single} is the total consumption of customers with a single tariff scheme, E_{total} is the total electricity consumption of customers in a utility in a particular year, 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 single tariff customers, and FF is the fixed fee with subscripts tou and $single$ denoting the time-of-use and single tariff schemes, respectively, calculated for all customers.

Using the average price, depending on the data used, can create an endogeneity problem. If disaggregated data are used, two-part and block pricing schemes mean that the average price depends on the quantity consumed by the household, and are therefore endogenous with one another. At the aggregate level, however, Shin (1985) argues that the potential for the price to be endogenous with consumption is mitigated by the presence of many different pricing levels and schemes at different locales.[36]

[36] We have estimated our model using the instrumental variable method. We used the ElCom price as an instrument for the average price, similar to Boogen et al. (2014), and find that the estimates for the price variable are statistically insignificant. A test for endogeneity indicated that the average price variable is not endogenous so we proceed without considering any endogeneity issues.

Table 14: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Total consumption per customer (in kWh)	4547.52	1311.02	1856.77	8418.08	182
Average price (in Rappen/kWh)	20.12	3.39	12.89	28.46	182
Degree days	3705.51	841.61	2449.22	6452.90	210
Average taxable income (in CHF/year)	30661.23	4541.94	23745.54	47150.28	210
Household size	1.86	0.55	0.76	4.24	185

3.5 Estimation and Results

We estimate equation (13) using, first, ordinary least squares (OLS). The results are provided in Table 15 in the column labelled "OLS". However, OLS is unable to account for unobserved heterogeneity. The estimates are also biased and inconsistent since the inclusion of the lagged dependent variable violates the strict exogeneity condition since it is correlated with the error term. There are also several disadvantages of OLS over other panel data methods when we have panel data at our disposal.[37] The unobserved heterogeneity in panel data models can be incorporated by using fixed effects. In our case, we use utility-specific fixed effects to account for observations at the utility level. The results of estimating the dynamic demand model using utility-specific fixed effects (FE) are provided in the column labelled "FE" in Table 15. However, estimating a dynamic panel data model with a lagged dependent variable in a fixed effects framework, as in the case with OLS, is not appropriate since the strict exogeneity assumption is violated. The estimated coefficients are biased and inconsistent since the lagged dependent variable is correlated with the error term. The literature mentions that the estimated coefficient for the lagged variable using OLS is biased upwards while the coefficient in a fixed effects model (or least squares dummy variable model) is biased downwards in a dynamic model.[38]

Several solutions have been proposed using the method of instrumental variables. These include proposals by Anderson and Hsiao (1982), Blundell and Bond (1998), and Arellano and Bond (1991). The general idea is to use lagged levels and, alternatively, complement them with lagged differences as valid instruments for the lagged dependent variable, i.e., they are uncorrelated with the error term. However, this can be problematic in estimation using small samples, as suggested by Baltagi (2008) and Roodman (2009). In small samples, using too many instruments leads to estimates that are biased towards OLS estimates. Also, the GMM estimators proposed by Arellano and Bond (1991) and Blundell and Bond (1998) are appropriate for samples with a large number of panel units, N, and a small number of units may lead to biased estimates.[39]

An alternative to the GMM estimators has been proposed by Kiviet (1995). This method is based on the correcting the bias of the least squares dummy variable (LSDV) method. Kiviet (1995) and Judson and Owen (1999) use Monte Carlo simulations show that in usual aggregate dynamic panel data models, with less than 20 time periods and number of units less than 50, the GMM estimator proposed by Arellano and Bond (1991) is outperformed by the estimators proposed by Anderson and Hsiao (1982) and Kiviet (1995). Since our data is relatively small, with 7 time periods and 30

[37] For a description of the advantages of panel data methods over OLS please refer to a standard panel data econometrics text book, e.g. Baltagi (2008).

[38] Refer to Nickell (1981) for a discussion.

[39] We have also used GMM estimation to estimate our models. However, the results were not satisfactory.

utilities, we follow the method proposed by Kiviet (1995). In what follows, we refer to the corrected LSDV estimator proposed by Kiviet (1995) as the LSDVC estimator. The results of estimating the dynamic demand model using the Kiviet correction to utility-specific fixed effects are provided in the column labelled "LSDVC" in Table 15.

The results from the OLS estimation procedure indicate that the short-run elasticity of electricity is extremely inelastic with a value of -0.12 while the long-run elasticity is extremely elastic with a value of -1.41. These are estimated by using the average price as calculated in equation (14). These results provide a good indication of the unsuitability of using OLS to estimate the price elasticities, both short- and long-run. Therefore, we next focus on the results using the utility-specific fixed effects.

Table 15: Dynamic models of (log) residential electricity demand

	OLS	FE	LSDVC
L.(Log) Total consumption per customer	0.92^a	0.27^c	0.48^a
	(0.03)	(0.16)	(0.10)
(Log) Average price	-0.12^b	-0.33^b	-0.30^a
	(0.05)	(0.15)	(0.11)
(Log) Degree days	0.02	-0.50^b	-0.52^c
	(0.02)	(0.21)	(0.29)
(Log) Household size	0.02	0.15^a	0.13^c
	(0.02)	(0.04)	(0.08)
(Log) Taxable income	-0.05	0.54	0.52
	(0.04)	(0.45)	(0.51)
Intercept	1.35^b		
	(0.63)		
Utility fixed effects	No	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	152	152	152
Adjusted R^2	0.94	0.96	

Standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels respectively.
L.: Lagged variable.

Table 16: Price elasticities for dynamic models

	OLS	FE	LSDVC
Long-run	-1.41^a	-0.46^c	-0.58^b
	(0.41)	(0.24)	(0.22)
Short-run	-0.12^b	-0.33^b	-0.30^a
	(0.05)	(0.15)	(0.11)
Observations	152	152	152
Test for equality	0.00^a	0.31	0.05^b

Standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels respectively.

The coefficients for the fixed effects specification indicate that the price elasticity of residential electricity consumption are inelastic in the long-run but are more elastic in the short-run. The long-run elasticity is estimated to be around -0.5 while the the short-run elasticity is around -0.3. The coefficients for the bias-corrected LSDV model lie between the OLS and FE estimates, as expected, with the estimates closer to the FE estimates than the OLS estimates. The long-run elasticity is around -0.6 while the short-run elasticity is -0.3. It is also reassuring to note that the elasticities when using the Kiviet correction are also statistically significant at the 5% level of significance.

Given the calculations of the short- and long-run estimates of price elasticities we need to make sure that the estimates are, indeed, different from each other. Therefore, to do this we test the equality of the short- and long-run elasticities. We report the results of these tests for our various models in Table 16. The results indicate that the short- and long-run are statistically different from each other when we consider the bias-corrected LSDV model. In all other cases, apart from the OLS model using $P_{average}$ as the average price, the estimates are not statistically different from each other. This is important because most studies do not test for the equality of the estimates and while the point estimates may appear to be different, the associated standard errors may lead to the estimates not being statistically different from each other.

The estimates for the socio-demographic and weather variables are, in general, not statistically significant. In the instances where they are statistically significant, the level of significance is mostly at the 10% level. This observation is consistent with fixed effects panel data studies that make it difficult to estimate variables that exhibit low within-variation as is typically the case for socio-demographic and weather variables. It is, however, interesting to note that when these variables are statistically significant, the signs are as expected. So, for example, increasing the heating degree days will increase per customer electricity consumption while and increase in the household size will have the same effect. All models include year fixed effects that are common to all utilities and control for overall unobserved macroeconomic factors that may affect electricity consumption.

If we compare our estimates to those of the other existing studies for Switzerland we see that, while similar to the estimates of Zweifel et al. (1997) and Filippini (1999), ours are less inelastic than those studies. Our long-run estimates are comparable to those by Spierer (1988) but not as high as the estimates reported by Carlevaro and Spierer (1983). Our short-run estimates are also lower than those reported by Carlevaro and Spierer (1983). Our estimates indicate that Swiss households are relatively price-inelastic with respective to electricity prices. Therefore, an increase in electricity prices may not get the desired effect of reducing electricity consumption by a large amount. The results suggest that a 1% increase in electricity price will cause a 0.45% reduction in electricity consumption in the long run while it will cause only a 0.23% reduction in the short run.

3.6 Conclusion

In this chapter we estimate the residential electricity demand for households in Switzerland using a dynamic model of demand. We use an unbalanced panel dataset of 30 utilities covering 7 years from 2006 till 2012. Our results indicate that the price elasticity of electricity is inelastic, both in the short- and long-runs. We estimate the short-run price elasticity to be about -0.3 and the long-run price elasticity to be about -0.6. If we compare these results to those we obtained in chapter 2 using disaggregated data we find that they are remarkably similar. The long-run estimates in chapter 2 are generally around -0.6 which are also the long-run estimates using aggregated data. The short-run estimates that we obtain in chapter 2 can be considered to be more medium-term estimates due to the argument, as mentioned in section 2.6.3, that the data are cross-sectional and we do not directly observe any adjustment decisions. In that case, the medium-term estimate of between -0.4 and -0.5 lies between the short-run estimate we obtain using aggregated data (-0.3) and the long-run estimate using both aggregated and disaggregated data (-0.6).

These estimates indicate that, from the point of view of reducing electricity consumption, pricing policy may have a moderate impact, at least on residential customers and specifically in the short run. However, the higher estimate of the long-run price elasticity of electricity consumption indicates that pricing policy will have a stronger influence on the long-run demand for electricity. Policy makers concerned about reducing electricity consumption may need to discuss the possibility of using a combination of policies, including pricing policy, to effectively reduce or, at least, stabilise the per customer electricity consumption in Switzerland. As in section 2.7 using disaggregated data, our results in this chapter using aggregated data suggest that, in view of the recent proposal to introduce a tax on electricity, an increase in the price of electricity may result in a moderate decrease in electricity consumption. The importance of *Energy Strategy 2050* emphasises the need to have appropriate energy policies in place to mitigate the difficulties of a switch away from nuclear energy to other sources of electricity. Given the lack of recent studies in the estimation of price elasticity of electricity demand in Switzerland, especially for non-residential consumers, it is important that further research is carried out in all sectors, residential and non-residential, to obtain reliable estimates of the responsiveness of customers to price changes. Generally, this applies also for price elasticities of demand for other fuels, as the energy tax proposed within the *Energy Strategy 2050* will not only be applied to electricity.

4 Demand-Side Management by Electric Utilities: Analysing its Impact on Residential Electricity Demand

4.1 Introduction

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 programmes began in the late 1970s as a response to the energy crises primarily by utilities on the west coast of the USA before gradually spreading to the east coast, north central and 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 programmes was to change the pattern of electricity demand so as to modify the load faced by a utility. It was subsequently modified to take into account the programmes 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 programmes, information campaigns and voluntary programmes (Gillingham et al., 2006).[40] Table 17 provides an overview of some market and non-market instruments for demand-side management, both for load management and reducing energy demand.

Table 17: Demand-side management instruments

	Load management	**Energy efficiency**
Market instruments	1. Time-of-use tariff 2. Critical peak pricing 3. Critical peak rebates 4. Real-time pricing 5. Interruptible load tariff	1. Efficiency bonus 2. Rebate systems 3. Energy tax
Non-market instruments	1. Ripple control 2. Smart metering	1. Information campaign 2. Voluntary agreements on efficiency goals 3. Appliance standards 4. Labelling

The World Energy Outlook (International Energy Agency, 2009) emphasises the huge potential of energy efficiency (EE) measures. These measures are viewed by many as "low-hanging fruit" due to their low marginal cost. It is, therefore, important to analyse the impact of various EE measures since there is a lack of a systematic analysis of DSM efforts in Switzerland. This includes a qualitative analysis of DSM programmes as well as a rigorous econometric analysis of the effectiveness of

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

such programmes on Swiss residential electricity demand. There are two major contributions of this chapter. Firstly, we provide a description of the various DSM activities carried out by Swiss utilities using information from a survey carried out in 2013. This is, to our knowledge, one of the first studies of such a kind for Switzerland. Secondly, we also present results of an econometric estimation of the impact of EE and conservation efforts carried out by Swiss utilities which is, to the best of our knowledge, the first study of its kind using longitudinal data for Switzerland. In this chapter we consider energy efficiency and conservation measures but not load management programmes for our econometric estimation since we are unable to identify their impact on load. However, we consider both energy efficiency and conservation measures as well as load management programmes for our descriptive analysis.

The structure of this chapter is as follows. In the rest of this section we provide a brief overview of energy policy and DSM efforts in Switzerland as well as review of previous research on DSM in Switzerland. In section 4.2 we provide a description of our survey performed on some Swiss utilities as well as the construction of an energy efficiency score. Section 4.3 describes the utilities in our survey and their DSM activities. The following section on policy evaluation, section 4.4, describes the existing literature on evaluating DSM activities. The variables used in our model and their sources are also described in section 4.4. Our identification strategy and estimating equation of the impact of EE programmes on residential electricity demand are described while the results of the econometric estimation are also provided in section 4.4. Section 4.4 also has several robustness checks. The final section has concluding remarks.

4.1.1 Energy Policy and DSM in Switzerland

Switzerland is a federal state consisting of 26 cantons. The 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 is to ensure an economic and sustainable provision of energy and the promotion of local and renewable energy sources. Federal Councillor Adolf Ogi started a programme called "*Energie 2000*" that ran between 1990 and 2000. This programme was relaunched as "*EnergieSchweiz*" in 2001 by Federal Councillor Moritz Leuenberger. 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 programme 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).

The Electricity Supply Act (StromVG) brought forward the relatively late start of liberalising the electricity market in Switzerland, which is planned in two phases. In the first phase, customers with a yearly consumption over 100 MWh can choose to go to the free market. In the second phase, which has not started yet, it is planned that all other small consumers can also choose their electricity supplier. The experiences from 2009 showed that the goals of liberalisation where not reached completely. Therefore, the government started a process for the revision of the Electricity Supply Act. These activities had to be stopped in March 2011, because of the urgent need to draw up a new energy concept for 2050 (SFOE, 2013b).

Following the decision of the Swiss Federal Council to phase out nuclear energy after the Fukushima Daiichi incident, the Swiss Federal Office of Energy (SFOE) developed the *Energy Strategy 2050*. This sees the utilities as key players for reducing electricity consumption because they have direct contact with end-customers. With this in mind the Federal Council proposed, within the initial package of measures, mandatory efficiency goals on a national level for the utilities that sell more than 30 GWh as one way to reduce electricity consumption. With this in mind the Federal Council proposed, within the initial package of measures, mandatory efficiency goals on a national level for the utilities that sell more than 30 GWh as one way to reduce electricity consumption with a white certificates scheme.[41]

Given the mandatory efficiency goals for large utilities it is important for utilities to take a leading role in implementing DSM measures for improving energy efficiency. As mentioned previously, DSM instruments are mostly defined and implemented at the local level. There is no policy framework on utility-centred DSM at the national level. In Switzerland, 681 utility companies (as of May 2014) are involved in the production, distribution and supply of electricity.[42] 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 loads in order to keep the electricity network stable. 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 faced by residential consumers vary between 50 and 100% (SFOE, 2009). There are also utilities that price differently in winter and summer. However, 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, the parliament in the canton of Basel-Stadt voted for a new energy law that was pioneering. It allowed the canton to raise a tax on electricity, that would be redistributed equally among the residents and companies (SFOE, 2003). Zürich and Basel are two early examples of DSM measures introduced by utilities in Switzerland. In recent years, several utilities introduced

[41] 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).

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

energy efficiency measures such as rental of smart meters, awareness campaigns and funding help for efficient appliances. However, as mentioned above, there has been no policy framework on utility-centred DSM at the national level until now.

4.1.2 Previous Work

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.[43] The diversity of utility companies in Switzerland does not help to gain a broad overview. In 2011, two environmental organisations, the World Wide Fund for Nature (WWF) and Pro Natura, developed a rating system for the ecological comparison of Swiss utilities. Vettori et al. (2011) compare 12 utilities on five criteria, namely, composition of the electricity mix, ecological efforts in hydro power production, electricity products and services, efforts in promoting energy efficiency and strategic orientation with respect to ecology. They use a multi-criteria analysis to rate the utilities. This evaluation method transforms ratings of different scales in performance levels and thus allows comparison across different ranges. For each criterion, a score between 0 and 4 is assigned. Each criterion has a specific weighting. The scores are multiplied by the weighting, resulting in the score per criterion. This scores per criterion are then summed up to a total score. The maximum possible score is achieved when each criterion is fully met. In their report, Vettori et al. (2011) use publicly available information on the utilities in a first draft. In a second step, the utilities could add information left out in the first draft.

Similarly, Vettori et al. (2014) assess the extent to which the utilities promote energy efficiency and renewable energy using data on 24 utilities. They compare the utilities based on their strategic orientation, role model effect, renewables (production, water protection and supply), energy efficiency services, funding programmes and tariff measures. They use a multi-criteria analysis and the aim of this benchmarking was to trigger a reaction in utilities, the target group, which contributes to the energy transition and the goals of the *Energy Strategy 2050*. A prerequisite is that the benchmarking concept should be widely accepted by the utilities. In developing the conceptual framework Vettori et al. (2014) have laid great emphasis on a participatory approach, which integrated the utilities and other involved organizations as a "sounding board". In addition, the process was also split into two parts, a pilot survey after which the benchmarking was improved and an additional survey afterwards.

Blumer et al. (2014) use cross-sectional data on 114 utilities and a two-step cluster analysis to identify three different clusters of Swiss utilities based on their activity in implementing DSM programmes. In addition they use analysis of variance to find that the clusters differ significantly on utility characteristics such as size.[44]

[43] See section 4.4.1 for an overview of the impact of DSM in the US.
[44] Further information on this paper can be found in section 4.3.

4.2 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 to 105 utilities in Switzerland between April and November, 2013. 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 certain 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. The reason for splitting the questionnaire into two parts was to make it easier for utilities to report the respective values since the two functions are usually the responsibilities of two different employees within a utility. The survey questionnaire and the cover letters in German, French and Italian are provided in the Appendix.

Table 18 shows the response rates to the survey, differentiating between the three major language areas in Switzerland.[45] 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 18: 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%**

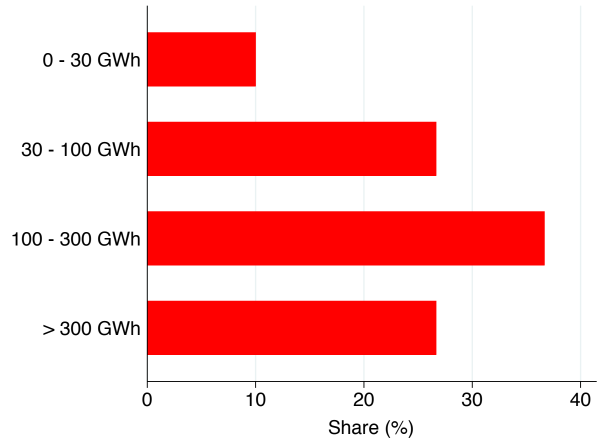
In Switzerland, electricity utilities are quite diverse in the sense of their organisation and ownership, size and field of activity. There are different ways to measure the size of a utility. Different proxies for the size of a utility could be, e.g., the sales revenue, the number of employees or the quantity of electricity delivered. Figure 6a presents four groups according to the utilities' supply of

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

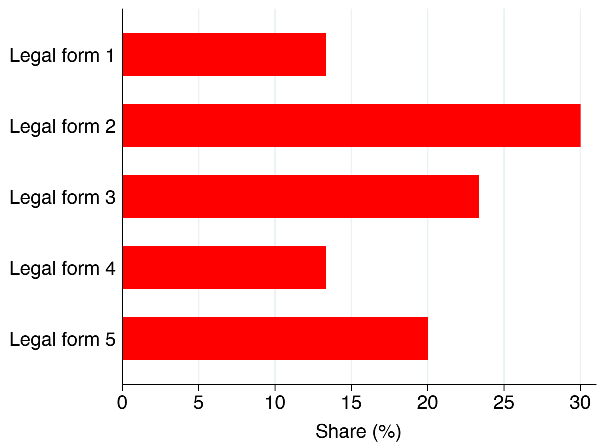
electricity to their residential customers in 2012. The graph shows that the majority of utilities supply between 100 and 300 gigawatt hours (GWh).

Another feature of Swiss electricity utilities is its legal form. We distinguish between five legal forms. They are (1) dependent public institution (Legal form 1), (2) independent public institution (Legal form 2), (3) publicly owned stock company (Legal form 3), (4) stock company with a majority of public ownership (Legal form 4) and, (5) stock company with a minority of public ownership (Legal form 5). Figure 6b 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.

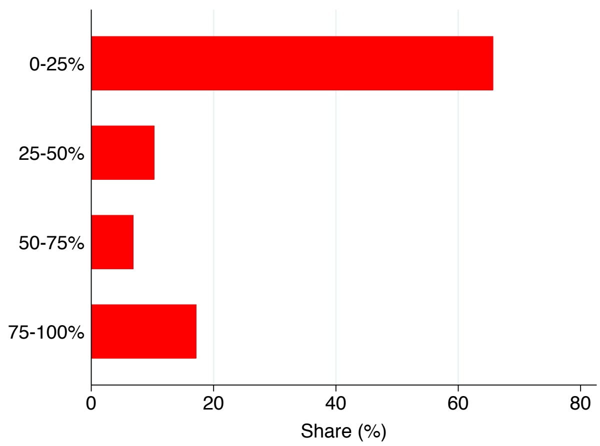
Utilities can be active in production, transmission and distribution of electricity. As we focus on utilities with residential end-use consumers, the utilities in the sample are mostly distribution companies. Nonetheless, some of the utilities also generate their own electricity. Figure 6c shows the 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 focussed on the distribution side. Only a minority, close to 20%, produce more than three quarters of their supply for residential customers.



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



(b) Share of utilities by legal form



(c) Share of utilities by own production

Figure 6: Utility characteristics

4.3 Descriptive Analysis of DSM in Swiss Utilities

In this section we provide a detailed descriptive overview on the activities of the sampled utilities in the field of DSM. We have data on 30 utilities for seven years from 2006 to 2012.[46] Since not all utilities could provide information in all seven years, we do not have all the observations (210 from 30 utilities for 7 years) for our analyses.

In the previous section, we discussed that Swiss electric utilities are quite diverse in the sense of their organisation and ownership, size and field of activity. Blumer et al. (2014) state that even if the size of utilities is not sufficient to explain the variance in the programme activities, a certain size could be a necessary condition for a utility to adopt and run an energy efficiency programme. They measure size of a utility as the number of employees to capture the organisational capacity, and hypothesise that if there is a lack of human resources, utilities will not be able to implement DSM. The authors also use the legal form as an explanation for measuring the activity of a Swiss utility in promoting energy efficiency measures. They argue that stock companies should have more interest in energy efficiency promotion, as they need to position themselves in the changing Swiss electricity market. However, there is also an argument for an opposite effect. Public utilities may be required by law to introduce measures for energy efficiency. Such a public mandate for energy efficiency might be introduced due to a referendum or an governmental initiative, either at the city or cantonal level. For example, in 1989, the inhabitants of Zürich voted for the “Stromsparbeschluss”. This included the establishment of a fund to promote the rational electricity use and the use renewable energy sources. Similarly, the canton of Basel-Land has a public mandate for information and advice on the rational use of electricity. It is financed by the municipalities and the canton with each municipality and the canton paying CHF 0.25 each per inhabitant per year. Feiock et al. (2012) find that municipality-owned utilities that have their own generation capacities are more likely to implement energy efficiency programmes. Utilities with their own capacities are interested in DSM since, it is argued, it might be less expensive to implement conservation measures than to build new power plant capacity, especially peak power plants, as they are only used for a few hours a year.

Table 19 provides the summary statistics of the various strategies used by Swiss utilities for the promotion of energy efficiency. A fifth of the utilities surveyed also have a corporate strategy for promoting energy efficiency. In addition, around a fifth has a public mandate to promote energy efficiency.[47] As mentioned previously, a public mandate obliges a utility to implement energy efficiency measures by law. While only 7% of the utilities have quantified goals to do this, 14% have a fund to which a fixed amount of the revenue is dedicated for DSM or renewable projects. Another 7% have a voluntary fund where the customers can choose an electricity product that also transfers a fixed amount of the electricity price to such a fund. Figure 7 shows the development of the characteristics listed in Table 19 from 2006 to 2012. In the beginning, the number of utilities that have specific types of EE programmes seems to be quite stable. However, after 2009, there appears to be an increase in the number of utilities having such EE programmes. Still the share of utilities with, for example, a corporate EE strategy, is very low. In 2012, there are only 8 utilities out of the 30 in our sample that have a corporate EE strategy. This may reflect the fact that there is no coherent policy framework at a national level for Swiss electricity utilities. We first evaluate tariff design characteristics. In the second, third, and fourth parts of this section we describe the utilities’ activities in three DSM areas:

[46] Note that in this study the term “utility” makes no distinction between grid operators and energy suppliers.

[47] There are few utilities that have both a corporate strategy and public mandate.

energy efficiency consulting, replacement of appliances and funding activities. The last part reports the calculation and description of an energy efficiency score for utilities .

Table 19: Summary statistics of utility EE measures

Variable	Mean	Std. Dev.	Min.	Max.	N
Dummy for public EE mandate (Leistungsauftrag)	0.19	0.39	0	1	210
Dummy for corporate EE strategy	0.20	0.40	0	1	210
Dummy for quantified EE goals	0.07	0.26	0	1	210
Dummy for EE fund	0.14	0.35	0	1	210
Dummy for voluntary EE fund	0.07	0.25	0	1	210

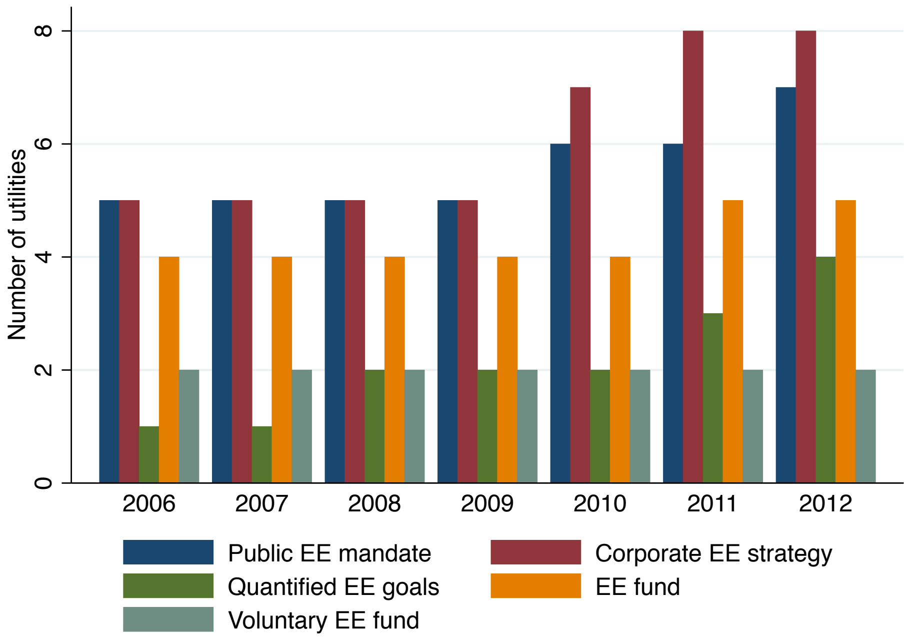


Figure 7: Utility energy efficiency measures (2006–2012)

4.3.1 Tariff Design

Designing a tariff system properly is also a way to promote energy efficiency by providing incentives to the consumer to reduce their electricity consumption. For example, a fixed fee combined with an increasing block pricing scheme can provide incentives to consumers for high electricity savings. Since the introduction of the Swiss Electricity Supply Law (StromVG) in 2007, Swiss utilities are obliged to report their electricity prices for customers in the basic supply to the regulator, ElCom, by the 31st of August each year.[48] ElCom then publishes the average prices for different household (or industry) types.[49] Generally, the electricity price in Switzerland has three components: a price for grid utilisation, a price for the electricity itself, and federal and municipal duties. Table 20 shows a breakdown of the price components.

[48] Customers in the basic supply (Grundversorgung) are not on the free market.
[49] http://www.strompreis.elcom.admin.ch, website accessed 15. October 2014.

Table 20: Electricity price components for residential customers in Switzerland

1	**Grid utilisation**		
1a		Fixed fee	CHF/year
1b		Energy price (peak)	Rp./kWh
1c		Energy price (off-peak)	Rp./kWh
1d		Price for system services	Rp./kWh
2	**Energy**		
2a		Fixed fee	CHF/year
2b		Energy price (peak)	Rp./kWh
2c		Energy price (off-peak)	Rp./kWh
3	**Duties**		
3a		Duties to municipality	Rp./kWh
3b		Federal duties (KEV)	Rp./kWh

With regard to the electricity tariff structure, Figure 8 shows that most of the utilities surveyed have a fixed fee and time-of-use pricing policy (FF+P/OP in Figure 8) for their residential customers. There are also a number of utilities in our sample that have a fixed fee and single tariff scheme (FF+Single in Figure 8). There are only 3 utilities in our sample that do not have a fixed fee (P/OP in Figure 8). There are also a few utilities that have either a fixed fee and a progressive tariff scheme (FF+PT in Figure 8) or a fixed fee and a regressive tariff scheme (FF+RT in Figure 8).

In our survey we also asked for tariff measures that the utilities introduced to promote energy efficiency. The utilities reported several such measures including a progressive tariff, including a bonus for energy efficiency, and a tax on electricity (see Figure 9). More than half of the utilities surveyed also have a special tariff for interruptible loads.[50]

[50] In the survey we asked utilities if they have an option for customers using appliances with heavy loads, e.g. electric boilers and heat pumps, to choose a special tariff scheme where they are charged lower electricity prices but where utilities have the option to regulate electricity supply depending on the total load faced by the utility.

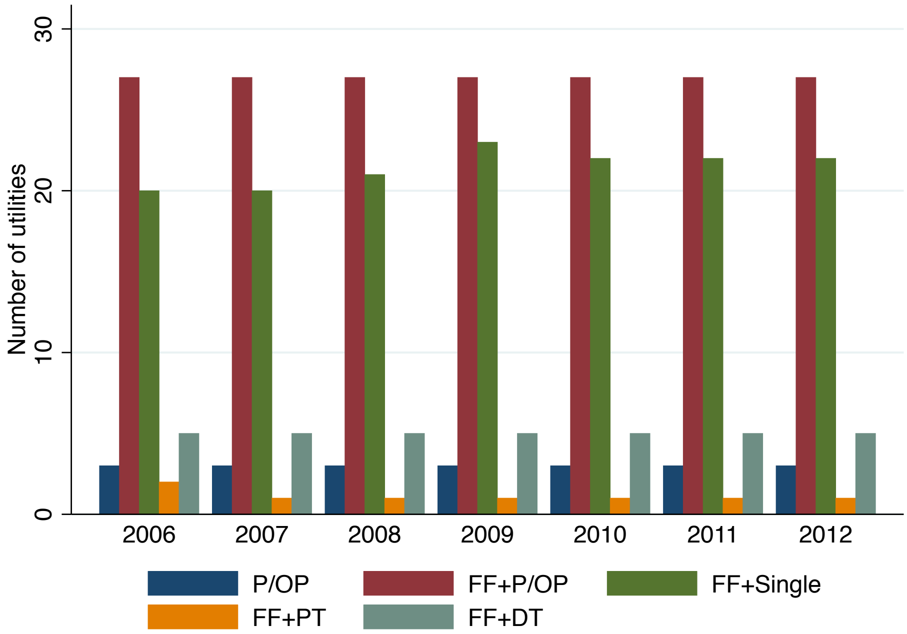


Figure 8: Utility tariff structure (2006–2012)

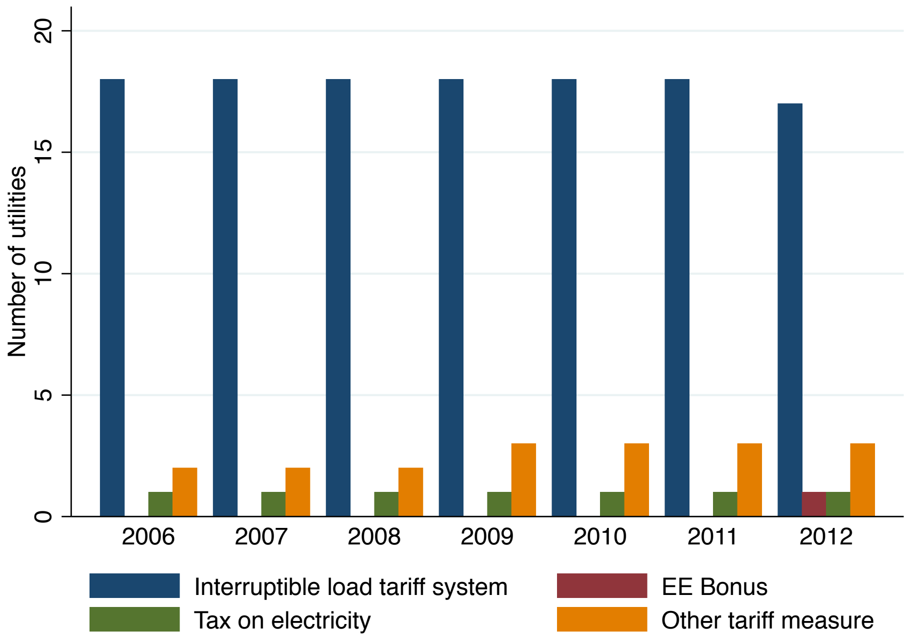


Figure 9: Utility tariff measures (2006–2012)

4.3.2 Consulting Activities

Despite the lack of a coherent national policy to promote energy efficiency, one of the areas in which utilities in Switzerland are quite active is in energy efficiency consulting. Consulting includes various forms of information programmes in order for the consumer to gain knowledge on either his consumption or on means and ways to save energy. We group these measures into six different fields. They include information programmes on the internet and leaflets, public relation events, smart meter rentals, EE information on the electricity bill, energy advice centres and energy audits. Table 21 shows the summary statistics of the adoption of these programmes by the surveyed utilities. The table shows that, on average, a utility runs at least three of these measures. The most abundant form is giving the customers information on the utility's respective webpage. Three quarters of the utilities use this form of consultancy. However, only a third of the utilities run an energy advice centre, as this is a more expensive measure to introduce. Figure 10 plots the number of utilities that implemented the respective measure as a function of time. The graph shows that, in general, the number of utilities active in consulting is growing for all six measures during our study period. This is even more pronounced from 2009 onwards, except for the rental of smart meters, whose numbers declined in 2012. Rental of smart meters used to be a rather popular measure in the beginning of the study period but it was overtaken by most of the other measures in 2012.

Table 21: Summary statistics - Consulting activities

Variable	Mean	Std. Dev.	Min.	Max.	N
Information on Web, leaflets etc.	0.76	0.43	0	1	210
Public relation, fairs etc.	0.61	0.49	0	1	210
Rental of smart meters	0.55	0.50	0	1	210
EE Information on bill	0.46	0.50	0	1	210
Energy Advice Centre	0.28	0.45	0	1	210
Energy Audits	0.53	0.50	0	1	210
All Consulting (Sum of measures)	3.19	1.89	0	6	210

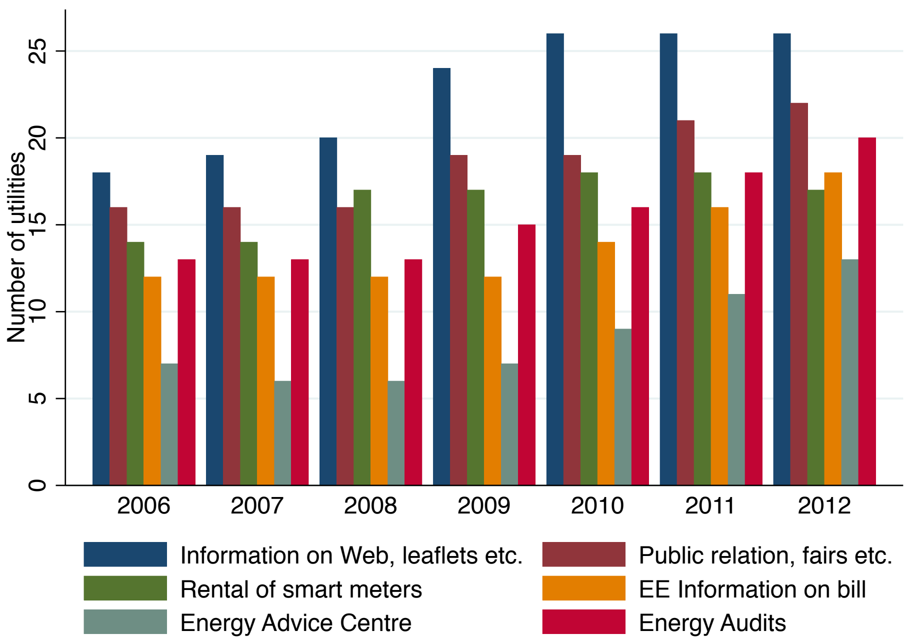


Figure 10: Utility consulting measures (2006–2012)

4.3.3 Replacement of Appliances

Another option for the utilities to promote energy efficiency is through helping their customers to replace old and inefficient home appliances and (electric) heating systems. This can be carried out by providing them with information on new and energy efficient appliances or even with financial help. Figure 11 shows the number of utilities that have DSM measures concerning consulting and funding of home appliances and heating systems from 2006 to 2012. While 41% of the utilities consult their residential customers on home appliances by giving them information and advice on energy efficient home appliances, only 20% help their clients with the funding of such energy efficiency investments. The same applies for heating systems with 44% providing consulting while 30% of the utilities help with funding. Figure 11 shows that the number of utilities providing consulting activities has increased since 2009. Table 22, meanwhile, provides a snapshot of appliance and heating system measures in 2012 and provide a breakdown of our surveyed utilities that provide consulting, funding or both for home appliances as well as heating systems. While most utilities provide one or the other, there are 7 utilities that provided both for home appliances and 10 utilities that provided both to consumers interested in buying heating systems.

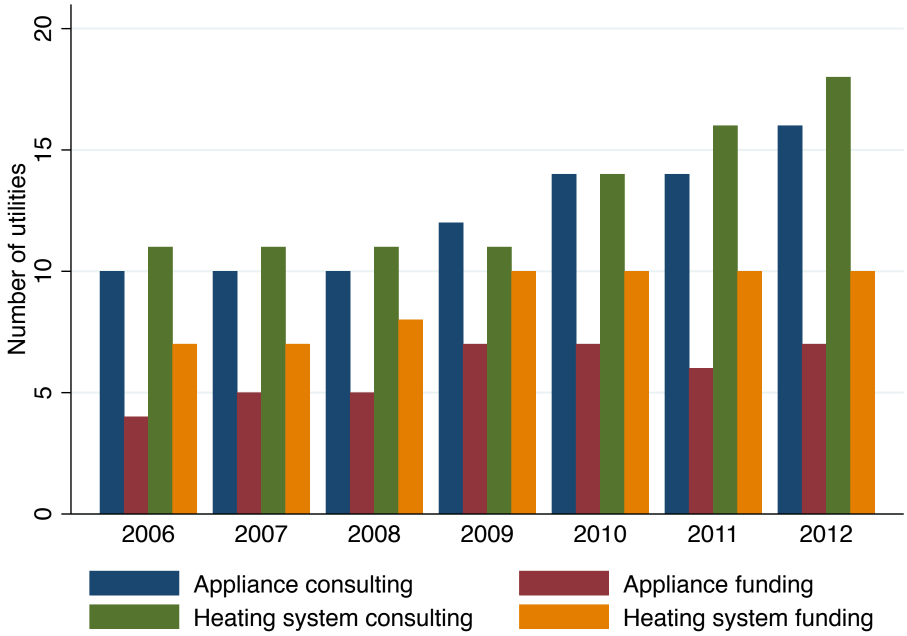


Figure 11: Utility measures for replacement of appliances (2006–2012)

Table 22: Appliance and heating system measures in 2012

	Consulting	Funding	Both
Home appliances	16	7	7
Heating system	18	10	10

4.3.4 Funding Activities

In order to measure the utilities' activity in DSM a popular method is to use the monetary effort for their programmes. In Table 23 we summarise the DSM expenditures between 2006 and 2012 for the 30 surveyed utilities. DSM expenditure is measured as the yearly expenditure on all energy efficiency measures directed at residential customers. Utilities spent, on average, CHF 2.86 per residential customer during the survey period.[51] 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 12, where we plot electricity consumption per customer against DSM expenditure per customer. Note that Figure 12 includes all the surveyed 30 utilities and not only utilities with positive spending. We can see that there is a clear bunching around zero expenditure and only a few utilities that spend a large amount, per customer, on DSM measures. To take a closer look in Figure 13 we plotted the variation in spending for each utility separately. Apart from observing the evolution of individual utility DSM spending over time, the graphs also 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 14 shows a box-plot of the positive spending binary variable against the consumption per customer from 2006 to 2012, whereas Figure 15 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 23: Summary statistics - Funding activities

Variable	Mean	Std. Dev.	Min.	Max.	N
Expenditure on all DSM measures	313129	1048719	0	5900000	210
Expenditure on Funding	98089	336516	0	2951717	210
Expenditure on all DSM measures per customer	2.86	6.13	0	30.83	201
Expenditure on all DSM measures per MWh	0.97	2.56	0	15.22	184
Expenditure on Funding per customer	1.28	3.49	0	30.14	185
Expenditure on Funding per MWh	0.32	0.82	0	5.33	184

[51] Utilities spent CHF 4.42 per residential customer on DSM conditional on DSM spending being greater than zero.

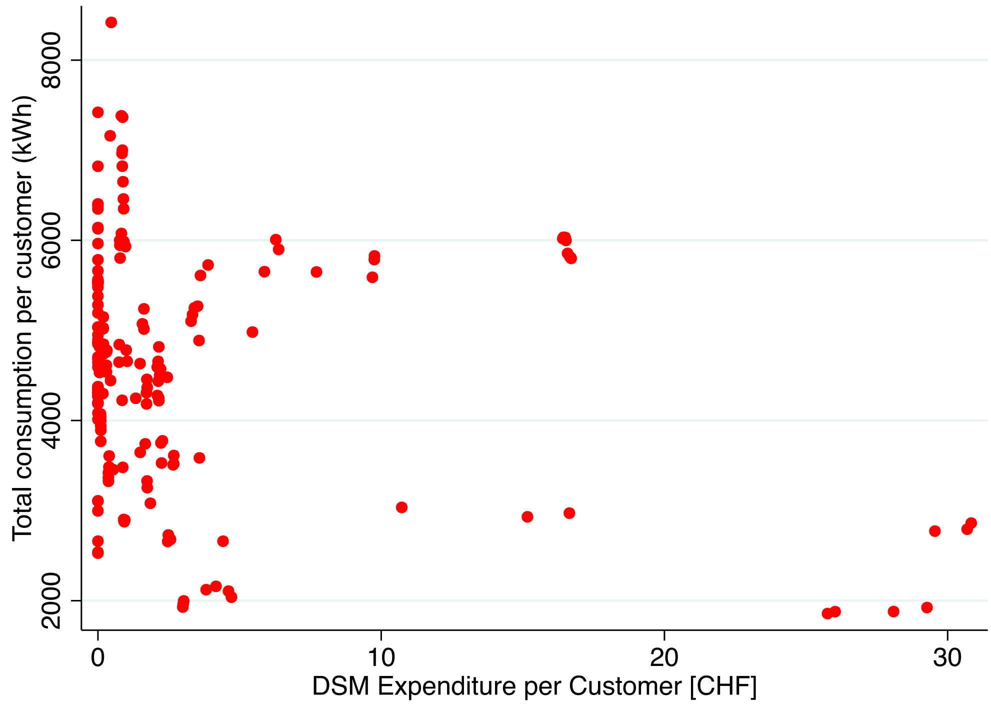


Figure 12: Electricity consumption per customer versus DSM Expenditure per customer

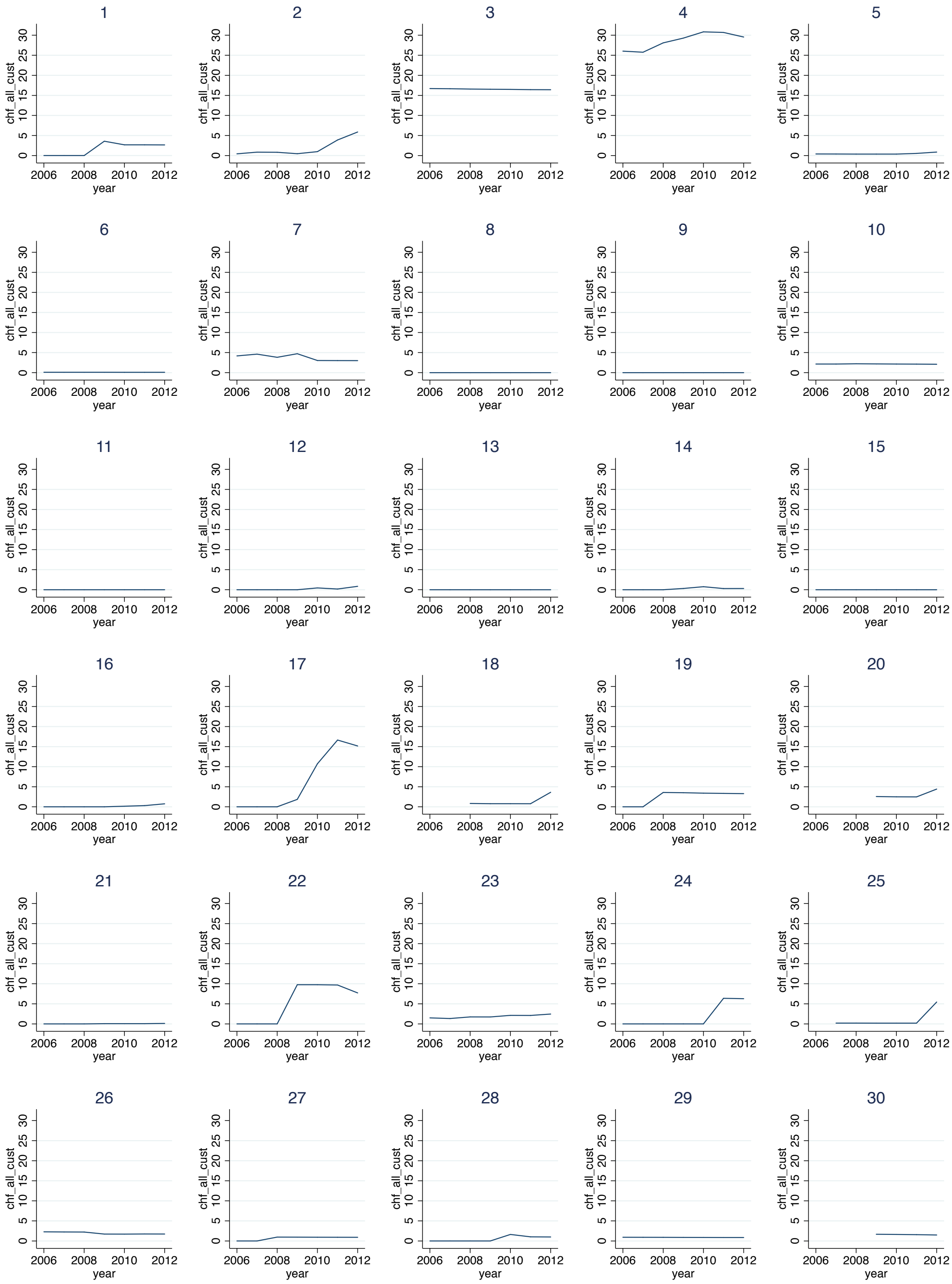


Figure 13: DSM Expenditure per customer for utilities in our sample (2006–2012)

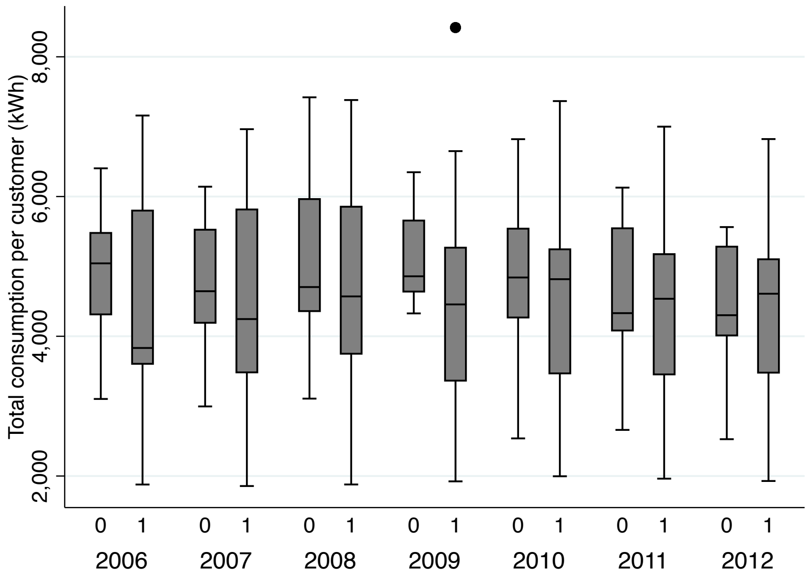


Figure 14: Electricity consumption per customer versus positive DSM spending (2006–2012)

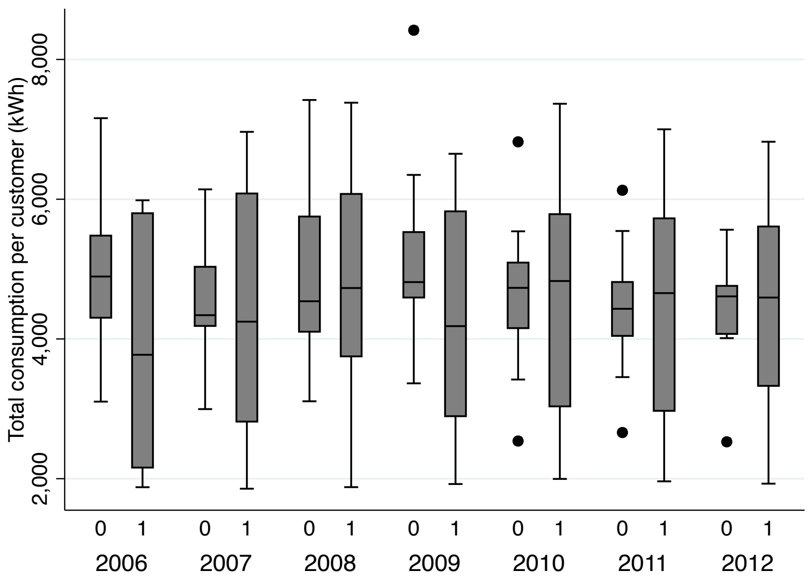


Figure 15: Electricity consumption per customer versus 1st Quartile positive DSM spending (2006–2012)

4.3.5 Energy Efficiency Score

It is possible to aggregate all the different DSM activities performed by utilities and represent them in 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 programmes. It considers six policy areas, one of which is utility and public benefits programmes and policies. Within this sub-score programme 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 programmes. We assign an equal weight of 20% to each of these EE strategies.

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. This is because a decreasing average price reduces the incentive 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 during peak hours.[52] This helps to shift the peak demand to off-peak demand hours. We are not considering the traditional time-of-use tariff scheme since all the utilities in our sample offer this scheme to, at least, some of their customers. 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.

[52] In the survey we asked utilities if they have an option for customers using appliances with heavy loads, e.g. electric boilers and heat pumps, to choose a special tariff scheme where they are charged lower electricity prices but where utilities have the option to regulate electricity supply depending on the total load faced by the utility.

	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 16: Calculation of EE score

The **third field of action** covered by our score is consulting offers by a utility. We aggregate the various offers into six categories of measures: information (leaflets, webpages, etc.); public relations (fairs, etc.); rental of smart meters; information on the bill; energy advice centres; 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 programmes 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 programmes per MWh sold to residential customers as an indicator.

Figure 16 shows how the EE score was calculated using the different criteria and their corresponding 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 24 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 17 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

Table 24: Summary statistics - EE score

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

spending and the EE score with higher EE spending being reflected, on average, with a higher EE score.

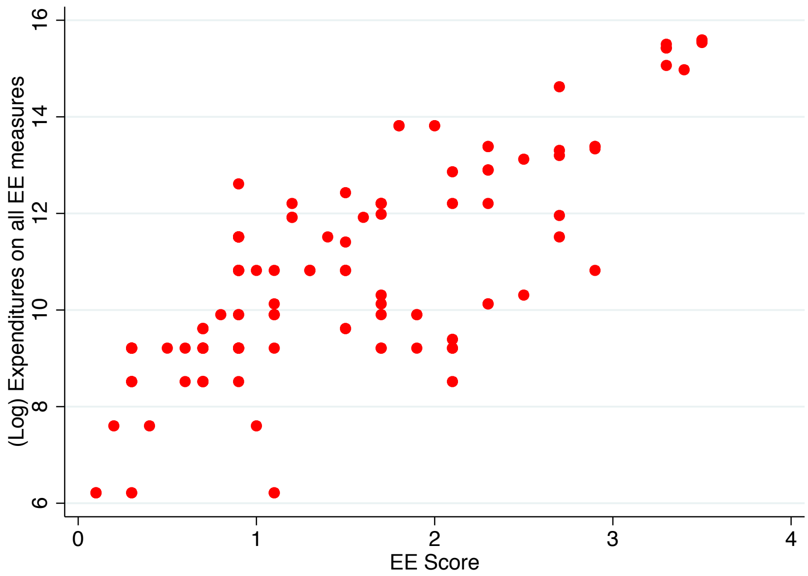


Figure 17: EE Score

Figure 18 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.

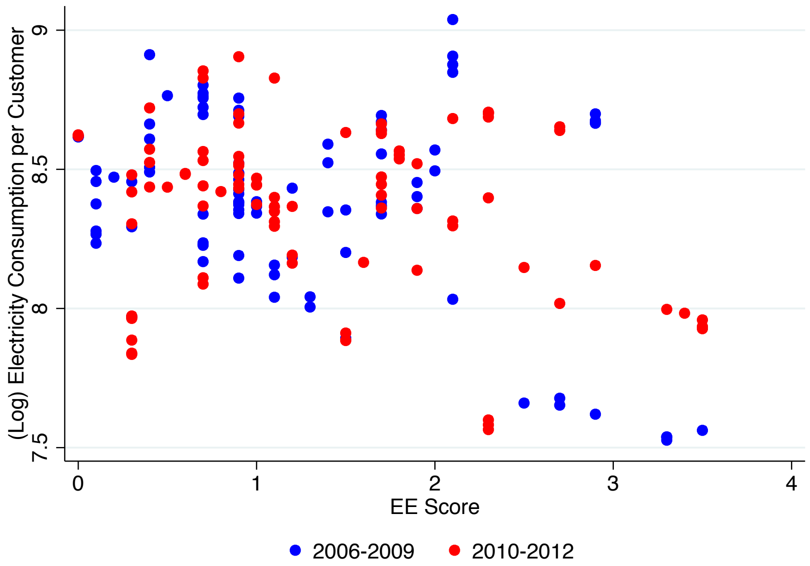


Figure 18: EE spending versus EE score

In addition, we also provide a rough idea on the relative evolution of the utilities with regard to their EE scores. We do this to see if utilities have, relative to each other, remained stable with regard to EE measures. The results of this exercise are provided in Table 25. We provide a list of all the 30 (anonymous) surveyed utilities in this table. We then calculate the average EE score for each utility between, firstly, 2006 and 2009 and, secondly, 2010 and 2012. We then rank these scores for both periods to get an idea of how the ranking has changed over the two periods. For example, utility 1 was ranked 21st for the average EE score between 2006 and 2009 and ranked 14th between 2010 and 2012. While a glance at the rankings seems to indicate that there is a high correlation between the rankings in the two periods, this is confirmed with a more concrete indicator of the correlation between the two series. We use Spearman's rank correlation coefficient measure to have a more quantitative measure. Spearman's rank correlation coefficient for the two rankings is calculated to be 0.82, which indicates a high degree of correlation. Therefore, we conclude that the ranking of utilities, in terms of their EE score, has remained fairly stable over our study period. We also provide this graphically in Figure 19 where we plot the energy efficiency score ranking in 2006-2009 against the ranking in 2010-2012.

Table 25: Ranking of the utilities according to EE score

Utility ID	Rank (2006-2009)	Rank (2010-2012)
1	21	14
2	4	3
3	2	6
4	1	1
5	13	4
6	29	20
7	3	5
8	11	17
9	24	26
10	12	19
11	30	30
12	16	16
13	25	29
14	27	25
15	5	7
16	23	21
17	9	2
18	15	15
19	7	10
20	10	13
21	28	27
22	6	12
23	8	8
24	20	9
25	14	18
26	19	24
27	26	28
28	22	11
29	18	22
30	17	23

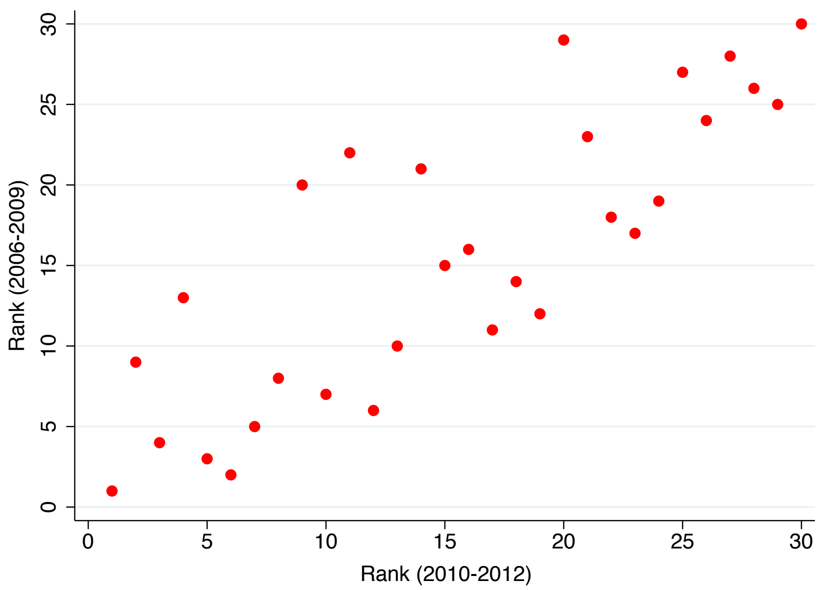


Figure 19: Relative EE score ranking

4.4 Policy Evaluation

In this section we perform an econometric estimation of the effectiveness of DSM programmes in Switzerland using the information from our survey. First, we provide a review of the current literature on DSM effectiveness, based mostly on the US. In the second section, we provide a brief description of the additional data that we use to supplement our survey data. Thirdly, we describe our empirical strategy which is based on a difference-in-differences framework. We then provide results of our econometric estimation and, in the final section, present results of robustness checks.

4.4.1 Previous Work

The empirical literature on the effectiveness of demand side management (DSM) programmes in the US is extensive.[53] Early analyses concentrated on estimating its cost-effectiveness measured in terms of the cost of kWh saved compared the cost of producing it. For example, Joskow and Marron (1992) and Eto et al. (1996) find that these programmes were both cost-effective and also effective in reducing energy consumption. There are also several other qualitative studies that show that DSM programmes 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 programmes.

Parfomak and Lave (1996) analyse the aggregate industrial and commercial conservation impacts, which were reported by 39 utilities in the north-east U.S. and California between 1970 and 1993. They estimate the effect of the reported conservation on electricity demand while controlling for average electricity price, other fuel prices, economic activity, and weather by estimating a regression equation in first differences and a weighted-least-squares (WLS) estimator. They conclude that 99.4% of the self-reported conservation is statistically observable.

Further, Loughran and Kulick (2004) analyse the electricity sales of 324 utilities in the US from 1989 to 1998. They use a subsample of 119 utilities that had positive DSM expenditures throughout the whole study period and estimate the electricity sales as a function of DSM expenditures, utility-level controls (concentration in residential, commercial, industrial sales) and state-level controls (weather, energy prices, gross state product) by using a first differences regression equation. They conclude that DSM expenditures lower electricity sales significantly, by 0.3% to 0.4% for the total sample and by 0.6% to 1.2% for the sub-sample, but the effect is smaller than those reported by the utilities. As an explanation, they suggest that utilities do not completely control for selection bias.

In a follow-up to the Loughran and Kulick (2004) study, Auffhammer et al. (2008) use the same data and econometric models as in Loughran and Kulick (2004) but use an alternative, sales-weighted, test statistic and non-parametric bootstrapped confidence intervals to improve the analysis. Their results show that the reported electricity savings from utility DSM programmes may not be as inaccurate as reported by Loughran and Kulick (2004). This supports the earlier conclusions reached by Parfomak and Lave (1996).

A second wave of empirical studies modelled electricity policy trends more generally. Horowitz (2004) concludes that "market transformation" programmes might affect conservation as well. Therefore, if this is not taken into account in the model, the model will produce biased estimates. Therefore,

[53] Table 26 provides an overview on the empirical analyses in DSM.

Horowitz (2004) explicitly separates market effects from DSM programme effects. He uses panel data set from 42 states between 1989 and 2001 but only from the commercial sector. Using a dynamic generalised least squares-fixed effects model, Horowitz (2004) finds that electricity intensity in the commercial sector is reduced by about 2% through DSM programmes.

Horowitz (2007) uses a difference-in-differences approach to analyse whether changes in electricity demand and electricity intensity from the pre-1992 period (1977–1992) to the post-1992 period (1992–2003) for the residential, commercial, and industrial sectors were related to the intensity of commitment to DSM programmes. He measures the intensity of commitment as the quartile groups of accumulated electricity savings reported by the utility between 1992 and 2003. He finds that US states that are in the upper three quartiles reduce electricity intensity relative to the lowest quartile in the residential sector by 4.4%.

Berry (2008) analyses the relationship between state-level efficiency programme effort, obtained from the efficiency programme scorecard published by the American Council for an Energy-Efficient Economy (ACEEE), and growth in electricity sales between 2001 and 2006 using data of 47 US states. He uses an OLS regression on the differences between 2001 and 2006 electricity sales, controlling for efficiency programme score, differences in GDP, price changes and weather. He shows that the higher the utility efficiency programme expenditures per capita and the greater the range of other efficiency programmes offered, the greater the reduction in the growth of electricity sales. A one-point increase in the efficiency programme score was associated with about a 3.2% decrease in the growth of electricity sales over the 5-year study period.

Recently, Arimura et al. (2012) use the basic approach of Loughran and Kulick (2004) to estimate the cost-effectiveness of DSM programmes. However, they adapt it by explicitly addressing possible endogeneity in spending, by using a nonlinear GMM approach, and an extended study period till 2006. Following Auffhammer et al. (2008), they calculate confidence intervals for the estimates of percentage savings and cost effectiveness. Arimura et al. (2012) conclude that DSM expenditures were responsible for annual average electricity savings of 0.9%.

Finally, Carley (2012) analyses the effect of four different DSM policy variables on electricity savings using cross-sectional data of 3090 utilities in 48 US states from 2007. She uses a two-step Heckman model to help minimise the selection bias of the policy variables. The DSM policy variables she uses are: (1) DSM policy effort (from the ACEEE scorecard), (2) public benefit funds spending, (3) a dummy for the presence of energy efficiency portfolio standard in a state, and (4) a dummy for the presence of performance incentives in a state. She finds a significant impact of state-run DSM programmes in increasing electricity savings.

The literature on evaluation of DSM programmes outside of the US and especially the empirical estimation of the effectiveness of DSM measures is very scarce. Dulleck and Kaufmann (2004) conduct a study in Ireland using monthly time-series data between 1976 and 1993. They focus on information programmes and use a dummy variable that has a value of 0 before 1990 and linearly increases afterwards to reach a value of 1 in December 1990. This represents the gradual implementation and diffusion of the information programme in Ireland. Interestingly, Dulleck and Kaufmann (2004) find that while the short-run demand behaviour does not change significantly, the long-run demand changes by a great amount. More specifically, they conclude that the information programme reduces electricity demand by around 7%. Another non-US study was performed in Canada by Rivers and Jaccard (2011). Compared to the US, Canada introduced DSM programmes only in the late 1980s. Rivers and Jaccard (2011) apply a partial adjustment model with bias-corrected estimators, based on Kiviet (1995), using data on electricity sales and DSM expenditure from 160 utilities between 1990 and 2005. They conclude that DSM expenditure has only a marginal effect on electricity consumption in Canada.

To the best of our knowledge, there are only these two empirical studies conducted outside of the US. This leaves a noteworthy gap of 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 as unobserved factors that influence the residential electricity demand may also influence the state's decision on whether or not to introduce a policy (simultaneity). We therefore try to overcome this problem by using an instrumental variable (IV) approach. In addition, similar to Carley (2012), we use different version of policy variables: DSM expenditure per customer, a dummy for positive DSM spending and a score that measures the DSM effort of a utility. In this way, we can estimate the effect in Switzerland in more robustly and compare between the different measures of DSM.

Table 26: Summary of selected DSM 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 programme 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 programmes were responsible for reducing commercial sector electricity intensity in 2001 by 1.9% relative to the 1989 level.	Dynamic GLS-FE model

Continued on next page

Table 26 – continued from previous page

Source	DSM Policy Variable	Effect	Model
Horowitz (2007)	Reported accumulated (1992-2003) electricity savings attributable to DSM programmes to categorize utilities in four different quartiles of different commitment to EE policies.	Those states that have moderate to strong commitment to energy efficiency programmes reduce electricity intensity relative to what it would have been with weak programme 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
Berry (2008)	1. ACEEE efficiency programme score 2. Utility efficiency programme spending score and 3. Other efficiency programme score	The higher the utility efficiency programme expenditures per capita and the greater the range of other efficiency programmes offered, the greater is the reduction in the growth of electricity sales. A one-point increase in the efficiency programme 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)

Continued on next page

Table 26 – continued from previous page

Source	DSM Policy Variable	Effect	Model
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 programmes. 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 programme participation or total DSM electricity savings.	Two-step Heckman method

4.4.2 Data

There are 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). The final source is MeteoSchweiz from where we obtain information on heating and cooling degree days.

Table 27 shows the summary statistics of all the variables used and their source. 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.[54]

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 4.4.5. We also use heating and cooling degree days, collected 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 programmes. We calculate this in several ways. The first way is through an indicator variable that takes the value 1 if the utility has *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 measure is by using the reported DSM spending by a utility. The last measure uses the energy efficiency score calculated in section 4.3.5.

[54] Details are provided in the Appendix to Chapter 4.

Table 27: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N	Source
Total consumption per customer (kWh)	4547.52	1311.02	1856.77	8418.08	182	Survey
Average price	20.91	3.75	13.16	28.96	182	Survey
Average taxable income (per taxpayers)	69127.31	9894.18	56006	104537.19	210	BFS
Household size: population/customer	1.86	0.55	0.76	4.24	185	Survey & BFS
Heating degree days	3567.52	904.93	2130.16	6452.90	210	MeteoSchweiz
Cooling degree days	137.99	90.15	0	442.12	210	MeteoSchweiz
Positive DSM expenditure dummy	0.66	0.47	0	1	210	Survey
DSM expenditure: 1. quartile dummy	0.51	0.50	0	1	210	Survey
DSM expenditures per customer	2.86	6.13	0	30.83	201	Survey
DSM expenditures per customer†	4.42	7.17	0.06	30.83	130	Survey
EE score	1.21	0.88	0	3.50	210	Survey
Percentage of left-wing parties	28.37	11.84	0	53.43	210	BFS
Stock company: 100% publicly owned	0.23	0.42	0	1	204	Survey
Stock company: majority publicly owned	0.14	0.34	0	1	204	Survey
Stock company: minority publicly owned	0.21	0.41	0	1	204	Survey

†: Conditional on DSM expenditure greater than zero.

All these measures have their respective advantages over each other. 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.

4.4.3 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. See Table 28 and Figure 20 for an illustration. The policy intervention is assumed to be a natural experiment with units that receive the policy intervention, or treatment, and units that do not receive the policy intervention, called the control.

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. We perform various robustness checks to ensure that we do not need to be concerned with regard to these issues.

Table 28: Difference-in-differences method and the subgroups

	Treated group	**Control group**
Before treatment (t=0)	N_V	A_V
After treatment (t=1)	N_N	A_N

The DD method is illustrated in Figure 28 where there are two groups, the treated group (N) and the control group (A). The treatment on N occurs between the time periods $t = 0$ and $t = 1$. The

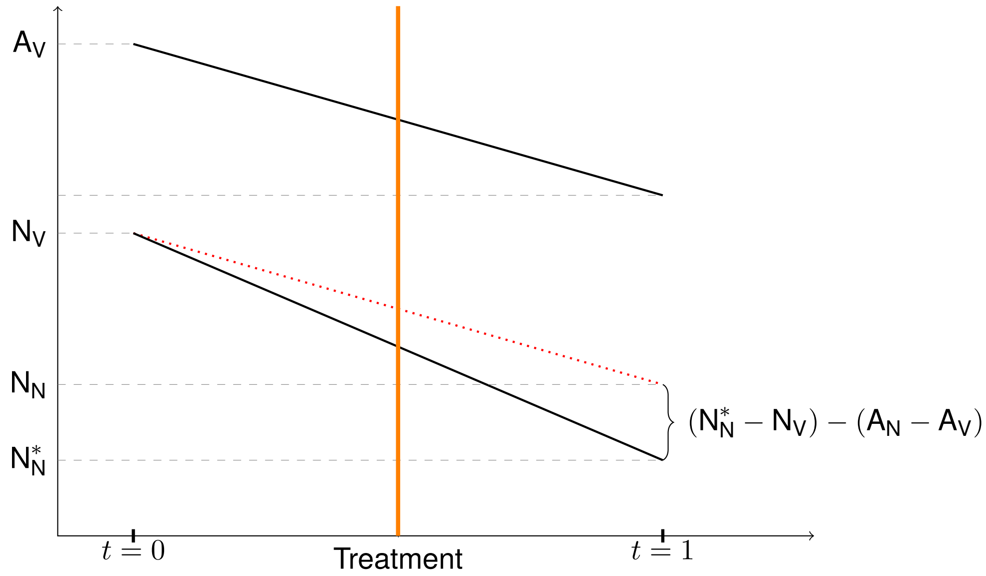


Figure 20: Graphical illustration of the difference-in-differences method

average treatment effect on the treated is the change in the outcome variable introduced through the treatment and can be estimated by calculating the difference of the difference in the outcomes of the treated group and the difference of the control group: DD = $(N_N^* - N_V) - (A_N - A_V)$. In our case, the treatment is the implementation of EE initiatives at the utility level. The outcome that we want to test is the effectiveness of such incentives in Switzerland with respect to a reduction in electricity consumption. We consider the utilities that have spent money on DSM as the treated utilities while those utilities without any DSM spending belong to the control group.

The simplest formulation in our framework is

$$\ln E_{it} = \beta_0 + \beta_1 DSM_{it} + \lambda_i + \delta_t + \epsilon_{it}, \tag{15}$$

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 (15) as

$$\ln E_{it} = \beta_0 + \beta_1 DSM_{it} + \beta_2 p_{it}^E + \beta_3 Y_{it} + \beta_4 HS_{it} + \beta_5 HDD_{it} + \beta_6 CDD_{it} + \lambda_i + \delta_t + \epsilon_{it}, \tag{16}$$

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.[55]

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

Our specification, equation (16), is in semi-log form since the continuous DSM measure contains zeros and the logarithm of zero is undefined.[56]

4.4.4 Results

The results of estimating equation (16) are in Table 29. Columns (1) and (2) are the results from estimating equation (16) with indicator variables for 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 (16) with a continuous measure of DSM measures, the DSM expenditure per customer. Column (4) estimates equation (16) using the EE score.

Our results from columns (1) and (2) indicate that spending on EE programmes has a statistically significant effect on the electricity consumption per customer. Positive EE spending reduces electricity consumption per customer by around 5% in column (1) and by around 6% in column (2).[57] 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 is around CHF 0.04.[58] 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.[59,60]

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 29 shows that an increase in the EE score by one point leads to a reduction in electricity consumption by around 3%. 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 29 are statistically insignificant. The only variables that show consistent significance statistically are electricity price and household size. The price elasticity of electricity, evaluated at the mean of the average price, is around -0.38 for all models so the results are quite stable. Even though it is not our objective to estimate the price elasticity for residential electricity consumption in this chapter, we observe that the estimate is very close to the short-run estimates obtained in the fixed effects model and the corrected least squares dummy variable model in Table 15 of chapter 3. The estimates obtained in this chapter are based on a static model of electricity consumption. The elasticity for household size is around 0.11

[56] 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.

[57] The percentage change is calculated by using $100[e^{\beta_1}-1]$ where β_1 is the coefficient of the DSM measure in equation (16).

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

[59] 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.

[60] Elasticity for a semi-log equation, ln$Y = \beta x$, is calculated as follows: Taking derivatives of both sides we get $\frac{dY}{Y} = \beta\frac{dx}{x}x$. The elasticity is then, usually, calculated at the mean value of x. Therefore, the elasticity is $\beta\bar{x}$ where $\bar{x}$ is the mean value of x.

which implies that increasing the household size by 1% increases electricity consumption by around 0.11%. The coefficients for the other explanatory variables are statistically insignificant probably due to the lack of 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.

Table 29: FE models of (log) per customer residential electricity demand

	(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: Taxpayers	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.

4.4.5 Robustness

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.[61] 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 30. We also perform a similar regression for the continuous DSM spending variable.[62] The results from this regression are in column (2) of Table 30. 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 31. We also carry out a similar regression for the continuous DSM spending variables. The results from this regression are in column (2) of Table 31. 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 32. We also carry out a similar regression for the continuous DSM spending variables. The results from this regression are in column (2) of Table 32. 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 33. We also estimate a similar regression for the continuous DSM spending variables. The results from this regression are presented in column (2) of Table 33. 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 29 appear to be robust.

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. These instruments should have the property of being correlated with the potentially endogenous EE spending variables in our regression equation but not correlated with the electricity consumption. However, a weakness of using an instrumental variables procedure is the difficulty of finding valid and convincing instruments. Using political variables is a potential solution in our regression model since they are potentially correlated with energy or electricity policy but, presumably, not correlated with the decision of a utility company to implement EE programmes. Another 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.

[61]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.

[62]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 30: FE models of (log) per customer residential electricity demand

	(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: Taxpayers	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 31: FE models of (log) per customer residential electricity demand

	(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: Taxpayers	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 32: FE models of (log) per customer residential electricity demand

	(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: Taxpayers	-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 33: FE models of (log) per customer residential electricity demand

	(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: Taxpayers	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.

A problem 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 political variables and firm characteristics that show very little variation over time. The instrumental variables we consider are the share of left parties and the legal form of a utility. The share of left parties is calculated by adding the percentage of votes obtained by the parties considered to belong to the left-of-centre in Switzerland at the municipality level in the national elections in 2007 and 2011.[63] The municipality level data is then aggregated to the utility service area level with a population-weighted average. The legal form of a utility is obtained from our survey. As shown in Figure 6b, there are five different kinds of utilities. The legal form is constructed as dummy variables with a utility being, e.g., either a dependent public institution or not. The legal form of a utility does not show any variation over our survey period and, therefore, a traditional fixed effects model with instrumental variables will not work since the legal form is constant over time. To circumvent this problem, we use a non-linear probit first stage selection model where we regress the potentially endogenous DSM indicator variable on the exogenous independent variables as well as the instrumental variables. Next, we obtain the predicted probabilities and then perform fixed effects regressions, first, the so-called "forbidden" regression (Angrist and Pischke, 2008) with the predicted probabilities directly in the regression, and second, an instrumental variables regression, as described in Heckman (1978), where the predicted probabilities are used as instruments for the potentially endogenous DSM indicator variable. We refer to this second approach, in subsequent descriptions, as the "nonlinear" approach.[64] This is a consistent estimation method proposed by Amemiya (1978), Heckman (1978) and Lee (1979).[65]

The results of these estimation procedures are provided in Table 34. Columns (1a) and (1b) correspond to estimation using instrumental variables for column (1) in Table 29 with (1a) being the "forbidden" regression approach ("Forb.") and (1b) being the "nonlinear" approach ("Nonlin."). The potentially endogenous DSM binary variable is the positive DSM spending. Columns (2a) and (2b) correspond 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 29. However, it is reassuring to find that the direction of the effects corresponds to the results in Table 29 in terms of the coefficients being negative and significant, except in column (2b). The coefficient in column (2b), while extremely high, is not statistically significant.

In order to solve the problem of instruments with low within-variation for the continuous possible endogenous variable, we use OLS and random effects in the first stage. As this is not a standard procedure available in Stata, we estimate the IV manually by plugging the predicted values of the first stage into the second stage. However, this method produces incorrect standard errors (Wooldridge, 2012). To correct the standard errors we use the bootstrapping method. The results are displayed in Tables 35 and 36.

The results in Table 35 show that DSM activities reduce residential electricity consumption and while the estimated coefficients are higher comparable to our results in Table 29 the signs of the coefficients are comparable. The comparison between Table 36 and Table 29 for the EE score are also the same with a much higher impact reported in Table 36 but with the expected negative signs.

[63]We consider the Social Democratic Party, the Green Liberal Party and the Green Party as left-of-centre parties.

[64]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.

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

Table 34: FE models of (log) per customer residential electricity demand

	(1a) Forb.	(1b) Nonlin.	(2a) Forb.	(2b) Nonlin.
Predicted DSM dummy	-0.372^{a}		-0.286^{b}	
	(0.117)		(0.116)	
Positive DSM expenditure		-0.329^{b}		
		(0.143)		
DSM expenditure: 1.quartile				-1.791
				(5.063)
Average price	-0.025^{a}	-0.024^{a}	-0.019^{a}	0.010
	(0.006)	(0.009)	(0.006)	(0.086)
Taxable income: Taxpayers	0.005	-0.001	0.004	-0.071
	(0.004)	(0.007)	(0.005)	(0.227)
Household size	0.058	0.083^{c}	0.106^{a}	0.064
	(0.038)	(0.044)	(0.039)	(0.242)
Heating degree days	-0.010	-0.011	-0.008	-0.060
	(0.009)	(0.012)	(0.009)	(0.153)
Cooling degree days	-0.056^{c}	0.019	-0.092^{b}	-0.384
	(0.031)	(0.052)	(0.040)	(1.032)
Utility fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	182	182	182	182

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 35: Bootstrapped IV for DSM expenditure per customer

First stage	**Mean**	**Std. Err.**	***t*-stat**	***p*-value**
OLS	-0.049	0.019	-2.579	0.010
RE	-0.040	0.014	-2.857	0.004

Notes: IVs used are left and legal form.
Number of iterations, $N = 10,000$.

Table 36: Bootstrapped IV for EE Score

First stage	**Mean**	**Std. Err.**	***t*-stat**	***p*-value**
OLS	-0.389	0.115	-3.383	0.001
RE	-0.207	0.141	-1.468	0.142

Notes: IVs used are left and legal form.
Number of iterations, $N = 10,000$.

A summary of the results for our variable of interest, the DSM variable in its various forms, are provided in Table 37. The table reproduces the results of all our estimation methods. Even though we have used various estimation methods we prefer to use the basic difference-in-differences method, column DD in Table 37, because the variant of the DD model using instrumental variables may suffer from biased estimates. This is likely to occur because our instruments do not exhibit a lot of variation over time and are relatively weak. Also, we perform these additional regressions to ensure that our DD results are robust and the estimates from the IV regressions confirm that DSM programmes reduce the consumption of electricity per customer.

Table 37: Summary of results

Variable	DD	Forbidden	Nonlinear	Bootstrapped IV	
				OLS	RE
Positive DSM expenditure	-0.047	-0.372	-0.329		
DSM expenditure: 1. quartile	-0.058	-0.286	-1.791		
DSM expenditure per customer	-0.005			-0.049	-0.040
EE Score	-0.030			-0.389	-0.207

4.4.6 Policy Implications

We now perform a simple counterfactual exercise, using the results of our econometric estimation of the impact of DSM initiatives from column (3) in Table 29, to obtain a rough estimate of the cost of DSM programmes for a utility.[66] This is done to get an idea of the approximate range within which the costs of DSM may lie. We use the continuous measure of DSM and the semi-log (log-linear) specification since a number of our observations for DSM spending have zero values. To perform the counterfactual exercise we first estimate the electricity consumed per customer in the absence of any DSM programme. Using equation (16), we assign zero to the value of the DSM_{it} variable. Therefore, assuming that $DSM_{it} = 0$ we get

$$\widehat{\ln E_{it}} = \beta_0 + \beta_2 p^E_{it} + \beta_3 Y_{it} + \beta_4 HS_{it} + \beta_5 \cdot HDD_{it} + \beta_6 CDD_{it} + \lambda_i + \delta_t, \tag{17}$$

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 $\widehat{E_{it}}$ 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

$$\Delta E_{it} = \widehat{E_{it}} - \widetilde{E_{it}} \tag{18}$$

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 electricity saving from DSM programmes:

$$\text{Total } E \text{ Saved} = \sum_{i,t} (\Delta E_{it} * \text{No. of customers}_{it}). \tag{19}$$

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.

$$\text{Total } DSM \text{ Cost} = \sum_{i,t} (DSM_{it} * \text{No. of customers}_{it}). \tag{20}$$

Now, the only calculation remaining is to divide the total DSM cost, equation (20), by the total

[66] 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.

electricity saved due to the DSM programmes, equation (19), to get an estimate of the cost to utilities of reducing a unit of electricity by implementing DSM programmes:

$$\text{Cost of a kilowatt hour} = \frac{\text{Total } DSM \text{ Cost}}{\text{Total } E \text{ Saved}} \tag{21}$$

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.[67] 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.

4.5 Conclusion

In this chapter 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.[68] The difference, in terms of the maximum per customer DSM spending, is also very large with CHF 190 in the US compared 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, as shown in Table 1. 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 values indicate that utility efforts on DSM in the US are substantially higher than similar efforts in Switzerland.[69] 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

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

[68] The value 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.

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

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.

We also find that, while it is not our objective to estimate the price elasticity for residential electricity consumption in this chapter, the estimate of around -0.3 is very close to the short-run estimates obtained in the fixed effects model and the Kiviet-corrected least squares dummy variable model in chapter 3. 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 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. In comparison to US studies of DSM programmes that estimate the cost-effectiveness of such programmes to be between \$0.008−\$0.229/kWh saved, our point estimate lies in the lower part of that range. Given our findings, it appears that DSM programmes may be a valuable option for Switzerland to pursue its goals in *Energy Strategy 2050*.

Finally, our experience with the survey conducted on the Swiss utilities suggests that it would be useful for Swiss regulators, policy makers as well as researchers to have an easily available dataset with information on utilities and their DSM efforts, similar to the one that is provided in the EIA Form 861 by the US Energy Information Administration. US utilities of a certain size have to, by law, fill in the form and report on their DSM efforts. Having a similar system would be useful for analysing DSM efforts in Switzerland, especially due to the high importance of *Energy Strategy 2050*.

5 Conclusion and Policy Implications

In this project our primary objectives were to estimate the price elasticity of residential electricity demand and analyse various demand-side management practices by Swiss electric utilities and estimate their impact on household electricity demand. Our estimates of the short- and long-run elasticities indicate that electricity demand is inelastic. The estimates that we obtain using the household survey from the VSE indicate a short-run elasticity of around -0.4 while the long-run elasticity is estimated to be slightly higher and between -0.4 and -0.6. We complement this analysis with another study that is, however, at the aggregate level and not at the disaggregate level as is the case with the household survey. We perform an aggregate study due to the fact that cross-sectional results may be more medium-term since we do not directly observe any adjustment decisions. The aggregate level study uses longitudinal data from our own survey of Swiss utilities. We obtain short- and long-run estimates of electricity consumption of -0.3 and -0.6, respectively.

Our estimates indicate that, from the point of view of policy makers, pricing policy may have a small impact on households' electricity consumption in the short run. However, since the estimate of the long-run price elasticity of electricity consumption is higher this indicates that households will be influenced by pricing policy even though the impact may not be as substantial as needed. It may be the fact that electricity is priced very low and since the fraction of a household's budget allocated to electricity expense is small, there is not much impact observed in the responsiveness of consumption to electricity price. Policy makers concerned about reducing electricity consumption may need to discuss the possibility of using a combination of policies, including pricing policy, to effectively reduce or, at least, stabilize the per customer electricity consumption in Switzerland. The importance of *Energy Strategy 2050* emphasises the need to have appropriate energy policies in place to mitigate the difficulties of a switch away from nuclear energy to other sources of electricity. Given the lack of recent studies in the estimation of the price elasticity of electricity demand in Switzerland, especially for non-residential consumers, it is important that further research is carried out in all sectors, residential and non-residential, to obtain reliable estimates of the responsiveness of customers to price changes.

In terms of other implications for policy, the estimates provide policy makers and utility companies with estimates needed for forecasting electricity demand and enable them to plan for generation, transmission and distribution capacities. These estimates are also a much-needed update for Switzerland and will provide future researchers, especially researchers working with computable general equilibrium models, to model various aspects of the Swiss and European Union electricity systems, with better values of price elasticities. For example, researchers can study the welfare analysis of the introduction of an energy/electricity tax by using our estimates. From our experience with this project we recommend a regular household survey, in the form of a longitudinal survey, of Swiss households to obtain a more precise estimate of a dynamic model of residential demand to observe how the electricity consumption of households evolves over time.

In our analysis of DSM programmes by Swiss electric utilities we find that while a lot of utilities have some kind of DSM programmes in place, the intensity of such programmes is 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.[70] The difference,

[70]The value for per customer DSM spending in the US is from Arimura et al. (2012). They report an average DSM spending per customer of $9.41 between 1989 and 2006. We have converted the amount, and subsequent US dollar

in terms of the maximum per customer DSM spending, is also very large with CHF 190 in the US compared to CHF 31 in Switzerland. 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. We observe 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 efforts.[71] The second explanation is that there may not be much scope for Swiss households to reduce their electricity consumption. Around 77% of Swiss households live in multiple family houses (SFSO, 2014).[72] Therefore, we may expect a principal-agent type of problem to exist 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 our 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 while the current cost of producing and distributing electricity in Switzerland falls above this range. Our costs may be overestimated since there may be positive external benefits by not having to produce an additional unit of electricity. Given our findings, it appears that DSM may be a valuable option for Switzerland to pursue its goals in *Energy Strategy 2050*.

Finally, our experience with the survey conducted on the Swiss utilities suggests that it would be useful for Swiss regulators as well as researchers to have an easily available dataset with information on utilities and their DSM efforts, similar to the one that is provided in the EIA Form 861 by the US Energy Information Administration. US utilities of a certain size have to, by law, fill in the form and

amounts, to Swiss Francs by using an exchange rate of 1 USD = CHF 0.97.

[71] Recent work by the Lawrence Berkeley National Laboratory calculates the average total cost of saving energy to be US$ 0.044 per kilowatt hour (Goldman et al., 2014).

[72] SFSO (2014) divides housing categories into Einfamilienhäuser (single family housing), Mehrfamilienhäuser (multi-family housing), Wohngebäude mit Nebennutzung and Gebäude mit teilweiser Wohnnutzung. We aggregate the values for Mehrfamilienhäuser, Wohngebäude mit Nebennutzung and Gebäude mit teilweiser Wohnnutzung to obtain the value for multi-family housing. SFSO (2014) also reports that the percentage of households living in multi-family housing is slightly higher for cities than for rural areas.

report on their DSM efforts. Having a similar system would be useful for analysing DSM efforts in Switzerland, especially due to the high importance given to it in *Energy Strategy 2050*.

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6 Appendix

Appendix to Chapter 2

VSE 2011 Survey

The database consists of a random sample of 1,200 households in five utility areas (four utilities with 200 households and one with 400). For the interviews, the five utilities delivered a random sample of 800 household contacts with the according last meter reading. The utilities prepared the contacts as follows:

1. If the household has a heat pump, the consumption of a heat pump was subtracted from the total, if not possible the household was dropped from the list.

2. Households with an electrical heating system were also dropped.

However as a control measure the households were asked again in the interview. If they said yes, the interview was aborted. If the household did not agree to disclose their consumption information, the interview was aborted as well.

The Computer Assisted Telephone Interviews (CATI) were conducted between 19th of September and 17th of October 2011. For the interview the head of households was required. Approximately 36% of contacted persons refused the interview. The survey followed a predefined and structured questionnaire. Three out of these five utilities offer energy efficiency incentives for their residential customers. Variables collected include characteristics of houses (e.g. number of rooms they live in), demographics of households (gender and age group), stock of appliances, rough characteristics of appliances (e.g. older than 10 years), the usage of appliances (hours switched on) and the annual electricity consumption of the household.

Tables

Table 38: Rural versus Urban Households

Utility	Rural	Urban	Total
1	252	68	320
2	203	135	338
3	0	468	468
4	88	75	163
5	3	145	148
6	229	114	343
7	0	164	164
Total	775	1,169	1,944

Table 39: First-stage regression of short-run log electricity demand

	(1)		(2)	
	(a)	(b)	(a)	(b)
(Log) ElCom price	0.99^a	-0.20^a	0.99^a	-0.21^a
	(0.02)	(0.05)	(0.02)	(0.05)
Average (neighbouring) price per Watt	-0.16^a	-0.52^a	-0.16^a	-0.55^a
	(0.02)	(0.09)	(0.02)	(0.09)
Income group 2	-0.00	0.07		
	(0.01)	(0.06)		
Income group 3	0.01	0.16^a		
	(0.01)	(0.05)		
Income group 4	-0.00	0.22^a		
	(0.01)	(0.05)		
Income group 5	-0.02	0.31^a		
	(0.01)	(0.06)		
Income group 6	-0.01	0.33^a		
	(0.02)	(0.06)		
(Log) Household size	0.00	0.09^b		
	(0.01)	(0.04)		
Children dummy	0.01	-0.01		
	(0.01)	(0.03)		
Retired dummy	0.01^c	-0.00		
	(0.01)	(0.03)		
Share of females	0.01	-0.02		
	(0.01)	(0.04)		
Single family housing dummy	0.16^a	-0.07^a	0.16^a	-0.14^a
	(0.01)	(0.03)	(0.01)	(0.03)
Urban dummy	0.01	-0.05^b	0.00	-0.02
	(0.01)	(0.02)	(0.01)	(0.02)
Tenant dummy	0.00	-0.19^a	0.00	-0.18^a
	(0.01)	(0.03)	(0.01)	(0.03)
(Log) No. of rooms	0.01	0.25^a	0.02	0.30^a
	(0.01)	(0.04)	(0.01)	(0.04)
No. of meals per day			0.00	0.01
			(0.00)	(0.01)
Hours of entertainment per day			-0.00	0.00^b
			(0.00)	(0.00)
No. of hot water services per day			-0.01^a	0.06^a
			(0.00)	(0.01)
No. of washing services per week			-0.00	0.02^a
			(0.00)	(0.00)
Dummy for utility 1 in 2011	-0.02^c	0.06^b	-0.01	-0.01
	(0.01)	(0.03)	(0.01)	(0.03)
Time-of-use dummy	-0.12^a	-0.02	-0.12^a	-0.03
	(0.01)	(0.03)	(0.01)	(0.03)
Year 2011 dummy	-0.07^a	-0.09^a	-0.08^a	-0.01
	(0.01)	(0.02)	(0.01)	(0.03)
Intercept	0.02	8.19^a	0.03	8.15^a
	(0.07)	(0.19)	(0.06)	(0.18)
Observations	1,844	1,844	1,844	1,844
Adjusted R^2	0.82	0.32	0.82	0.34

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 40: First-stage regression of short-run log electricity demand without utility 1 in 2011

	(1)		(2)	
	(a)	(b)	(a)	(b)
(Log) ElCom price	0.98^{a}	-0.19^{a}	0.99^{a}	-0.20^{a}
	(0.02)	(0.05)	(0.02)	(0.05)
Average (neighbouring) price per Watt	-0.14^{a}	-0.52^{a}	-0.13^{a}	-0.55^{a}
	(0.02)	(0.10)	(0.02)	(0.10)
Income group 2	-0.00	0.07		
	(0.01)	(0.06)		
Income group 3	0.01	0.16^{a}		
	(0.01)	(0.06)		
Income group 4	0.00	0.23^{a}		
	(0.01)	(0.06)		
Income group 5	-0.01	0.32^{a}		
	(0.01)	(0.06)		
Income group 6	-0.01	0.33^{a}		
	(0.02)	(0.07)		
(Log) Household size	0.01	0.09^{b}		
	(0.01)	(0.04)		
Children dummy	0.01	-0.02		
	(0.01)	(0.04)		
Retired dummy	0.01^{c}	0.00		
	(0.01)	(0.03)		
Share of females	0.01	-0.03		
	(0.01)	(0.04)		
Single family housing dummy	0.16^{a}	-0.06^{b}	0.17^{a}	-0.14^{a}
	(0.01)	(0.03)	(0.01)	(0.03)
Urban dummy	0.00	-0.05^{b}	0.00	-0.02
	(0.01)	(0.03)	(0.01)	(0.02)
Tenant dummy	0.00	-0.18^{a}	0.00	-0.18^{a}
	(0.01)	(0.03)	(0.01)	(0.03)
(Log) No. of rooms	0.01	0.25^{a}	0.02	0.30^{a}
	(0.01)	(0.04)	(0.01)	(0.04)
No. of meals per day			0.00	0.01
			(0.00)	(0.01)
Hours of entertainment per day			-0.00	0.00^{b}
			(0.00)	(0.00)
No. of hot water services per day			-0.00	0.05^{a}
			(0.00)	(0.01)
No. of washing services per week			-0.00	0.02^{a}
			(0.00)	(0.00)
Time-of-use dummy	-0.12^{a}	-0.02	-0.12^{a}	-0.03
	(0.01)	(0.03)	(0.01)	(0.03)
Year 2011 dummy	-0.07^{a}	-0.09^{a}	-0.08^{a}	-0.01
	(0.01)	(0.02)	(0.01)	(0.03)
Intercept	0.03	8.15^{a}	0.05	8.11^{a}
	(0.07)	(0.20)	(0.07)	(0.19)
Observations	1,688	1,688	1,688	1,688
Adjusted R^2	0.83	0.30	0.83	0.32

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 41: First stage regression of long-run log electricity demand

	(1)	(2)		(3)	(4)	
		(a)	(b)		(a)	(b)
(Log) ElCom price	0.97^a	0.99^a	0.08^c	0.97^a	0.99^a	0.09^b
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.04)
Average (neighbouring) price per Watt		-0.16^a	0.37^a		-0.16^a	0.34^a
		(0.02)	(0.08)		(0.02)	(0.08)
Income group 2	0.00	-0.00	0.03			
	(0.01)	(0.01)	(0.05)			
Income group 3	0.01	0.01	0.02			
	(0.01)	(0.01)	(0.05)			
Income group 4	0.01	-0.00	0.03			
	(0.01)	(0.01)	(0.05)			
Income group 5	-0.01	-0.02	0.01			
	(0.01)	(0.01)	(0.05)			
Income group 6	-0.00	-0.01	0.09			
	(0.02)	(0.02)	(0.06)			
(Log) Household size	0.03	0.00	0.05^c			
	(0.04)	(0.01)	(0.03)			
Children dummy	0.01	0.01	0.00			
	(0.01)	(0.01)	(0.03)			
Retired dummy	0.01	0.01^c	-0.14^a			
	(0.01)	(0.01)	(0.02)			
Share of females	0.01	0.01	-0.02			
	(0.01)	(0.01)	(0.04)			
Single family housing dummy	0.16^a	0.16^a	0.07^a	0.16^a	0.16^a	0.10^a
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
Urban dummy	-0.01^c	0.01	0.04^b	-0.02^b	0.00	0.04^c
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Tenant dummy	-0.00	0.00	0.08^a	-0.00	0.00	0.09^a
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)
(Log) No. of rooms	0.01	0.01	-0.02	0.01	0.02	0.04
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.04)
No. of meals per day				0.00	0.00	-0.01
				(0.00)	(0.00)	(0.01)
Hours of entertainment per day				-0.00	-0.00	0.01^a
				(0.00)	(0.00)	(0.00)
No. of hot water services per day				-0.01^a	-0.01^a	-0.02^b
				(0.00)	(0.00)	(0.01)
No. of washing services per week				-0.00	-0.00	-0.01^b
				(0.00)	(0.00)	(0.00)
Dummy for utility 1 in 2011	-0.02	-0.02^c	-0.02	-0.01	-0.01	-0.01
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
Time-of-use dummy	-0.13^a	-0.12^a	0.01	-0.13^a	-0.12^a	0.02
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
Year 2011 dummy	0.03	-0.07^a	0.04^c	0.03	-0.08^a	0.00
	(0.07)	(0.01)	(0.02)	(0.07)	(0.01)	(0.02)
Intercept	-3.58	0.02	-0.94^a	-3.93	0.03	-1.07^a
	(2.74)	(0.07)	(0.18)	(2.77)	(0.06)	(0.17)
Observations	1,844	1,844	1,844	1,844	1,844	1,844
Adjusted R^2	0.82	0.82	0.07	0.82	0.82	0.06

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Table 42: First stage regression of long-run log electricity demand without utility 1 in 2011

	(1)	(2)		(3)	(4)	
		(a)	(b)		(a)	(b)
(Log) ElCom price	0.97^a	0.98^a	0.08^c	0.97^a	0.99^a	0.10^b
	(0.02)	(0.02)	(0.05)	(0.02)	(0.02)	(0.04)
Average (neighbouring) price per Watt		-0.14^a	0.36^a		-0.13^a	0.33^a
		(0.02)	(0.08)		(0.02)	(0.09)
Income group 2	0.00	-0.00	0.02			
	(0.01)	(0.01)	(0.05)			
Income group 3	0.02	0.01	0.02			
	(0.01)	(0.01)	(0.05)			
Income group 4	0.01	0.00	0.02			
	(0.01)	(0.01)	(0.05)			
Income group 5	-0.01	-0.01	-0.00			
	(0.01)	(0.01)	(0.05)			
Income group 6	-0.00	-0.01	0.08			
	(0.02)	(0.02)	(0.06)			
(Log) Household size	0.04	0.01	0.05			
	(0.04)	(0.01)	(0.03)			
Children dummy	0.01	0.01	0.02			
	(0.01)	(0.01)	(0.03)			
Retired dummy	0.01	0.01^c	-0.14^a			
	(0.01)	(0.01)	(0.02)			
Share of females	0.01	0.01	-0.01			
	(0.01)	(0.01)	(0.04)			
Single family housing dummy	0.17^a	0.16^a	0.06^b	0.17^a	0.17^a	0.09^a
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
Urban dummy	-0.02^c	0.00	0.05^b	-0.02^b	0.00	0.04^c
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Tenant dummy	0.00	0.00	0.08^a	-0.00	0.00	0.08^a
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
(Log) No. of rooms	0.01	0.01	-0.02	0.01	0.02	0.04
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.04)
No. of meals per day				-0.00	0.00	-0.01
				(0.00)	(0.00)	(0.01)
Hours of entertainment per day				-0.00	-0.00	0.01^a
				(0.00)	(0.00)	(0.00)
No. of hot water services per day				-0.01^c	-0.00	-0.01^c
				(0.00)	(0.00)	(0.01)
No. of washing services per week				-0.00	-0.00	-0.01^b
				(0.00)	(0.00)	(0.00)
Time-of-use dummy	-0.13^a	-0.12^a	0.01	-0.13^a	-0.12^a	0.02
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.03)
Year 2011 dummy	0.05	-0.07^a	0.04^c	0.05	-0.08^a	0.00
	(0.07)	(0.01)	(0.02)	(0.07)	(0.01)	(0.03)
Intercept	-3.80	0.03	-0.94^a	-4.10	0.05	-1.08^a
	(2.73)	(0.07)	(0.18)	(2.78)	(0.07)	(0.18)
Observations	1,688	1,688	1,688	1,688	1,688	1,688
Adjusted R^2	0.82	0.83	0.07	0.82	0.83	0.05

Heteroscedasticity-robust standard errors in parentheses.
^{a}, ^{b}, ^{c}: Significant at the 1%, 5% and 10% levels, respectively.

Appendix to Chapter 4

Electricity Price

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

$$\begin{aligned} P_{average} = & \frac{customer_{tou}}{customer_{total}} \cdot \frac{E_{peak} \cdot MP_{peak} + E_{off-peak} \cdot MP_{off-peak} + FixedFee_{tou}}{E_{tou}} \\ & + \left(1 - \frac{customer_{tou}}{customer_{total}}\right) \cdot \frac{E_{single} \cdot MP_{single} + FixedFee_{single}}{E_{single}}, \end{aligned} \tag{22}$$

where E_{peak} is the peak period consumption per customer with a time-of-use tariff, $E_{off-peak}$ is the off-peak period consumption per customer with a time-of-use 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 time-of-use 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.

Cover Letter - German

Sehr geehrter Herr/Frau ...,

Das Centre for Energy Policy and Economics (CEPE) der ETH Zürich befasst sich seit langem mit dem Thema Stromnachfrage in der Schweiz. Das CEPE führt nun wiederum eine Untersuchung durch, nachdem im Jahr 2008 eine wissenschaftliche Studie zum Effekt zeitabhängiger Strompreise (Hoch-/Niedertarif) auf das Nachfrageverhalten erstellt wurde. Eine Zusammenfassung dieser Studie finden Sie im Anhang. Nun sollen diese Ergebnisse im Hinblick auf die Energiestrategie 2050, welche der Energieeffizienz eine grosse Rolle beimessen wird, aktualisiert und erweitert werden. Die Studie "*Eine Evaluation der Auswirkungen von Energieeffizienzmassnahmen auf den Stromverbrauch von Haushalten*" wird mit der Finanzierung des Bundesamts für Energie (BFE) und der Unterstützung des Verbands Schweizerischer Elektrizitätsversorgern (VSE) durchgeführt.

Im Rahmen dieses Projektes führen wir eine Befragung bei Schweizer Elektrizitätsversorgern durch, wobei wir Daten zum Stromabsatz an Haushaltskunden, zur Anzahl Haushaltskunden und zu den Stromtarifen für die Jahre 2006 bis 2012 sammeln. Zusätzlich möchten wir in einem zweiten Schritt auch Daten zu durchgeführten Effizienzmassnahmen bei Haushaltskunden und deren Kosten erheben.

Wir sind überzeugt, dass die Ergebnisse dieser neuen Untersuchung sowohl als hilfreiches Element für die zukünftige Ausgestaltung energiepolitischer Massnahmen, als auch für das Beantworten von unternehmens-strategische Fragestellungen dienen. Wir wären Ihnen daher sehr dankbar, wenn Sie das angehängte Excel-File bis spätestens am XX. YY 2013 ausfüllen könnten. Die Daten werden streng vertraulich behandelt und nur im Rahmen des Projektes und für wissenschaftliche Arbeiten am CEPE verwendet. Zudem werden die Daten nur in aggregierter und anonymisierter Form publiziert.

Wir danken Ihnen im Voraus für die wertvolle Unterstützung. Am Ende des Fragebogens haben Sie die Möglichkeit anzugeben, ob Sie über die Resultate informiert werden möchten. Bei Rückfragen steht Ihnen Frau Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) gerne zur Verfügung.

Mit freundlichen Grüssen
Nina Boogen

Cover Letter - French

Monsieur/Madame ...,

Le Centre for Energy Policy and Economics (CEPE) de l'EPF Zurich travaille depuis longtemps sur le théme de la demande d'électricité en Suisse. Le CEPE effectue à présent une nouvelle étude faisant suite à l'étude scientifique de 2008 qui traitait des effets de la tarification de l'électricité en fonction de l'heure (haut/bas tarif) sur la demande. Vous trouverez un résumé de cette étude en annexe. Ces résultats doivent maintenant être actualisés et élargis dans l'optique de la Stratégie énergétique 2050, laquelle accorde un rôle majeur à l'efficacité énergétique. Cette étude "*Eine Evaluation der Auswirkungen von Energieeffizienzmassnahmen auf den Stromverbrauch von Haushalten*" (Une évaluation des effets des mesures d'efficacité énergétique sur la consommation en électricité des ménages) est réalisée grâce au financement de l'Office fédéral de l'énergie (OFEN) et au soutien de l'Association des entreprises électriques suisses (AES).

Dans le cadre de ce projet, nous effectuons un sondage auprès des entreprises électriques suisses et collectons ainsi des données sur les ventes d'électricité aux ménages, le nombre de ménages clients et les tarifs de l'électricité dans les années 2006 á 2012. Nous aimerions de plus, au cours d'une deuxième étape, récolter des données relatives aux mesures d'efficacité appliquées auprès des ménages et á leurs coûts.

Nous sommes convaincus que les résultats de cette nouvelle étude constitueront des aides précieuses pour l'organisation future des mesures de politique énergétique ainsi que pour répondre aux questions d'ordre stratégique des entreprises. Nous vous serions donc très reconnaissants de remplir le fichier Excel ci-joint d'ici le XX. YY 2013 au plus tard. Ces données seront traitées de manière strictement confidentielle et ne seront utilisées que dans le cadre du projet et de travaux scientifiques au CEPE. Elles ne seront en outre publiées que sous forme regroupée et anonyme.

Nous vous remercions d'avance de votre précieux soutien. Vous avez la possibilité, en fin de questionnaire, d'indiquer si vous souhaitez être informé des résultats. Madame Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) se tient volontiers à votre disposition pour tout complément d'information.

Meilleures salutations,
Nina Boogen

Cover Letter - Italian

Gentile Signor/Signora...,

il “Centre for Energy Policy and Economics (CEPE)” del Politecnico Federale di Zurigo e diretto dal Prof. Massimo Filippini, si occupa da tempo di analizzare con metodi empirici i fattori che influenzano la domanda di energia elettrica. A questo proposito il CEPE ha pubblicato nel 2008 uno studio scientifico sull’effetto delle tariffe differenziate nel tempo (giorno-notte) sulla domanda di elettricitá (si veda il riassunto nel documento allegato).

Nell’ambito dei progetti di ricerca promossi dall’Ufficio federale dell’energia per la realizzazione della Strategia Energetica 2050, il CEPE sta realizzando un nuovo studio sulla domanda di energia elettrica e sull’impatto sulla domanda delle misure a favore dell’efficienza energetica. Il titolo dello studio realizzato anche con l’appoggio della Verband der schweizerischen Elektrizitätsunternehmen (VSE) è: “*Eine Evaluation der Auswirkungen von Energieeffizienzmassnahmen auf den Stromverbrauch von Haushalten*”

Per svolgere questo studio sono necessari dei dati riguardanti la domanda di energia elettrica come ad esempio le vendite ed il numero di clienti. A questo proposito stiamo conducendo un’inchiesta presso un campione di aziende di distribuzione di energia elettrica. Inoltre, in una seconda parte dell’inchiesta verranno chieste informazioni su misure introdotte dalle singole aziende elettriche a favore di un miglioramento dell’efficienza energetica

Siamo convinti che i risultati di questa nuova indagine possano sia all’Ufficio federale dell’energia che alle aziende elettriche nella definizione delle nuove strategie di politica energetica. Le saremmo pertanto molto grati se potesse compilare il file Excel allegato entro e non oltre il XX. YYY 2013. I dati verranno trattati in modo strettamente confidenziale e utilizzati esclusivamente nell’ambito del progetto e per lavori scientifici presso il CEPE. Inoltre, i dati verranno pubblicati solamente in forma aggregata e anonima.

La ringraziamo anticipatamente per il prezioso sostegno! Alla fine del questionario Le viene fornita la possibilità di indicare se desidera ricevere informazioni sui risultati dello studio. In caso di chiarimenti può rivolgersi a Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) che è a Sua completa disposizione.

Cordiali saluti,
Nina Boogen

Survey - German

Bitte füllen Sie diese Tabelle möglichst vollständig aus. Bei Fragen steht Ihnen Frau Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) gerne zur Verfügung. Haushaltskunden werden hier als Kleinkunden (Niederspannung) ohne Leistungsmessung definiert. Wenn möglich geben sie die Angaben in den Kalenderjahren an. Falls sich Ihre Daten auf das hydrologische Jahr bezieht, bemerken Sie das bitte.

Unternehmen
Bezeichnung

Preise	2006	2007	2008	2009	2010	2011	2012
Hochtarif (Rp./kWh)							
Niedertarif (Rp./kWh)							
Monatlicher Grundtarif Doppeltarif (CHF)							
Einheitstarif (Rp./kWh)							
Monatlicher Grundtarif Einheitstarif (CHF)							

Anteil der Kunden des repräsentativsten Produkts	2006	2007	2008	2009	2010	2011	2012
50-70%							
70-90%							
über 90%							

Grüner Strom	2006	2007	2008	2009	2010	2011	2012
0-5%							
5-10%							
10-15%							
über 15%							

	Ja	Nein
Haben sie in der Periode zwischen 2006 und 2012 die Tarifzeiten für Hoch und Niedertarifstrom geändert?		

Anzahl private Haushaltskunden	2006	2007	2008	2009	2010	2011	2012
Anzahl Haushaltskunden total							
Anzahl Haushaltskunden im Doppeltarifsystem							
Anzahl Haushaltskunden im Einheitstarifsystem							

Stromlieferungen an private Haushaltskunden	2006	2007	2008	2009	2010	2011	2012
Hochtarif (MWh)							
Niedertarif (MWh)							
Einheitstarif (MWh)							

Kontaktperson für Energieeffizienzmassnahmen
Name
E-Mail
Telefon

Rechtsform des Unternehmens	Ja
unselbstständige öffentlich rechtliche Anstalt	
selbstständige öffentlich rechtliche Anstalt	
Aktiengesellschaft: 100% öffentlich	
Aktiengesellschaft: mehrheitlich öffentlich	
Aktiengesellschaft: minderheitlich öffentlich	

Eigenproduktion	0-25%	25-50%	50-75%	75-100%
Anteil Eigenproduktion am Verkauf				

Gas	2006	2007	2008	2009	2010	2011	2012
Gas-Produktpreis (Rp./kWh)							
Grundpreis (CHF/Monat)							

	Ja	Nein
Möchten Sie über die Ergebnisse dieser Studie informiert werden?		

Kommentar:

Figure 21: Survey Part I

Bitte füllen Sie diese Tabelle möglichst vollständig aus. Bei Fragen steht Ihnen Frau Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) gerne zur Verfügung. Haushaltskunden werden hier als Kleinkunden (Niederspannung) definiert. Wenn möglich geben sie die Angaben in den Kalenderjahren an. Falls sich Ihre Daten auf das hydrologische Jahr bezieht, bemerken Sie das bitte.

	Unternehmen							
1	Bezeichnung							
		Ja	**Nein**	**Seit wann**				
2a	Hat Ihr Unternehmen einen gesetzlichen Leistungsauftrag zur Steigerung der Stromeffizienz bei Haushaltskunden							
2b	Verfügt Ihr Unternehmen über eine Strategie und konkrete Ziele zur Steigerung der Stromeffizienz bei Haushaltskunden							
	Falls 2a oder 2b mit ja beantwortet:	**Ja**	**Nein**	**Seit wann**				
2c	Sind Ihre Ziele quantifiziert?							
2d	Hat Ihr Unternehmen aufgrund des gesetzlichen Leistungsauftrag / Strategie ein Fonds für Effizienzmassnahmen bei Haushaltskunden?							
	Tarifstruktur für Haushaltskunden	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
3a	Haben Sie verschiedene Tarife für Haushaltskunden entsprechend ihrem Verbrauch							
3b	Falls ja: Sin d diese Tarife abfallend mit steigendem Verbrauch							
3c	Falls ja: Sin d diese Tarife ansteigend mit steigendem Verbrauch							
3d	Haben Sie einen Tarif für unterbrechbare/sperrbare Geräte für Haushaltskunden							
	Welche der folgenden Massnahmen führen Sie in Ihrem EVU zur Förderung der Stromeffizienz bei Haushaltskunden durch? Bitte zutreffendes ankreuzen	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
4a	Informationsmaterial							
4b	Öffentlichkeitsarbeit							
4c	Verleih Strommessgeräte							
4d	Information zur Entwicklung des Stromverbrauchs der einzelnen Kunden							
4e	Energieberatungszentrum							
4f	Persönliche Energieberatung							
4g	Beratung Ersatz ineffizienter Haushaltsgeräte							
4h	Beratung Ersatz Elektrospeicherheizungen und Elektroboilern							
4i	Finanzielle Förderung Ersatz ineffizienter Haushaltsgeräte							
4j	Finanzielle Förderung Ersatz Elektrospeicherheizungen und Elektroboilern							
4k	Tarifliche Massnahmen zur Lenkung des Stromverbrauchs							
4l	Andere (bitte im Kommentarfeld spezifizieren)							
	Ausgaben	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
5a	Jährliche Ausgaben für alle Energieeffizienzmassnahmen bei Haushaltskunden (CHF)							
5b	Jährliche Ausgaben für die Finanziellen Förderprogramme bei Haushaltskunden (CHF)							
		Ja	**Nein**					
	Möchten Sie über die Ergebnisse dieser Studie informiert werden?							
	Kommentar:							

Figure 22: Survey Part II

Survey - French

Merci de compléter au mieux ce tableau. Madame Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) se tient volontiers à votre disposition pour toute question. Les ménages sont ici définis comme de petits clients (basse tension) sans mesure de puissance. Indiquez si possible les informations par année civile. Si vos données se rapportent à l'année hydrologique, merci de le mentionner.

Entreprise	
Désignation	

Prix	2006	2007	2008	2009	2010	2011	2012
Haut tarif (cts/kWh)							
Bas tarif (cts/kWh)							
Tarif de base mensuel tarif double (CHF)							
Tarif simple (cts/kWh)							
Tarif de base mensuel tarif simple (CHF)							

Part des clients utilisant le produit le plus représentatif	2006	2007	2008	2009	2010	2011	2012
50-70%							
70-90%							
Plus de 90%							

Courant vert	2006	2007	2008	2009	2010	2011	2012
0-5%							
5-10%							
10-15%							
Plus de 15%							

	Oui	Non
Avez-vous modifié les périodes tarifaires de l'électricité à haut et bas tarif entre 2006 et 2012?		

Nombre de ménages privés	2006	2007	2008	2009	2010	2011	2012
Nombre total de ménages							
Nombre de ménages au sein du système de tarif double							
Nombre de ménages au sein du système de tarif simple							

Livraison d'électricité aux ménages privés	2006	2007	2008	2009	2010	2011	2012
Haut tarif (MWh)							
Bas tarif (MWh)							
Tarif simple (MWh)							

Personne à contacter pour les mesures d'efficacité énergétique	
Nom	
E-mail	
Téléphone	

Forme juridique de l'entreprise	Oui
Etablissement de droit public non autonome	
Etablissement de droit public autonome	
Société anonyme 100% ouverte au public	
Société anonyme: majoritairement ouverte au public	
Société anonyme: majoritairement privée	

Production personnelle	0-25%	25-50%	50-75%	75-100%
Part de la production personnelle dans les ventes				

Gaz	2006	2007	2008	2009	2010	2011	2012
Prix du gaz (cts/kWh)							
Prix de base (CHF/mois)							

	Oui	Non
Souhaitez-vous être informé des résultats de cette étude?		

Commentaire	

Figure 23: Survey Part I

Merci de compléter au mieux ce tableau. Madame Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) se tient volontiers à votre disposition pour toute question. Les clients particulier (ménages) sont ici définis comme de petits clients (basse tension). Indiquez si possible les informations par année civile. Si vos données se rapportent à l'année hydrologique, merci de le mentionner.

	Entreprise							
1	Désignation							
		Oui	**Non**	**Depuis quand**				
2a	Est-ce que votre entreprise a un mandat légal pour accroître l'efficacité énergétique des clients particuliers (ménages)?							
2b	Votre entreprise dispose-t-elle d'une stratégie et d'objectifs précis pour accroître l'efficacité énergétique des particuliers (ménages)?							
	Si vous avez répondu "oui" à 2a ou 2b:	**Oui**	**Non**	**Depuis quand**				
2c	Avez-vous quantifié ces objectifs?							
2d	Votre entreprise dispose-t-elle d'un fonds destiné aux mesures d'efficacité énergétique des particuliers (ménages) qui résulte du mandat légal/de la stratégie?							
	Tarifs payés par les particuliers	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
3a	Appliquez-vous des tarifs différents en fonction de la consommation des particuliers (ménages)?							
3b	Si oui, ces tarifs baissent-ils avec la consommation?							
3c	Si oui, ces tarifs augmentent-ils avec la consommation?							
3d	Appliquez-vous un tarif propre aux appareils interruptibles / verrouillables des particuliers (ménages)?							
	Parmi les mesures suivantes, quelles sont celles que votre entreprise effectue afin de promouvoir l'efficacité énergétique des particuliers (ménages)? Veuillez cocher les cases correspondantes	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
4a	Matériel d'information							
4b	Relations publiques							
4c	Location de Power Meters							
4d	Informations relatives au développement de la consommation d'énergie du client							
4e	Centre de conseil destiné à l'efficacité énergétique							
4f	Entretiens individuels pour promouvoir l'efficacité énergétique							
4g	Conseils concernant le remplacement des appareils inefficaces							
4h	Conseils concernant le remplacement des chaudières et des chauffages électriques							
4i	Soutien financier au remplacement des appareils inefficaces							
4j	Soutien financier au remplacement des chaudières et des chauffages électriques							
4k	Mesures tarifaires pour diriger la consommation d'électricité							
4l	Autre (veuillez préciser dans les commentaires)							
	Dépenses	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
5a	Dépenses annuelles pour toutes les mesures d'efficacité énergétique des clients particuliers(CHF)							
5b	Dépenses annuelles pour les programmes de soutien financier destinés aux clients particulier (CHF)							
		Oui	**Non**					
	Souhaitez-vous être informé des résultats de cette étude?							
	Commentaire							

Figure 24: Survey Part II

Survey - Italian

La preghiamo di compilare questa tabella nel modo più completo possibile. Può rivolgere eventuali domande a Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) che è a Sua completa disposizione. I clienti domestici vengono qui definiti come piccoli clienti (bassa tensione) senza misurazione della potenza. Se possibile, riporti i dati negli anni civili. Se i Suoi dati sono riferiti all'anno idrologico, La preghiamo di annotarlo sul questionario.

Azienda
Nome

Prezzi	2006	2007	2008	2009	2010	2011	2012
Tariffa alta (ct./kWh) (tariffa diurna)							
Tariffa bassa (ct./kWh) (tariffa notturna)							
Tariffa di base mensile (CHF) per clienti con alta e bassa tariffa							
Tariffa unitaria (ct./kWh)							
Tariffa di base mensile (CHF) per clienti con tariffa unitaria							

Quota dei clienti con il tariffa più rappresentativa	2006	2007	2008	2009	2010	2011	2012
50-70%							
70-90%							
oltre il 90%							

Corrente verde	2006	2007	2008	2009	2010	2011	2012
0-5%							
5-10%							
10-15%							
oltre il 15%							

	Si	No
Nel periodo dal 2006 al 2012 sono stati modificati gli orari per l'applicazione della tariffa alta/bassa?		

Numero di clienti domestici privati	2006	2007	2008	2009	2010	2011	2012
Numero totale di clienti domestici							
Numero totale di clienti domestici nel sistema a tariffa doppia							
Numero totale di clienti domestici nel sistema a tariffa unitaria							

Forniture di corrente a clienti domestici privati	2006	2007	2008	2009	2010	2011	2012
Tariffa alta (MWh)							
Tariffa bassa (MWh)							
Tariffa unitaria (MWh)							

Referente all'interno dell'azienda per i provvedimenti di efficienza energetica
Nome
E-mail
Telefono

Forma giuridica dell'azienda	Si
Ente dipendente di diritto pubblico	
Ente indipendente di diritto pubblico	
Società anonima: 100% pubblica	
Società anonima: prevalentemente pubblica	
Società anonima: in minoranza pubblica	

Produzione propria	0-25%	25-50%	50-75%	75-100%
Quota di produzione propria nelle vendite				

Gas	2006	2007	2008	2009	2010	2011	2012
Prezzo dei prodotti gas (ct./kWh)							
Prezzo di base (CHF/mese)							

	Si	No
Interessa essere informati sui risultati di questo studio?		

Commento:

Figure 25: Survey Part I

La preghiamo gentilmente di compilare questa tabella nel modo più completo possibile. Può rivolgere eventuali domande a Nina Boogen (nboogen@ethz.ch, +41 44 632 88 45) . I clienti domestici vengono qui definiti come piccoli clienti (bassa tensione). Se possibile, riporti i dati negli anni civili. Se i dati dell'azienda sono riferiti all'anno idrologico, La preghiamo di annotarlo sul questionario.

	Azienda								
1	Nome								
		Si	**No**	**Da che anno**					
2a	La vostra azienda ha un contratto legale per aumentare l'efficienza energetica per i clienti domestici								
2b	La vostra azienda ha definito una strategia e fissato degli obiettivi annuali per aumentare l'efficienza energetica dei clienti domestici								
	Se la risposta alla domanda 2a o 2b è si:	**Si**	**No**	**Da che anno**					
2c	I vostri obiettivi sono quantificati?								
2d	La vostra azienda ha creato un fondo speciale per finanziare la realizzazione di misure di efficienza energetica presso i clienti domestici?								
	Struttura delle tariffe per i clienti domestici	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
3a	La tariffa varia al variare del consumo?								
3b	Se si, la tariffa diminuisce all'aumentare del consumo								
3c	Se si, la tariffa aumenta all'aumentare del consumo								
3d	Avete una tariffa speciale per i clienti con possibilità di blocco della fornitura per apparecchi elettrici?								
	Quale misure sono state adottate dalla vostra azienda per promuovere l'efficienza energetica dei clienti domestici? Apporre una crocetta alla risposta più appropriata	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
4a	Promozione di informazione riguardante l'efficienza energetica								
4b	Eventi pubblici								
4c	Noleggio di misuratori di consumo di elettricità								
4d	Informazioni riguardanti l'andamento del consumo di ogni cliente								
4e	Presenza di un centro di consulenza per l'efficienza energetica								
4f	Offerta di consulenza energetica a domicilio personalmente								
4g	Consulenza per l'acquisto o la sostituzione di elettrodomestici								
4h	Consulenza per l'acquisto o la sostituzione di impianti di riscaldamento elettrici e boiler elettrici								
4i	Sostegno finanziario per la sostituzione di elettrodomestici inefficienti								
4j	Sostegno finanziario per la sostituzione di impianti di riscaldamento elettrici e boiler elettrici								
4k	Avete misure tariffarie particolari per promuovere l'efficienza energetica?								
4l	Altre misure a favore dell'efficienza energetica (specificare nel box commenti)								
	Spese	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
5a	La spesa annua per tutte le misure a favore dell' efficienza energetica per i clienti domestici (CHF)								
5b	Spese annuali per tutti i programmi di sostegno finanziario all'introduzione di misure di efficienza energetica per i clienti domestici (CHF)								
		Si	**No**						
	Interessa essere informati sui risultati di questo studio?								
	Commento								

Figure 26: Survey Part II