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Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE

Schlussbericht 01.05.2019

Empirical Estimation of Electricity Demand Elasticities for Different Customer Groups in Switzerland and Implications for Energy Policies

ZEW

Datum: 01. Mai 2019

Ort: Bern

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BFE-Vertragsnummer: SH/8100087-00-01-01

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Zusammenfassung

In diesem Forschungsprojekt wird die Preiselastizität der Stromnachfrage in der Schweiz untersucht. Die Elastizitäten werden mittels Schweizer Verbrauchsdaten auf kantonaler Ebene ermittelt. Besonderes Augenmerk wird auf die Elastizität von Haushalten, Industrie und Dienstleistungen gelegt. Aufbauend auf einem umfangreichen Datensatz mit Informationen auf Kantonsebene für die Jahre 2011 bis 2016 schätzen wir strukturelle Ein-Gleichungs- und System-Gleichungsmodelle für verschiedene Zeitebenen.

Wir finden für keinen Sektor bedeutende Hinweise auf eine preiselastische Gas- oder Stromnachfrage auf Jahresniveau. Nur bei gewerblichen Stromkunden ergibt sich ein schwacher Hinweis auf statistisch signifikantes elastisches Verhalten auf. Es gibt weiterhin keine Hinweise auf eine preiselastische Stromnachfrage auf Monatsebene. Die fehlenden Hinweise sind möglicherweise durch unsere relativ kleine Datenbasis begründet und bedeuten nicht notwendigerweise, dass die Schweizer Nachfrage per se unelastisch ist. Unsere stündliche Analyse hingegen stützt sich auf detailliertere Daten, die auf eine signifikante Preiselastizität der Stromnachfrage auf Kantonsebene zwischen etwa -0,5 und -0,07 hinweisen. Die stündliche Analyse basiert auf dem Gesamtverbrauch des Kantons ohne Unterscheidung nach Sektoren. Mittels Kontrolle für die Nachfrage eher unelastischer Nutzer führen wir diese Elastizitäten auf flexible, große Kunden zurück. Das Ergebnis einer elastischeren Nachfrage bei den flexibleren Nutzern entspricht der Marktstruktur des Schweizer Strommarktes, in dem eher die sehr großen Kunden auf Spotpreise reagieren. In Kantonen mit höheren Industrieanteilen sind die Elastizitäten größer.

Wir nutzen diese geschätzten Parameter, um Nachfragereaktionen zu analysieren. Dabei konzentrieren wir uns auf die CO2-Preise, die ein interessantes Studienobjekt darstellen, da die Schweiz im Jahr 2020 auf ihr eigenes Emissionshandelssystem verzichten und am europäischen Emissionshandelssystem teilnehmen wird. In unserer stündlichen Analyse schätzen wir auch eine umfassende Preisgleichung unter Berücksichtigung der Rohstoffpreise, wenn ein entsprechendes fossil befeuertes Kraftwerk die Preise in den Nachbarländern bestimmt. Dies ermöglicht es uns, kontrafaktische Preise im Zusammenhang mit einem erhöhten CO2-Preis zu berechnen. Bei der Simulation eines gemeinsamen Emissionshandelssystems und eines gemeinsamen CO2-Preises von 25 Euro pro Tonne CO2 finden wir mögliche Nachfragereduzierungen von bis zu 7 Prozent aggregiert über ein gesamtes Jahr. Kantone mit höheren Industrieanteilen sind stärker betroffen als Kantone mit höheren Haushaltsanteilen.

Résumé

Le projet de recherche étudie les élasticités-prix de la demande d'électricité et de gaz en Suisse. Les élasticités de la demande pour la Suisse sont déterminées sur la base des données de la consommation suisse au niveau cantonal. Une attention particulière est accordée aux élasticités des ménages, de l'industrie et des services. À partir d'un riche ensemble de données comprenant des informations cantonales pour les années 2011 à 2016, nous estimons des modèles structurels à équation unique et à équations systémiques pour différents niveaux temporels.

Nous ne trouvons pas de preuves solides de l'élasticité-prix de la demande de gaz ou d'électricité au niveau de l'année pour aucun secteur. Seuls les clients commerciaux de l'électricité présentent de faibles preuves statistiques du comportement élastique. De plus, rien n'indique que la demande d'électricité est élastique au niveau du mois. Nous soupçonnons que la petite taille de l'échantillon

pourrait nous empêcher d'obtenir des résultats significatifs, ce qui ne signifie pas que la demande suisse est inélastique en soi. Notre analyse horaire, en revanche, s'appuie sur des données plus détaillées, ce qui se traduit par des élasticités-prix signifiantes de la demande d'électricité au niveau cantonal allant d'environ -0,5 à -0,07. L'analyse horaire est basée sur la consommation globale des cantons, sans distinction selon les secteurs. En contrôlant pour la demande des utilisateurs plutôt inélastiques, nous attribuons ces élasticités à des clients flexibles. Les élasticités sont plus grandes dans les cantons où la part de l'industrie est plus élevée.

Nous utilisons ces paramètres estimés pour analyser les réactions de la demande. Nous nous concentrons sur les prix du carbone, un sujet d'étude intéressant, car la Suisse abandonnera son propre système d'échange de quotas d'émission et participera au système européen d'échange de quotas d'émission en 2020. Dans notre analyse horaire, nous estimons également une équation de prix complète qui tient compte des prix des matières premières lorsqu'une centrale thermique alimentée aux combustibles fossiles détermine les prix dans les pays voisins. Cela nous permet de calculer des prix contrefactuels liés à une augmentation du prix du carbone. En simulant un système commun d'échange de droits d'émission et un prix commun du carbone de 25 euros par tonne de CO2, nous constatons des réductions de la demande pouvant atteindre 7 pourcent agrégées sur une année entière. Les cantons où la part de l'industrie est plus élevée sont plus touchés que les cantons où la part des ménages est plus élevée.

Abstract

The research project investigates price elasticities of electricity and gas demand in Switzerland. Demand elasticities are derived for Switzerland using consumption data at the canton level. Special focus is placed on the elasticities of households, industry and services. Building on a rich dataset comprising canton-level information for the years 2011 to 2016, we estimate structural single-equation and system-equation models for different time levels.

We do not find strong evidence for price elastic gas or electricity demand at the year level for any sector. Only commercial electricity customers show weak statistical evidence of elastic behavior. There is further no evidence for price elastic electricity demand at the month level. We suspect that the small sample size might preclude us from finding significant results, which does not imply that Swiss demand is inelastic per se. Our hourly analysis, in contrast, builds on more detailed data resulting in significant canton-level price elasticities of electricity demand ranging from about -0.5 to -0.07. The hourly analysis is based on aggregate canton consumption without any distinction by sectors. By netting out demand of rather inelastic users we attribute these elasticities to flexible, large customers. Finding more elastic demand when focusing on more flexible users is in line with the market structure of the Swiss electricity sector in which rather the very large customers are reacting to spot prices. Elasticities are larger in cantons with higher industry shares.

We use these fundamental market characteristics to analyze demand reactions. We focus on carbon prices representing an interesting study subject as Switzerland will abandon its own emission trading scheme and participate in the European emission trading scheme in 2020. In our hourly analysis we also estimate a comprehensive price equation taking into account commodity prices whenever a respective fossil-fuel fired plant is price setting in neighboring countries. This allows us to compute counterfactual prices related to an increased carbon price. Simulating a common emission trading scheme and a common carbon price of 25 euro per ton CO2 we find possible demand reductions of up to 7 percent aggregated over an entire year. Cantons with higher shares of industry are more affected than cantons with higher household shares.

Contents

1 Introduction

There is always the challenge to choose the right policy instruments for reaching a certain policy goal or target. Effectiveness and efficiency of many energy policy instruments depend on customers' reactions to these policies. It is thus of high relevance to analyze demand elasticities and to estimate the effects of a certain policy instrument in a specific case. Especially the welfare effects of the introduction of an environmentally motivated electricity tax might be of high value for policy makers. Losses in partial electricity market welfare from charging too high prices to elastic customers might counteract the positive effects of saving CO2-emissions. Investigating the trade-off between efficient taxation to obtain state-revenue at minimum cost inducing least possible quantity and welfare distortions on the one hand, and achieving environmental targets on the other hand is of great policy value.

To provide a better understanding of the behavior of Swiss gas and electricity customers we investigate price elasticities of electricity and gas demand in Switzerland. Special emphasis is put on the canton level to identify distributional effects across cantons. In addition, we make use of the cantons' different compositions of customer groups enabling us to distinguish among the elasticities of households, industry, and services. Demand of customer groups is identified extending previous work by Eymann et al. (2014).

Building on a rich dataset comprising canton-level information for the years 2011 to 2016, we estimate structural single-equation and system-equation models in order to determine price elasticities of gas and electricity demand in a static partial equilibrium model. Thereby, we model demand as a function of price, business cycle, income, houses with different heating systems, temperature, sunshine hours and time amongst others, and supply as a function of input prices as well as import, congestion and market power situations generation capacities amongst others.

By controlling for simultaneous supply and demand shocks we are able to disentangle their impact. Accounting for the simultaneity of supply and demand is crucial when estimating demand elasticities which otherwise would not be identifiable due to endogeneity. In addition, structural price-independent demand variation is accounted for by load profile controls and time dummies.

We do not find evidence for price elastic gas or electricity demand at the year level for any sector. There is also no evidence for price elastic electricity demand at the month level. Being contrary to previous studies we attribute these findings to the rather small sample size that does not seem to allow precisely identifying demand reactions regarding prices.

In contrast, our hourly analysis builds on more detailed data resulting in statistically significant canton-level price elasticities of electricity demand ranging from about -0.5 to -0.07. The hourly analysis is based on aggregate canton consumption without any distinction by sectors. By netting out demand of rather inelastic users we attribute these elasticities to flexible, large customers. Finding more elastic demand when focusing on more flexible users is in line with the market structure of the Swiss electricity sector. Being only partly liberalized, only customers with annual consumptions greater than 100 MWh can choose their own supplier while smaller users are stuck with local monopolistic electricity utilities. (A full liberalization was planned for 2014 but has not been realized by 2019). Thereby, larger customers are often not active at the spot market and rather choose among a greater pool of electricity utilities so that only very large customers react to spot prices (Swiss Academies of Arts and Sciences, 2012). Elasticities are larger in cantons with higher industry shares.

We use these fundamental market characteristics to analyze demand reactions. Thereby we focus on carbon prices representing an interesting study subject as Switzerland will abandon its own emission trading scheme and participate in the European emission trading scheme (EU-ETS) in 2020. In our hourly analysis we also estimate a comprehensive price equation taking into account comoditiy prices whenever a respective fossil-fuel fired plant is price setting in neighoring countries. This allows us, first, to calculate different pass-through rates for CO2 prices depending on their region use in production and respective market situations, and, second, to compute counterfactual prices related to an increased carbon price. We discover pass-through rates varying with congestion and market power situations. Assuming a common emission trading scheme and a common carbon price of 25 euro per ton CO2 (which is based on the recent peak in the European carbon price in April 2019) we find possible demand reductions of up to 7 percent. Cantons with higher shares of industry are more affected than cantons with higher households shares.

With these results we contribute to two well-established strands of literature. First, we estimate yearly, monthly and hourly demand elasticities for electricity and yearly demand elasticities for gas. We are able to differentiate yearly elasticities according to sectors as well as cantons and hourly elasticities according to flexible and inflexible customers as well as cantons. Current demand elasticities representative for whole countries are of practical value e.g. for policy simulation, given that many studies rely on smaller (individual-specific) sample data. In addition, evidence on commercial and industrial level with reference to whole countries is sparse as well. We thereby contribute to the existing literature in line with studies such as Bigerna and Bollino (2015) or Schulte and Heindl (2017).

Second, we contribute to the literature of tax efficiency and distributional consequences by generating evidence from a structural supply and demand model. The degree to which a tax decreases the quantity consumed informs about the efficiency of a tax. The relative share of price to cost increase, that is tax increase, informs about distributional equity between suppliers and customers. We are able to infer pass-through of CO2 cost effects between neighboring countries and Switzerland, which are subject to two different emission trading schemes. We can thereby estimate international spillover effects of the EU-ETS on Switzerland and further differentiate those according to their production technology as well as market tightness measured by (national) market power and international trading restrictions measured by congestion on electricity interconnector lines. This adds to recent studies such as Fabra and Reguant (2014) and Hintermann (2016) for Spanish and German electricity wholesale, respectively, Marion and Mühlegger (2011) and Kopczuk et al. (2016) for retail fuel, and Ganapati et al. (2019) for energy price pass-through in US manufacturing. None of these studies investigates cross-border spillovers. In addition, all of these studies either measure competition as a form of capacity restriction in production (not subsequent transportation (Marion and Muehlegger, 2011) or as a form of oligopoly behavior (Ganapati et al., 2019). We can disentangle congestion in transportation from situations, where tight supply conditions make unilateral market power exertion profitable. We then measure pass-through rates for these different situations. In addition, we can compare pass-through rates of technology-specific energy input prices to technology- and situation-specific pass-through rates of CO2 prices.

The paper is organized as follows. The next section describes our approach. Section 3 gives an overview of our dataset. Our results are presented in the fourth section. In section 5 we put the elasticities into perspective by analyzing the impacts of an increase in CO2 emission costs. The final section concludes.

2 Approach

Our empirical approach consists of several steps. As we are interested in the demand reactions of different customer groups, we first have to approximate their demand at the canton level. The approximation is based on nationwide, yearly figures regarding electricity and gas consumption, and canton characteristics. These annual consumption figures are then used for the yearly analyses, in which we estimate the elasticities accounting for endogeneity. For the hourly and monthly analyses of electricity demand, a decomposition into a higher time resolution would be necessary which unfortunately is not possible without many strong assumptions. We therefore conduct the respective estimations using aggregate demand figures. The respective steps are described in more detail in the following.

2.1 Approximation of annual canton-level consumption

The derivation of canton-level annual demand by customer group is based on Eymann et al. (2014). The authors develop allocation keys to distribute official country-level figures for energy consumption of households, industry, and services among cantons using canton characteristics. Specifically, they consider the cantons' composition of residents, buildings, dwellings, heating fuel, and employees by branch of economic activity. While they approximate the consumption of several energy sources in 2012 we only focus on electricity and gas and the extended period from 2011 to 2016. Moreover, we consider additional information like occupants per building, hot water generation, building age, and the size of dwellings to derive a more accurate approximation exploiting canton-level variation. Thereby, we also correct their methods for inaccuracies (like disregarding cantons that are not connected to gas infrastructure).

In the following we provide a condensed description of our approximation of the individual customer groups' consumption while the appendix contains the complete explanation (with differences to Eymann et al. (2014) and data sources). For our analyses, we will use figures derived by our refined approximation while figures replicating the methodology of Eymann et al. (2014) are used for robustness checks.

Regarding household gas consumption, our allocation procedure is twofold. Firstly, we approximate canton-level gas consumption related to hot water generation. Thereby, we employ canton-level information on buildings with gas boilers for hot water generation including the type and age of buildings and the number of occupants as well as the average hot water consumption per person in Switzerland (46.8 liters; Freiburghaus, 2015). After assigning the respective figures to the cantons, we secondly derive canton shares to allocate the remaining nationwide household gas consumption. Being related to heating purposes, we employ the buildings' heating energy requirements in the cantons for weighting, which are approximated with the help of canton-level information on the type and age of buildings with gas-fueled heating, energy reference area, and heating degree days.

Regarding household electricity consumption, our allocation procedure is threefold. Consumption related to hot water generation and to heating is derived and allocated in the same manner as for gas. While consumption related to hot water generation is thus also directly assigned, the amount of heating consumption to be allocated is set at 9 percent of Swiss electricity consumption.[1] As an additional consideration, the remaining nationwide household electricity consumption is allocated by canton

[1] This assumption is based on Eymann et al. (2014) referencing to Nipkow and Togni (2009) stating that the share of electric heating on Swiss electricity consumption ranges between 6 to 12 percent. We also conduct sensitivity checks using the upper and lower bounds.

shares derived from the typical electricity consumption of occupants in the cantons. The latter are based on Swiss figures provided by Nipkow (2013) and projected on the average number of occupants in the cantons' different types of buildings.

Regarding gas and electricity consumption of the sectors industry and services, we relate nationwide information on the average consumption per employee in the different branches to the respective number of employees in the cantons in order to derive canton weights. These weights are then used to allocate the nationwide gas and electricity consumption of the industry and services sectors, respectively, among the cantons. Table 1 shows the branches that belong to the respective sectors.

Table 1: Branches and sectors

Sector	Branch
industry	Manufacture of foods
	Manufacture of textiles and leather
	Manufacture of paper and print
	Manufacture of chemical and pharmaceutical products
	Manufacture of cement
	Manufacture of other non-metallic mineral products
	Manufacture of basic metals
	Manufacture of non-ferrous metals
	Manufacture of fabricated metal products, computer and electrical equipment
	Manufacture of machinery
	Other industries
	Construction
services	Wholesale and retail trade
	Accommodation
	Financial and insurance activities
	Public administration
	Education
	Human health and social work activities
	Other services

For a subsequent decomposition of annual figures into a higher time resolution we also need to account for the residual electricity and gas consumption related to transportation (besides the statistical difference which is addressed in the appendix). Nationwide consumption related to transportation is allocated among cantons with the help of canton shares derived from canton-level information on daily distance travelled by person and by transportation means taken from micro census data (regarding electricity, freight traffic is additionally considered using full time equivalents in the cantons' industry sector).

2.2 Estimation strategy

With the help of the annual, sector-specific consumption figures in the Swiss cantons, we estimate the sectors' price elasticity of gas and electricity demand in Switzerland, respectively. Based on this panel data, we consider a fixed effects model with a log-log demand of the form:

$$\log Q_{it} = \beta \log P_{it} + \gamma \log X_{it} + \delta\, T + \alpha_i + \varepsilon_{it} \tag{1}$$

The employed variables differ by sector and energy type and are described in the following. In general, Q_{it} represents the kWh quantity of energy consumed in canton *i* in year *t*. P_{it} captures the annual price that the sector has to pay, on average, for a kWh of energy. X_{it} comprises several variables controlling for demand in the cantons. T captures a time trend. α_i represents canton-fixed effects which help to additionally account for unobserved time-persistent effects. ε_{it} is a normally distributed random error term.

In a log-log specification the coefficient of the price variable directly shows the price elasticity of demand. That is, a one percent change in price will cause a β% change in consumption, keeping all else the same. Importantly, prices are considered to enter the model as endogenous variables since the relationship between supply prices and equilibrium quantity may introduce bias due to a possible reverse causality. We thus employ an instrumental variable (IV) technique and estimate the model employing the Generalized Method of Moments IV (IV-GMM) estimator. This yields unbiased estimates of elasticity. The respective instruments are described in the following.

With regard to the gas household sector, we employ the number of residents, the share of residents aged 65 years and older, income, the unemployment rate, the number of houses with heat pumps, the number of houses with gas heating, and the number of heating degree days as controls. All are expected to increase demand apart from the number of houses with heat pumps as the alternative heating system should lead to a reduced gas demand. The impact of gas price we derive is an average over typical prices households have to pay for single- or multi-family houses depending on their composition in the respective cantons (described in next section). This price is instrumented by a first and a second lag of the annual average of the TTF daily reference gas price to account for longer-term acquisition strategies of gas utilities. This instrument is related to consumption but does not affect consumer behavior apart from its influence through the supply side.

For the gas consumption of the industry sector, we employ the number of sites and the number of employees (as well as their interaction to capture a possible non-linearity), the canton's gross value added, and Swiss industry production as control variables. For the services sector, we also use the number of sites and the number of employees (and their interaction), and the canton's gross value added as controls. Yet, we additionally employ the number of heating degree days to capture that the gas use is more relevant for heating in this sector; in addition, some processes depend on outside temperature in their gas intensity. For both sectors the gas price is also derived as an average over typical prices industrial or service firms are charged by gas utilities, respectively. Again, the price is instrumented by a first and a second lag of the annual average of the TTF daily reference gas price.

Regarding electricity and the household sector, we use the following control variables. The number of residents, the share of residents aged 65 years and older, income, the number of houses with electric heating, the number of houses with heat pumps and the number of heating degree days. All variables are expected to increase electricity consumption. Whereas the reasoning seems clear for most variables, regarding the share of elderly people it is argued that pensioners are more often longer times at home or live (widowed) in one-person households (Swiss Academies of Arts and Sciences, 2012). The electricity price households have to pay is derived as an average over typical prices for single- or multi-family houses depending on their composition in the respective cantons and accounting for typical off-peak consumption (described in next section). As excluded instrument we utilize a first lag of the annual average of the spot price in the German/Austrian bidding zone. This instrument is related to consumption and only affects consumer behavior through its influence on the acquisition strategy of the electricity utility.

For the electricity consumption of the industry sector, we employ the number of sites and the number of employees (as well as their interaction), the canton's gross value added as well as the number of heating degree days as control variables. For the services sector, we use the same respective variables. In both sectors the first lag of the annual average of the spot price in the German/Austrian bidding zone also serves as excluded instrument.

For the annual analyses of both energy types, we conduct two robustness checks. First, we employ annual, cantonal sector-specific consumption figures derived from the methodology of Eymann et al. (2014). Second, we alter our derivation of consumption figures by considering the aforementioned lower and upper bound of the Swiss electricity heating consumption range.

Besides analyzing elasticities at the year level, we are also interested in the price sensitivity of consumption at a higher time resolution. We possess cantonal electricity consumption data at a month and hour level. Yet, this data comprises the aggregate consumption of all sectors in the respective cantons. Conducting sector-specific analyses would then necessitate to apportion the aggregate consumption in the respective months or hours among the sectors. Taking the annual sector-specific figures as a starting point, within-year (and within-day) variation of the sectors' consumption is needed to derive sector shares in the respective time units. Such variation could be taken from information on industry production or load profiles. However, this approach would always be subject to strong assumptions that impose a certain consumption behavior upfront so that a subsequent estimation of elasticities seems anticipated.

We therefore take a different approach and focus on the aggregate consumption while controlling for demand stemming from inflexible users. By this means we can separate out the price-insensitive consumption allowing us to assess the sensitivity of flexible users. These flexible users are, however, not sector-specific so that we will need to further relate the elasticities to the composition of sectors afterwards.

For estimation, we consider a system of equations. On the one hand, this comprises demand in the respective cantons. On the other hand, we model the supply side explaining the Swiss electricity price. Again assuming a log-log form, the system of equations is written as:

$$\log Q_{it} = \beta \log P_t + \gamma \log X_{it} + \delta \, Cal_t + \varepsilon_{it} \tag{2}$$

$$\log P_t = \beta \log P_{it} + \gamma \log W_{it} + \delta \, Cal_t + \varepsilon_{it} \tag{3}$$

Note that the quantity equation comprises several equations for the individual cantons *i*. As demand determinants, X_{it}, we consider sunshine duration, temperatures and their squares in canton *i* in hour *t*.[2] We also consider the interactions of the yearly number of plants in different branches and the respective quarterly gross value added to capture economic activity. Additionally, we account for possible inflexible consumption of households with the help of an interaction of the number of residents

[2] Higher temperatures increase electricity demand through the need for cooling, while lower temperatures require more electricity for heating. A squared term is included to account for a possible nonlinear relation.

and an off-peak dummy. Cal_t captures month, day, hour and day-hour dummies.[3] Especially the latter serve to capture the basic inflexible demand in hours of a weekday.

The Swiss electricity price is measured by the Swiss day-ahead spot price and explained by a thorough model of the supply side because further interest lies in the fundamental relationship with its determinants. Besides including the same time dummies we consider the integration of the Swiss electricity market with the neighboring countries (i.e. bidding zones). Specifically, we account for the price-setting technologies when measuring the influence of commodity prices on the electricity price. That is, even though Switzerland only possesses fossil-fuel fired plants that run with gas we also expect an influence of the coal and oil (and gas) price if respective plants are price setting in neighboring countries – given that Switzerland imports from the respective countries.

To account for these influences we follow Heim et al. (2017) and construct merit-orders for every hour in every country using the commodity prices and available generation capacity while accounting for net exports to other neighboring countries. Given that Switzerland is net-importing, a price-setting production technology in a neighboring country becomes price setting in Switzerland if there is no congestion on the border[4] and this technology is higher on the merit-order than the Swiss technology that is needed to satisfy demand in Switzerland (given the import situation).[5] The position on the merit-order is thereby also subject to carbon prices, which differ between Switzerland and the EU, and to market power so that in rare situations of equal positions the country with higher market power markups is placed higher. The same applies to cases in which there is congestion (and Switzerland is net-importing). But in these cases, the effect of the neighboring price-setting technology is measured with bias due to the congestion rent wedge. In the other cases, i.e. if Switzerland is net-exporting, only the gas price is of relevance and becomes effective if Switzerland employs gas-fired plants that are price-setting (Switzerland only exports when gas plants are marginal).

Moreover, similar to Hintermann (2016) we account for the situation of market power in the respective countries to learn about the pass-through of carbon prices. Whenever a fossil-fuel fired plant is price setting, the respective carbon price becomes effective. Thereby we distinguish the effect by the situation of market power. We presume a situation of market power in a country if the forecasted (day-ahead) load net of forecasted renewables generation is close to the available production of the remaining power generation plants where close means a share of 90 percent or higher.[6] In case of market power, we expect that the pass-through of carbon prices is higher than in more competitive situations. Knowing the relationship is key for subsequent policy applications.

In sum, we thus have the following supply shifting variables as depicted by W_{it} in Equation (3): a dummy for import situations, a dummy for a congestion situation with a neighboring country, the gas price whenever a gas-fired plant is price setting, the coal price whenever a coal-fired plant is price setting in net-import situations, and the oil price whenever an oil-fired plant is price setting in net-import situations. In addition, we include the Swiss carbon price in situations when Swiss gas-fired plants are price setting and either market power is assumed, or not. For European carbon prices we include the same distinction for price-setting coal-, gas- and oil-fired plants in the respective neighboring countries

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[3] We do not include year dummies as we only investigate two years.

[4] Congestion situations are presumed whenever price differences between two interconnected countries do not follow the Law of One Price. In fact, any price differential greater than zero would suggest that markets are not fully integrated. We assume a congestion situation if the differential of day-ahead spot prices between two countries is greater than one €/MWh in order to account for, e.g., expectation errors of electricity traders. This is in line with Heim et al. (2017), whose results are also robust to larger differentials.

[5] Specifically, we compute the net-import status by adding up day-ahead net transfer capacities (NTC) directed to Switzerland. That is, by not employing realized flows we maintain consistency with the focus on day-ahead spot prices. Merit-orders for the individual hours are also built on the basis of previous-day information (i.e. based on renewable infeed forecasts and available capacity (apart from hydro-related generation for which we refer to actual generation due to data availability)).

[6] We considered several other cut-off points and also different measures (based on whole capacity or of residual load on peak load); the results remained fairly comparable.

(when Switzerland is net-importing). Regarding the European carbon prices we additionally distinguish between congestion situations.[7]

Estimation is conducted using three-stage least squares (3SLS) (Zellner and Theil, 1962). While this estimator is efficient as it exploits cross-equation correlation of errors, it only yields consistent estimates under the assumption of independent and identically distributed errors. Acknowledging that this is a strong assumption given our hourly setting which likely exposes heteroskedastic and auto-correlated errors, we employ bootstrapping to obtain an appropriate variance-covariance matrix.

As robustness check we also perform IV-GMM estimation implying to estimate equation by equation (with the supply side serving as excluded instruments). IV-GMM allows obtaining robust errors; yet, we are no longer exploiting cross-equation correlation and cannot interpret structurally the coefficients of the first stage (which we use for assessing pass-through).[8]

Regarding the monthly focus, our specification is less sophisticated due to data availability. While we are able to capture more years than in the hourly analysis, the number of months naturally limits the sample size. Moreover, most generation-related variables are unfortunately not available prior to 2014 (see next section). The inflexible demand can thus only be captured by month dummies and a time trend (Cal_t in Equation (3), where t now depicts months).[9] In order to maintain a parsimonious number of parameters to estimate, demand variables, X_{it}, are restricted to temperatures and their squares, and interaction of industrial sites and quarterly industrial gross value added, and the number of houses with electric heating systems. In addition, only the monthly average of the spot price in the German/Austrian bidding zone serves as the excluded instrument W_{it} for the Swiss electricity price P_{it}. Even though this does not capture the supply side to the same degree as before, the IV quality is convincing.[10]

As for the hourly case, estimation is via three-stage least squares with bootstrapped errors. For robustness, we also conduct IV-GMM, but do not perform GMM estimation of the system of equations as this is infeasible with the sample size at hand.

[7] In our specification we only consider cases of price-setting technologies in France and Germany/Austria. That is, we disregard Italy for reasons of model parsimony since there are relatively few cases in which Switzerland is a net-importer and also relies on Italian gas-fired plants; transfer capacities to Switzerland are also low.
[8] We also tried to conduct GMM estimation of the system of equations but did not reach convergence. While GMM estimation would be asymptotically optimal, it might not be as precise as 3SLS in finite samples (Wooldridge, 2010). We thus remained with 3SLS and bootstrapped errors to get precise and robust estimates.
[9] Instead of more preferable month-year dummies. Their inclusion would raise the number of parameters above the number of observations.
[10] Data availability precludes considering the merit order and thus the pass-through. We experimented with aggregate commodity prices but the IV performance was inferior to the spot price in the German/Austrian bidding zone.

3 Data

Our analysis draws on a comprehensive dataset comprising canton-level information for the years 2011 to 2016. In the following we describe our data starting with consumption figures and then dwelling on price and control variables used in the analyses with different time levels.

Figure 1 shows the development of total Swiss electricity consumption from 2011 to 2016 and distinguishes among sectors. Total consumption ranges around 60 TWh per year with a slight decrease over the years. In 2015, about 18 TWh were consumed in the industry sector, 17 TWh in the services sector and 19 TWh by households.

Figure 2 shows the equivalent development for gas consumption. The total Swiss gas consumption amounts to about 30 TWh per year. In 2015, about 13 TWh were consumed in the industry sector, 7 TWh in the services sector and 11 TWh by households. The peak in 2013 is due to a relatively cold winter followed by warmer years. The fact that gas serves a prominent heating purpose is also captured by households driving this temperature-depending development. The gas consumption of the services sector also reacts to colder temperatures while the development in the industry sector is more independent due to a more pronounced use of process heat.

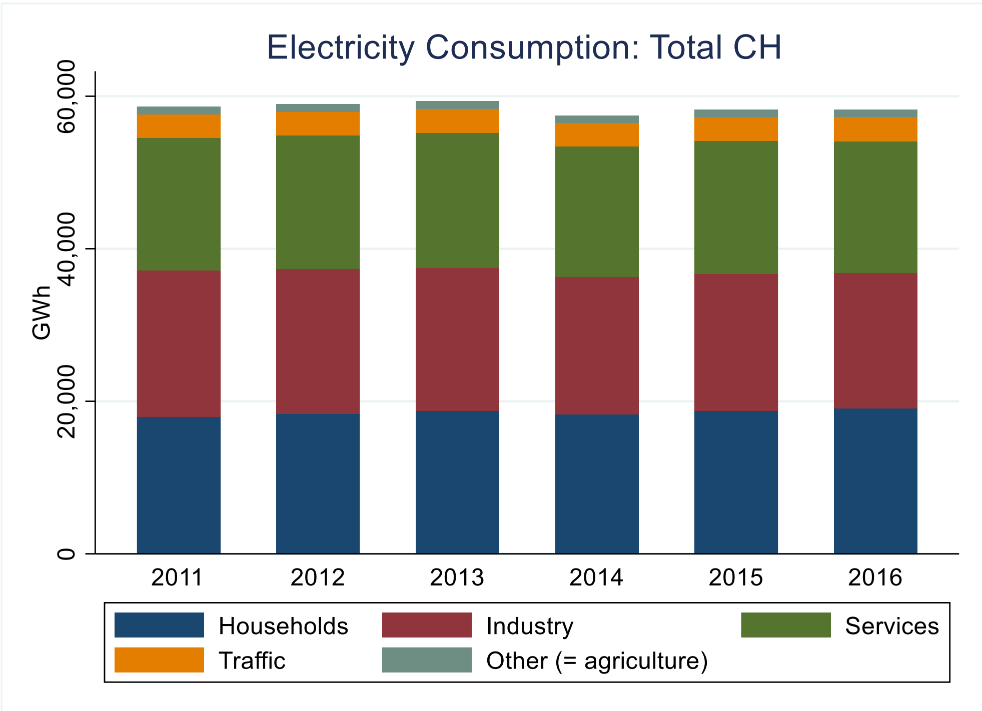

Figure 1: Electricity consumption by sector

Source: SFOE

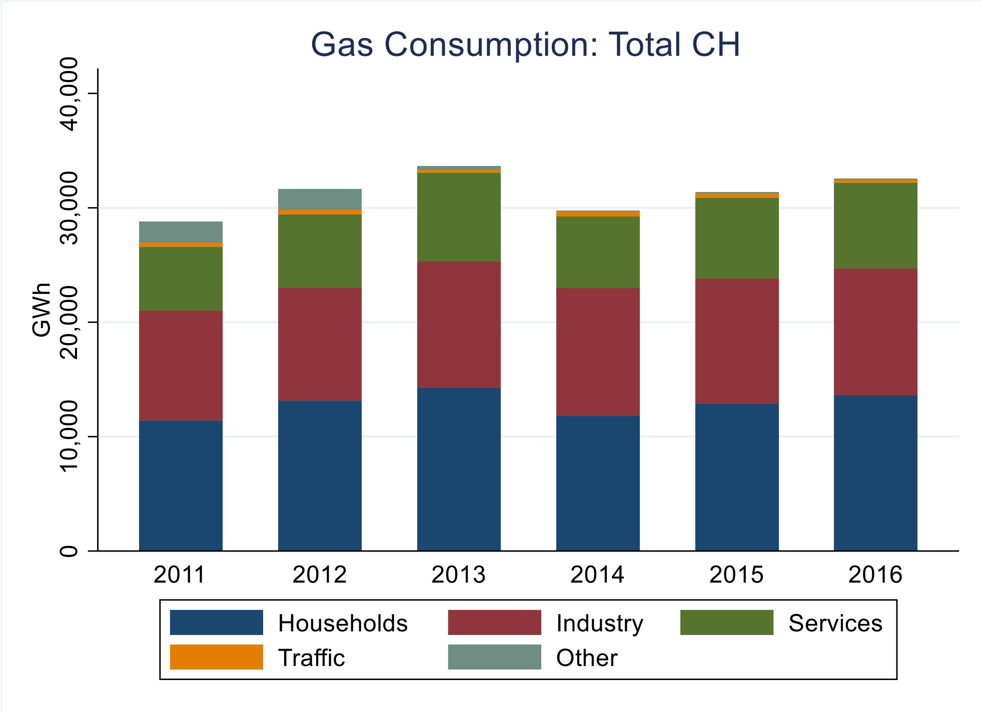

Figure 2: Gas consumption by sector

Source: SFOE

Taking a closer look at the individual cantons, Figure 3 and Figure 4 present the derived annual electricity consumption per canton distinguished by sector. The figures are printed with common y-axis by row to enable a better comparison of overall cantonal consumption. We note that figures for household consumption are missing in 2011 because our derivation relies on information on the size of dwellings which is not available in that year. This year will therefore not be used when analyzing household consumption (also regarding gas).

Regarding the ranking of cantons with highest total consumption, the populous cantons Zurich, Bern, Vaud, Aargau and St Gallen are at the top. Basel-City is placed in the middle field. The lowest consumption is found in Appenzell Inner and Ausser Rhoden, Nidwalden, Obwalden, Uri, and Glarus. The highest consumption share of industry is found in St Gallen while the highest shares of services are found in Zurich and Geneva.

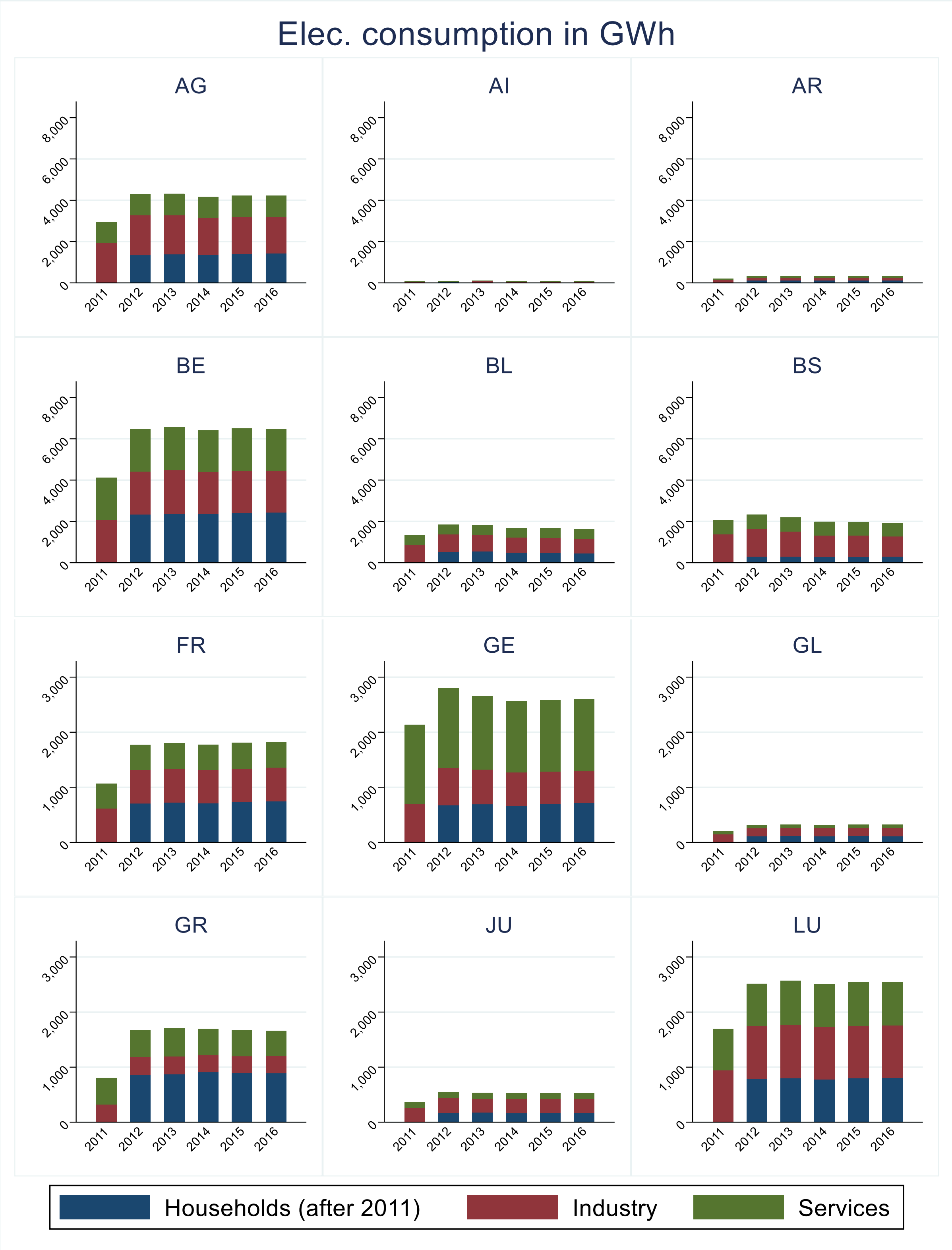

Figure 3: Electricity consumption by canton and sector (part 1)

Source: own derivation

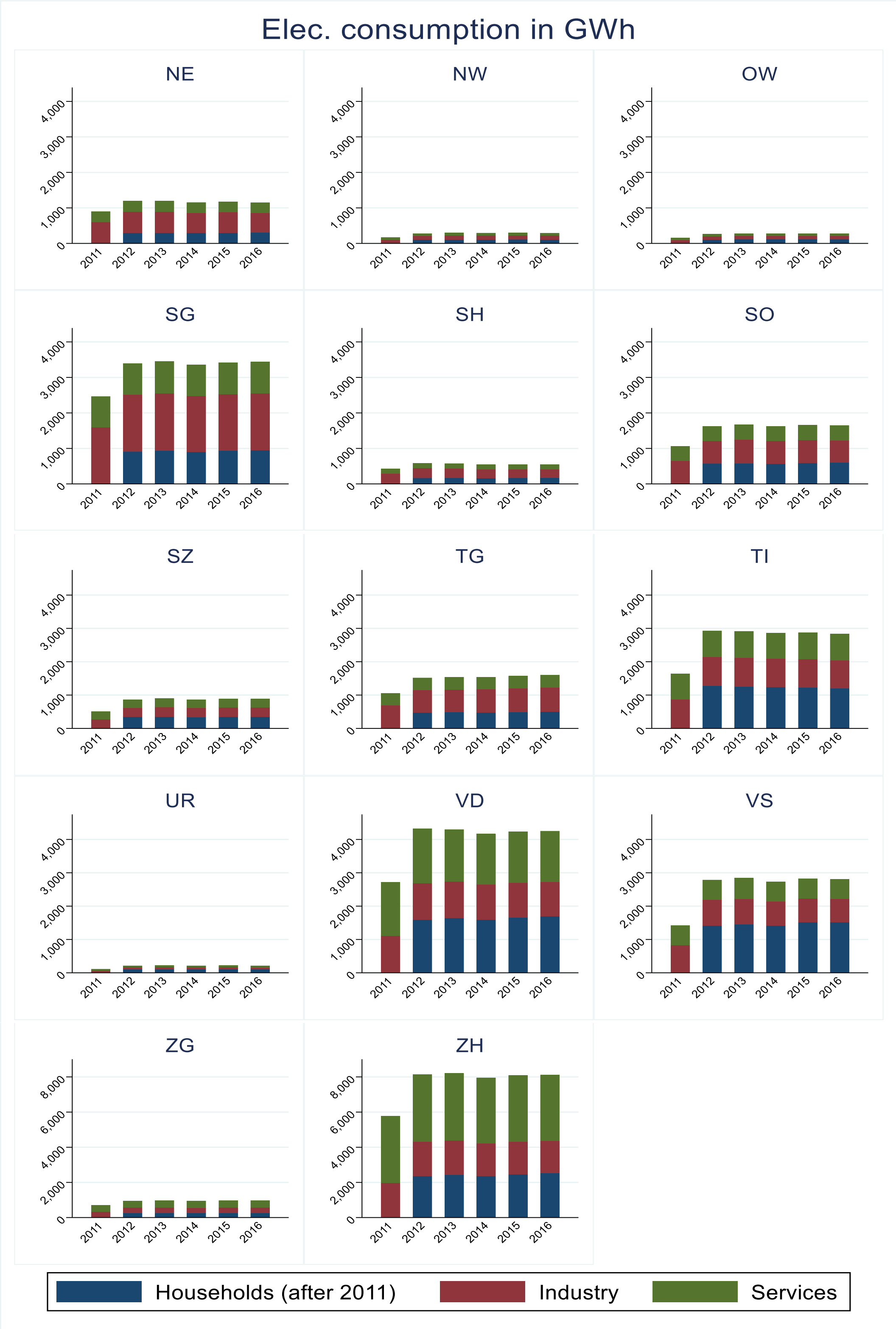

Figure 4: Electricity consumption by canton and sector (part 2)

Source: own derivation

Turning to gas consumption, Figure 5 and Figure 6 present the derived annual gas consumption per canton distinguished by sector. Apart from year 2011 we recover the temperature-dependent development of overall gas consumption in the cantons. The cantons with the highest average annual gas consumption are in decreasing order: Zurich, Bern, Vaud, Aargau, Basel-City, Geneva, and St Gallen. The least gas is consumed in Appenzell Inner and Ausser Rhoden, Glarus, and Jura. There is no gas consumption in Nidwalden, Obwalden, and Uri. While most populous Zurich has both high amounts of household and services consumption, Basel-City has a high (chemical) industry consumption despite a lower population than Vaud and Aargau. On the other hand, St Gallen shows a fairly lower total consumption compared to Geneva despite a comparable population; yet, St Gallen has a lower population density and a more pronounced industry sector. The decision to connect a canton to the gas infrastructure is commercially driven; i.e. there is no supply obligation in contrast to electricity (PUE, 2011). Therefore, especially regions with a high population density and more flat ground are supplied with gas. This involves only about 40 percent of Swiss municipalities.

In the appendix, we provide a table with the respective figures (Table A-2 for electricity and Table A-3 for gas). They also comprise the consumption figures using the derivation method by Eymann et al. (2014). For a better comparison the different derivation methods are paralleled at the canton-level in Figure A-1 to A-4 in the appendix. Both derivation methods show similar figures for the industry and services sector (because there were only slight differences in assigning economic activities). Differences in total consumption stem from the household sector. In our derivation we additionally consider consumption related to water heating, and heating load based on dwelling size by type of building and building age. Thus, especially cantons with a higher share of dwellings in multi-family houses are characterized by higher electricity consumption (e.g. Basel-City, Geneva, Vaud, Zug, and Zurich). The same applies to gas; yet, cantons show an additionally increased consumption when there are more houses with gas than electric heating (e.g. Geneva).

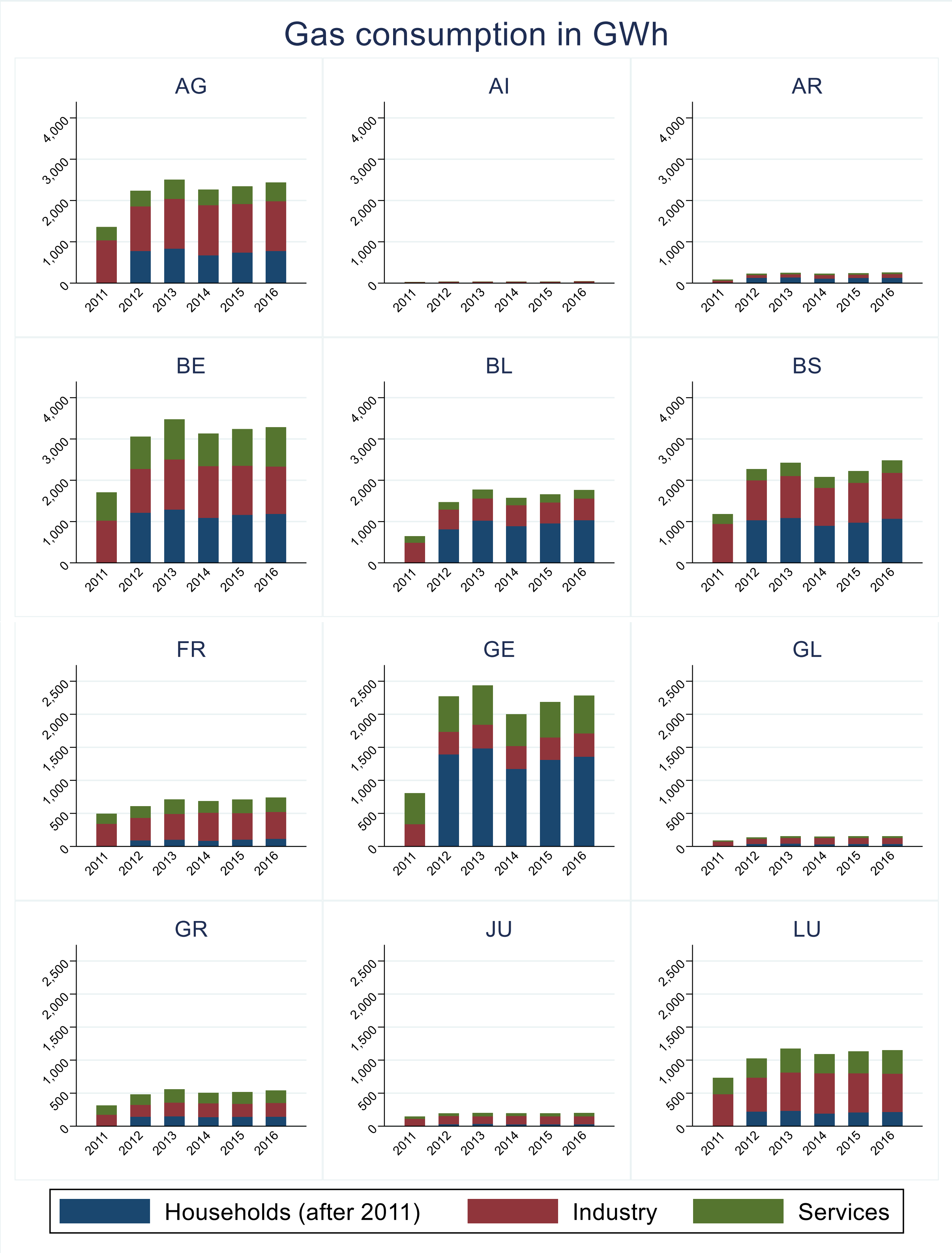

Figure 5: Gas consumption by canton and sector (part 1)

Source: own derivation

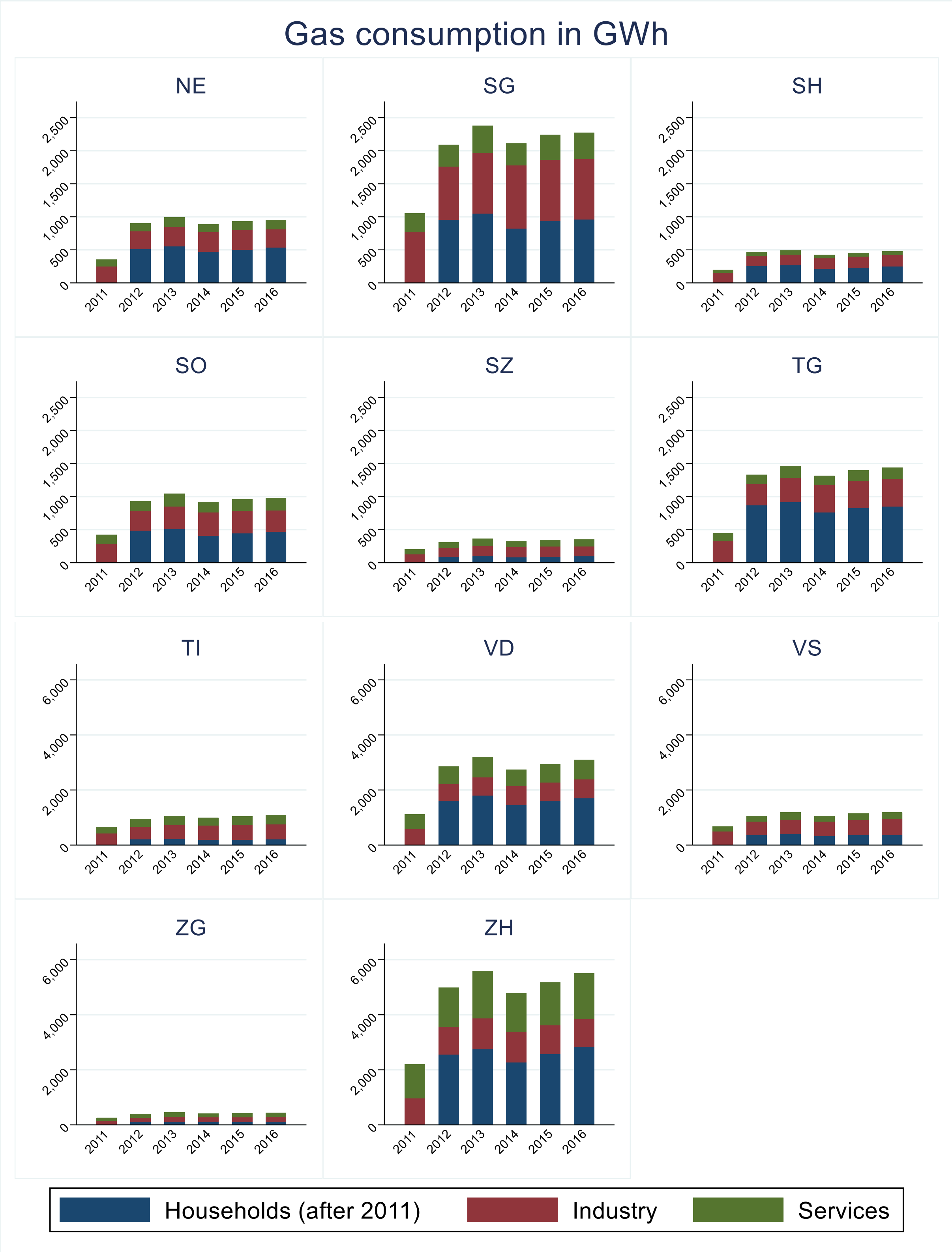

Figure 6: Gas consumption by canton and sector (part 2)

Source: own derivation

The annual consumption figures establish the basis for the analysis of price elasticities at the year level. Turning to the descriptive of the employed variables, Table 2 depicts summary statistics. In the first panel, the consumption data is summarized regarding the full observation period 2011-2016. The second panel entails information on prices. In the third panel, the demand shifters are summarized. We describe both panels in more detail in the following.

Electricity prices are taken from Electricity Commission ElCom, Switzerland's independent regulatory authority in the electricity sector. The Swiss electricity sector has been liberalized in 2009 enabling customers with an annual consumption above 100 MWh to choose their own supplier. Customers with lower consumption are dependent on their local electricity utility. (A full liberalization was planned for 2014 but has not been realized by 2019). They are local monopolists also operating the distribution network. ElCom rules on disputes relating to network access and monitors electricity prices possibly prohibiting unjustified electricity price increases or reducing excessively high tariffs.

ElCom publishes electricity prices of more than 650 electricity utilities.[11] Thereby prices are provided as average prices for different typical user profiles in order to make the usual two-part tariffs comparable and to account for on- and off-peak pricing. These categories cover differently sized dwellings in multi-family houses, single-family with different electric equipment (e.g. electric heating or heat pumps) as well as firm and industrial customers with different consumptions and peak loads. Note that these prices might not apply to large consumers choosing their own suppliers.

For our analysis we derive indices based on total prices of different consumer categories and information about the sectoral composition in the cantons. For households, we compute an average of two parts. On the one hand, we take the average over prices for dwellings in multi-family houses and weight this with the share of multi-family houses. On the other hand, we calculate weighted prices for single-family houses with electric heating, with heat pumps, or without any with the respective shares of such houses on all houses. For the services sector, we employ information on differently sized service sites (1-9, 10-49, 50-249, and more than 250 employees) and relate it to prices of categories with annual consumptions up to 1.5 GWh to also capture large warehouses with refrigerators. For the industry sector we employ information on differently sized industrial sites and relate it to prices of categories with consumptions up to 7.5 GWh/a. We consider total prices comprising energy, network and public levy components to capture the direct price a consumer has to bear regardless whether there is some form of reimbursement afterwards.

The information in Table 2 reveals that prices per kWh are on average lowest for industry. Prices for households range between 15 and 24 Swiss Rappen per kWh (excl. VAT). Figure 7 shows the development of the Swiss averages price over time and also depicts the distribution across cantons. Prices increase over the observation period. In order to account for endogeneity we employ the first lag of the annual average of the spot price in the German/Austrian bidding zone as excluded instrument.

Gas prices are taken from the Swiss price supervisor (PUE) who officially observes gas prices amongst other and aims to remedy anti-competitive prices. Similarly to ElCom, the Swiss price supervisor also publishes gas prices by about 100 gas utilities dating back to 2011.[12] The prices are provided as average prices for different typical gas user profiles in order to make the usual two-part tariffs comparable. These categories cover single-, double, and multi-family houses as well as firm and industrial customers with different consumptions and boiler capacities. Note that these prices might not apply to large consumers who could negotiate individual terms with their regional distributors.

[11] Cf. https://www.strompreis.elcom.admin.ch/Start.aspx, last accessed on April 29, 2019.
[12] Cf. http://gaspreise.preisueberwacher.ch/web/index.asp, last accessed on April 29, 2019.

For our analysis we derive indices based on prices of different consumer categories and information about the sectoral composition in the cantons.[13] For households, we employ the ratio of single- to multi-family houses with gas heating and relate it to the respective prices. For the services sector, we employ information on differently sized service sites (1-9, 10-49, 50-249, and more than 250 employees) and relate it to prices of categories with consumptions up to 1163 MWh/a to also capture larger administrations etc. For the industry sector we employ information on differently sized industrial sites and relate it to prices of categories with consumptions up to 250 GWh/a.

The information in Table 2 reveal that prices per kWh are on average lowest for the services sector. Prices for households range between 7 and 11 Swiss Rappen per kWh (excl. VAT). Figure 8 shows the development of the Swiss averages price over time and also depicts the distribution across cantons. Especially in the last years an overall price drop is visible after a peak in 2014. This peak might be related to the previous peak in demand due to a cold winter so that shrunk gas storage has to be refilled more expensively.

In our analysis we account for endogeneity of prices when analyzing consumption. As excluded instrument for gas prices we employ a first and a second lag of the annual average of the TTF daily reference gas price.[14] By this we aim to capture longer term acquisition strategies. Swiss gas utilities usually buy from regional companies (Erdgas Ostschweiz AG, Erdgas Zentralschweiz AG, Gasverbund Mittelland AG, Gaznat SA) who themselves buy from a commonly owned company, Swissgas AG, which is assigned the task to centrally purchase gas and to pass on the volume discounts. To account for exchange rare risks we convert any euro values to Swiss francs.

The third panel of Table 2 describes the variables used as demand shifters in the yearly analyses. Regarding the household sector, we employ the number of residents, the share of residents aged 65 years and older, income, and the unemployment rate. In addition, we consider houses with different heating systems. Houses with heat pumps are on average less common while their number is steadily increasing. The highest number can be found in Zurich. Houses with gas heating are on average more common than with electric heating. The number of the latter is decreasing over time (most popular in Valais, Ticino, Vaud and Bern) while gas heating system installations increase (most prevalent in Zurich and Vaud). The number of heating degree days varies similarly over time in the cantons. Yet, averages are varying strongly over cantons. The most heating degree days are observed in Grisons, Nidwalden and Obwalden (more than 4000) while most other cantons have about 3000-3500 with Ticino representing the lowest value (2400).

Regarding the industry and services sector, our control variables cover the number of sites and employees. While these numbers are also available at more disaggregated economic activities, their effective inclusion in the panel regression is limited by the rather small sample size. As an overall control we also consider industry production at the national level besides accounting of the development of the cantons’ gross value added.

[13] In all our analyses we also employed unweighted means of household- and firm-related categories without obtaining significantly different results.

[14] Although Switzerland imports more gas from Germany than from the Netherlands, we opt for prices from the TTF exchange instead to NCG due to a slightly better IV performance. Still, prices from both exchanges are highly correlated.

Table 2: Summary statistics (yearly) (continued on next page)

Variable	Effective Obs.	Mean	Std. Dev.	Min	Max	Unit, Source, Notes
Consumption						
Elec. consumption households	130	701.29	671.63	27.36	2530.77	GWh; cf. appendix
Elec. consumption households (via Eymann et al., 2014)	156	712.61	686.13	40.9	2655.26	GWh; cf. appendix
Elec. consumption industry	156	699.55	590.74	37.76	2096.31	GWh; cf. appendix
Elec. consumption industry (via Eymann et al., 2014)	156	698.8	607.72	37.69	2105.43	GWh; cf. appendix
Elec. consumption services	156	661.55	801.76	21.79	3825.88	GWh; cf. appendix
Elec. consumption services (via Eymann et al., 2014)	156	661.46	801.52	22.24	3818.65	GWh; cf. appendix
Gas consumption households (via Eymann et al., 2014)	138	558.13	583.37	3.58	2780.25	GWh; cf. appendix
Gas consumption industry	132	470.02	359.06	19.78	1249.07	GWh; cf. appendix
Gas consumption industry (via Eymann et al., 2014)	132	472.42	365.78	19.8	1252.18	GWh; cf. appendix
Gas consumption services	132	302.22	337.58	6.32	1720.32	GWh; cf. appendix
Gas consumption services (via Eymann et al., 2014)	132	302.14	337.73	6.44	1717.23	GWh; cf. appendix
Prices						
Elec. price households	156	18.93	1.9	14.66	24.48	CHF Rp./kWh (excl. VAT); Electricity Commission ElCom; weighted mean of typical total prices for households in multi (1.6, 2.5, 4.5 MWh/a) and single-family houses (7.5, 13, 25 MWh/a) based on houses in canton and averaged over electricity utilities in canton
Elec. price industry	156	18.27	1.91	14.69	25.39	CHF Rp./kWh (excl. VAT); Electricity Commission ElCom; weighted mean of typical total prices for firms with consumptions of 0.03, 0.15, 0.5, 1.5, 7.5 GWh/a based on differently sized industry sites in canton and averaged over electricity utilities in canton
Elec. price services	156	18.49	1.9	14.85	25.51	CHF Rp./kWh (excl. VAT); Electricity Commission ElCom; weighted mean of typical total prices for firms with consumptions of 0.03, 0.15, 0.5, 1.5 GWh/a based on differently sized services sites in canton and averaged over electricity utilities in canton
Elec. price AT/DE (annual mean)	6	49.32	11.64	33.77	63.16	CHF/MWh; epex spot: day-ahead spot price in German/Austrian bidding zone
Gas price households	138	8.86	0.84	7.49	11.41	CHF Rp./kWh (excl. VAT); Swiss price supervisor; weighted mean of typical total prices for single- (20 MWh/a) and multi-family houses (100 MWh/a) based on houses in canton and averaged over gas utilities in canton
Gas price industry	132	6.95	1.2	4	9.24	CHF Rp./kWh (excl. VAT); Swiss price supervisor; weighted mean of typical total prices for firms with consumptions of 0.5, 1.163, 11.63, 116.3, 250 GWh/a based on differently sized industry sites in canton and averaged over gas utilities in canton
Gas price services	132	6.66	1.02	4.25	9.14	CHF Rp./kWh (excl. VAT); Swiss price supervisor; weighted mean of typical total prices for firms with consumptions of 500 MWh/a and 1163 MWh/a based on differently sized services sites in canton and averaged over gas utilities in canton
Gas price (annual mean)	6	26.97	4.4	21.14	33.19	CHF/MWh; EEX: TTF Daily Reference Price

Variable	Effective Obs.	Mean	Std. Dev.	Min	Max	Unit, Source, Notes
Demand shifters						
Inhabitants	156	314.85702	329.40438	15.717	1487.969	in 1000; Federal Statistical Office
Share of residents aged 65 years and above	156	0.18	0.02	0.14	0.22	Federal Statistical Office
Income	156	7732.04	1692.67	5713.13	15472.92	CHF; Federal Department of Finance
Unemployment rate	156	2.68	1.25	0.77	5.81	%; Federal Statistical Office
Houses with heat pumps	156	7124.87	7582.82	63	31403	Federal Statistical Office
Houses with gas heating	138	11533.55	11361	105	50596	Federal Statistical Office
Houses with electric heating	156	6358.96	7817.31	224	29090	Federal Statistical Office
Heating degree days	156	3281.64	520.94	2066	4852	MeteoSwiss; 12°C base temperature
Sites industry	156	3469.9	3170.04	285	12821	Federal Statistical Office
Employees industry	156	36188.35	31418.02	2267	122323.8	Federal Statistical Office
Sites services	156	19332.84	20404.69	1004	99307	Federal Statistical Office
Employees services	156	106668.62	132090.36	3119.6	638347.6	Federal Statistical Office
Swiss industry production	6	99.86	1.48	97.78	102.05	2015 = 100; Federal Statistical Office
Gross value added	156	23941.06	27964.1	870.06	136332.24	CHF; Federal Statistical Office

Notes: Monetary values in constant 2015 CHF. Effective observations show how many individual values are available for cantons over the years 2011-2016. Variables with only 6 observations indicate yearly availability. Gas-related variables can have less observations than electricity-related ones because not all cantons are connected to the gas infrastructure. Household consumption figures are subject to the availability of dwelling-size information (missing in 2011).

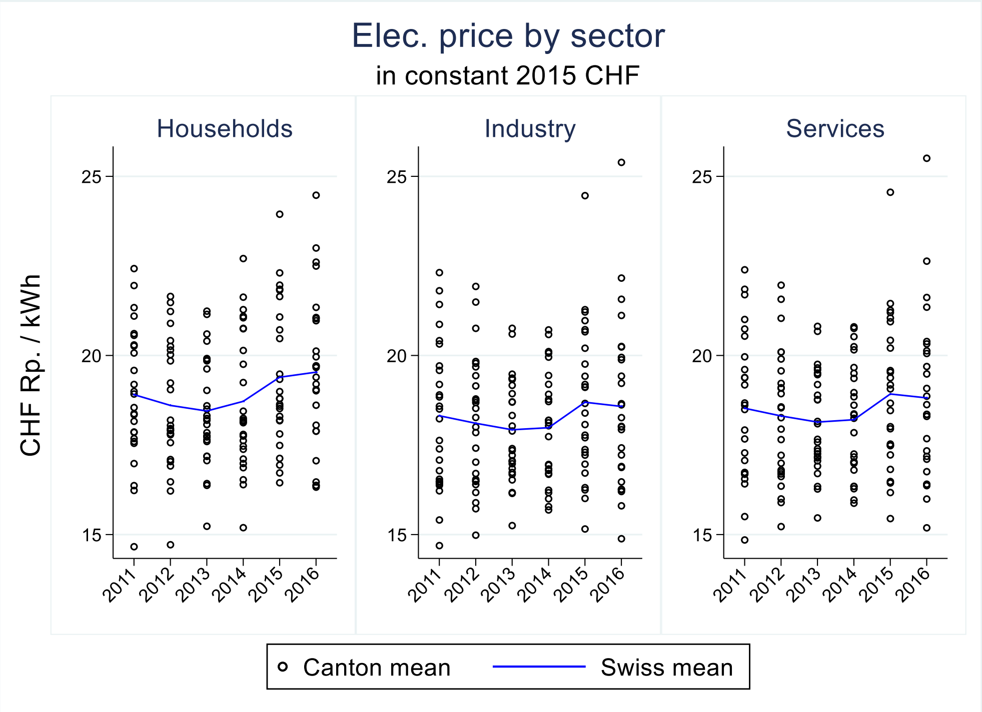

Figure 7: Electricity price by sector (yearly)

Source: ElCom, own calculation

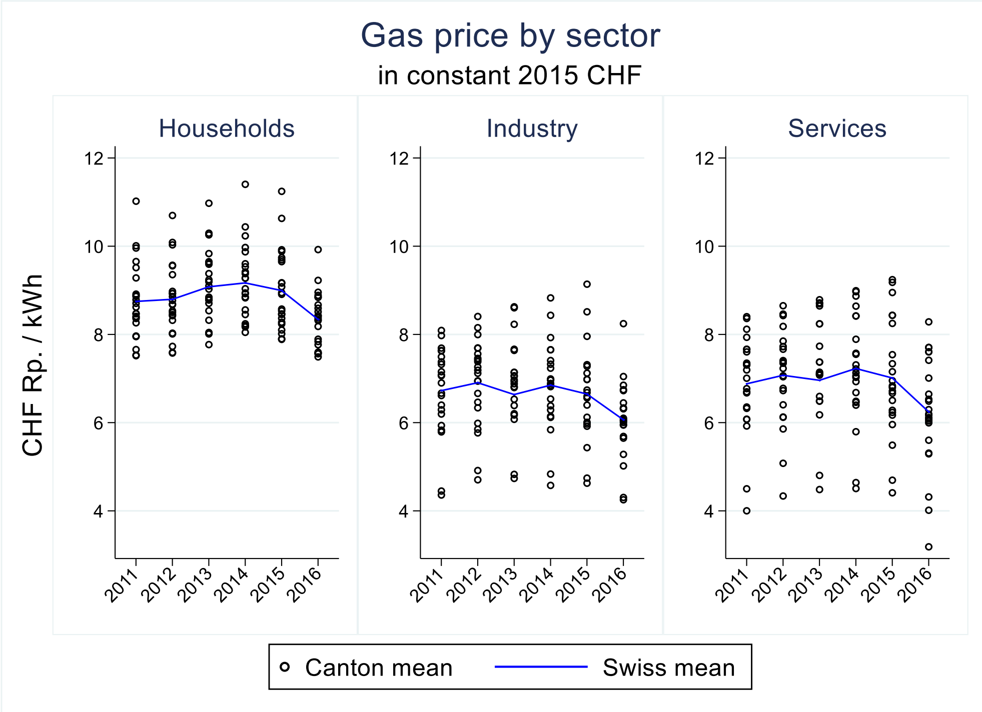

Figure 8: Gas price by sector (yearly)

Source: Swiss price supervisor, own calculation

Turning to the hourly analysis, data availability restricts the focus to electricity only. The Swiss transmission system operator Swissgrid provides canton-level information on consumption with an hourly resolution since 2015. Yet, there are two caveats. On the one hand, Swissgrid aggregates data of certain cantons to prevent inference to single grid operators (e.g. Zurich and Schaffhausen). On the other hand, canton-level information is only provided as total energy consumption, i.e. including losses and not solely energy consumed by end users. Both caveats can be handled with. Focusing on combined cantons does not restrict statistical analyses of inference but only restricts detail, whereas losses can be captured with the help of (time) fixed effects.

The first panel of Table 3 provides summary statistics on hourly consumption in the cantons. 18 combined cantons and two years provide more than 300,000 hours for our analysis. Figure 9 provides an overview of consumption by canton. Obviously, Schaffhausen and Zurich, Bern and Jura, and Geneva and Vaud are characterized by higher consumption levels than the other cantons. In the hourly analysis, we focus on the price sensitivity of customers that are able to purchase their electricity at the spot market. Given the partly liberalized Swiss electricity market this comprises customers with annual consumptions of more than 100 MWh. However, only the largest customers opt for such electricity procurement or have contracts based on spot prices; smaller customers rather choose individual contracts with suppliers that foresee fixed prices while being independent from offers of the local electricity utility. To focus on flexible customers, we net out inflexible demand with the help of time dummies and employ the Swiss electricity spot price as reference for all cantons. Figure 10 shows the development of the Swiss day-ahead spot price taken from the ENTSO-E Transparency Platform. The spot prices shows a seasonal pattern with higher prices in the winter months reaching up to 130 CHF/MWh.

Table 3: Summary statistics (hourly) (continued on next page)

Variable	Eff. Obs.	Mean	Std. Dev.	Min	Max	Unit, Source, Notes
Price and Consumption						
Elec. price CH (day-ahead spot price)	17544	44.15	14.99	-5.95	130.02	CHF/MWh; ENTSO-E
Elec. consumption	315792	0.38	0.31	0.02	1.64	GWh; Swissgrid
Demand shifters						
Temperature	315792	9.25	7.85	-16.56	36.9	°C; MeteoSwiss; canton average
Sunshine duration	315792	11.61	20.62	0	60	min; MeteoSwiss canton average
Sites (agriculture)	18	3102.39	2682.85	395	12351	Federal Statistical Office; yearly values; comprises agriculture, forestry and fishing
Sites (manufacturing)	18	5178.5	3933.25	571	13964	Federal Statistical Office; yearly values; comprises manufacturing, mining and quarrying, construction
Sites (other)	18	5927.78	6002.47	467	22103	Federal Statistical Office; yearly values; comprises electricity, gas, steam and air conditioning supply, water supply, sewerage, waste management and remediation activities, education, human health and social work activities
Sites (trade)	18	9516.44	8414.96	844	31887	Federal Statistical Office; yearly values; comprises wholesale and retail trade, transportation and storage, accommodation and food service activities, information and communication
Sites (financial services)	18	565.61	497.68	68	1758	Federal Statistical Office; yearly values; comprises financial and insurance activities
Sites (public administration)	18	479.11	370.56	38	1353	Federal Statistical Office; yearly values; comprises public administration
Gross value added (agriculture)	144	19.17	16.22	0.82	57.74	Federal Statistical Office; quarterly values; see composition above
Gross value added (manufacturing)	144	767.08	556.72	87.43	2001.86	Federal Statistical Office; quarterly values; see composition above
Gross value added (other)	144	262.02	239.68	25.53	840.67	Federal Statistical Office; quarterly values; see composition above
Gross value added (trade)	144	721.29	797.51	38.34	3219.18	Federal Statistical Office; quarterly values; see composition above
Gross value added (financial services)	144	315.5	589.27	11.89	2676.64	Federal Statistical Office; quarterly values; see composition above
Gross value added (public administration)	144	303.43	369.04	16.25	1228.01	Federal Statistical Office; quarterly values; see composition above

Variable	Eff. Obs.	Mean	Std. Dev.	Min	Max	Unit, Source, Notes
Supply shifters						
Net import situation	17544	0.66	0.47	0	1	ENTSO-E; dummy if CH is net-importing; based on day-ahead net transfer capacities at interconnectors
Congestion situation	17544	0.89	0.31	0	1	ENTSO-E; dummy if day-ahead spot price differential > 1 €/MWh between neighboring countries
Gas price (price-setting)	4655	18.24	3.79	11.41	25.54	CHF/MWh; EEX: TTF Daily Reference Price; only if techno-logy is price setting (in CH or neighboring country)
Coal price (price-setting)	3396	6.69	1.32	5.16	11.43	CHF/MWh; Datastream: EEX-COAL ARA Future; only if technology is price setting (in neighboring country when CH is net-importer)
Oil price (price-setting)	3198	27.12	4.97	15.97	36.1	CHF/MWh; Datastream: Crude Oil-Brent; only if technology is price setting (in neighboring country when CH is net-im-porter)
CH CO2 price (gas price-setting)	563	2.24	0.64	1.44	4.04	CHF/MWh; Datastream, ENTSO-E; only if technology is price setting (in CH)
EU CO2 price (gas price-setting)	4627	1.4	0.22	1	1.75	CHF/MWh; Datastream, ENTSO-E; ; only if technology is price setting (in neighboring country when CH is net-impor-ter)
EU CO2 price (coal price-setting)	3250	2.16	0.48	1.32	2.92	CHF/MWh; Datastream, ENTSO-E; only if technology is price setting (in neighboring country when CH is net-impor-ter)
EU CO2 price (oil price-setting)	3033	1.77	0.37	1.08	2.3	CHF/MWh; Datastream, ENTSO-E; only if technology is price setting (in neighboring country when CH is net-impor-ter)
CH market power situation	17544	0.11	0.31	0	1	ENTSO-E; dummy if the share of forecasted (day-ahead) load net of forecasted renewables generation on the available production of the remaining power generation plants is at least 90 percent
EU market power situation	17544	0.03	0.16	0	1	ENTSO-E; dummy if the share of forecasted (day-ahead) load net of forecasted renewables generation on the available production of the remaining power generation plants is at least 90 percent

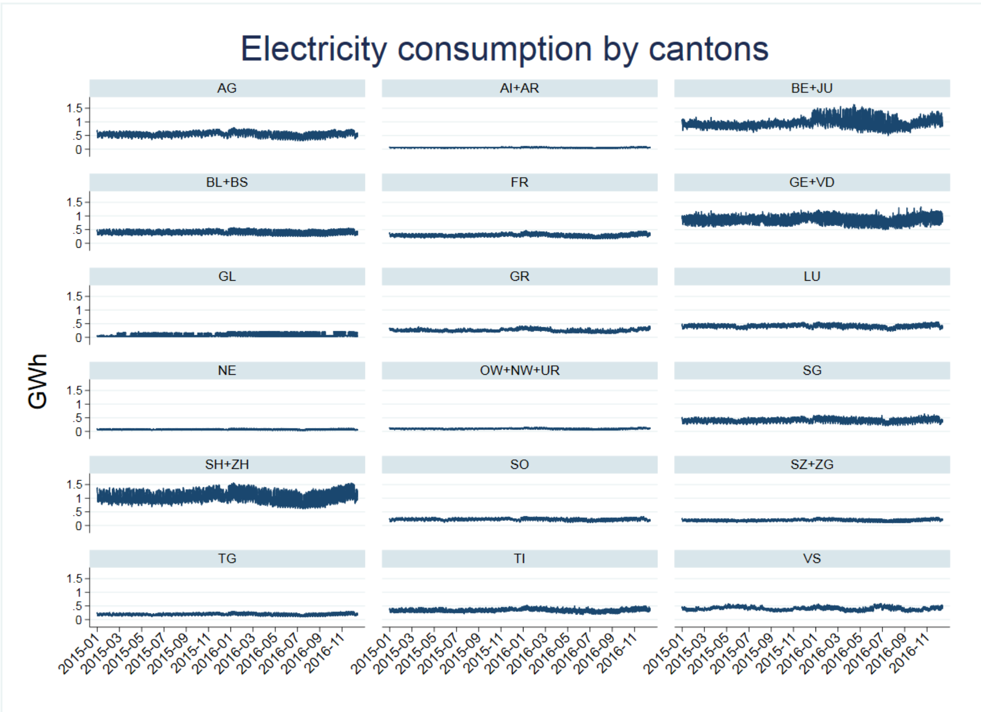

Figure 9: Electricity consumption by canton (hourly)

Source: Swissgrid

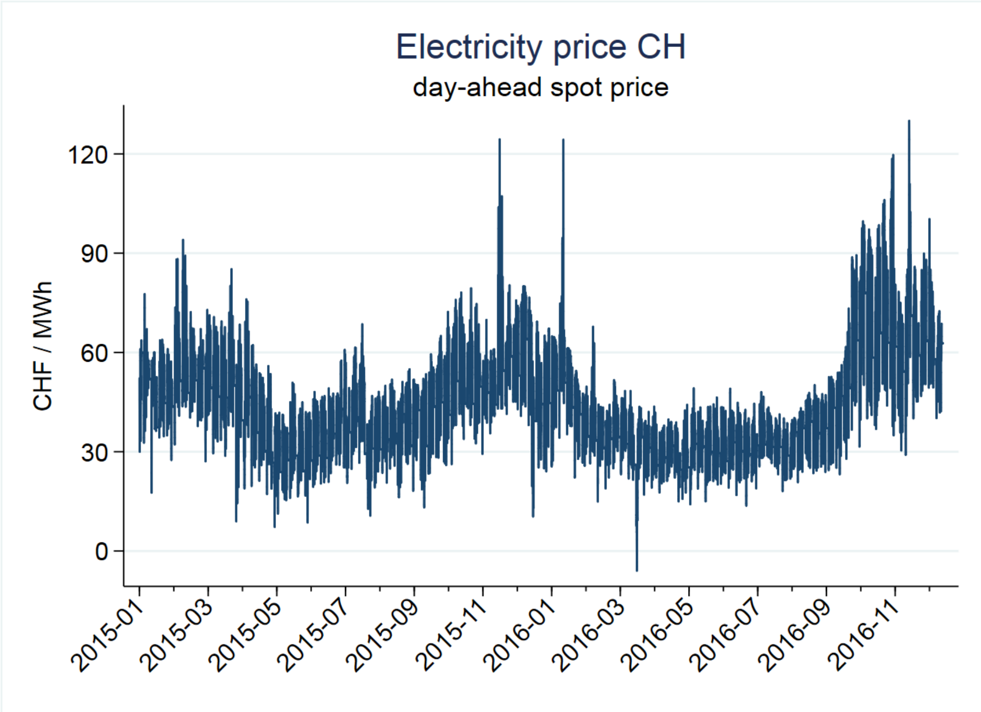

Figure 10: Electricity price in Switzerland (hourly)

Source: ENTSO-E Transparency Platform

As control variables for demand we consider the number of sites (yearly values) interacted with quarterly information on gross value added by different economic activities as depicted in the second panel of Table 3. In addition, we employ weather information. We include temperatures (and their squares), and sunshine duration to capture different situations of electricity demand for lighting and cooling or heating.

Regarding the supply shifters used to explain Swiss spot prices, we consider commodity and carbon prices in situations when the respective technologies are price setting – differentiated by states of net import, congestion and market power. The third panel of Table 3 provides summary statistics. In the years 2015 and 2016, Switzerland was net importing electricity in about two thirds of total hours.[15] In nearly about 89 percent of hours there was at least one congestion situation at the Swiss-French or Swiss-German/Austrian border as measured by price differentials being greater than 1 EUR/MWh (following Heim et al, 2017).[16]

Gas-fired electricity generation plants were price setting in 4655 hours (i.e. about 27 percent) with an average gas price of 18 CHF/MWh.[17] This only comprises situations in which Swiss plants are price-

[15] Net-import status is computed using day-ahead net transfer capacities. Although not relying on realized flows, this is internally consistent with the focus on day-ahead spot prices. Merit-orders for the individual hours are also built on the basis of previous-day information.
[16] In our specification we only consider cases of price-setting technologies in France and Germany/Austria. That is, we disregard Italy for reasons of model parsimony since there are relatively few cases in which Switzerland is a net-importer and also relies on Italian gas-fired plants; transfer capacities to Switzerland are also low.
[17] Prices in euro are converted in CHF to account for exchange rate risks.

setting or when there is a net-import situation and gas plants are price setting in France or in the German/Austrian bidding zone and these plants are more expensive than Swiss plants (given carbon prices and market power). In the same manner coal-fired and oil-fired plants were price setting in 19 and 18 percent, respectively. Both technologies are always located outside Switzerland.

The Swiss electricity generation portfolio is characterized by large capacities of hydro-related and nuclear plants (cf. stylized[18] merit order in Figure A-5 in the appendix). Still, Switzerland possesses small capacities of gas-fired plants (75 MW in 2016 (SFOE, 2014)). This comprises, e.g., the combined cycle power plant Monthey (57 MW), which takes part in the Swiss emission trading scheme (CH-ETS) for companies. Therefore, we also account for Swiss carbon prices when Swiss gas plants are price-setting. This, however, only concerns about 3 percent of hours. In contrast, European carbon prices are relevant whenever a fossil-fuel fired plant is price setting in a neighboring country and Switzerland imports from there. For gas this concerns about one quarter of the time (coal: 19%, oil: 17%). In any case carbon prices are measured at MWh level (i.e. converted from a ton of CO2 basis). Therefore, coal exhibits on average higher carbon prices than gas or oil. Swiss carbon prices are generally higher although there is a convergence to European prices at the end of the observation period (see Figure 11). Between 2015 and 2016 the auction price for a ton of CO2 dropped from 20 to 7.15 CHF. The European carbon prices ranges between 4 and 9 euro in the observation period. (Yet, in the meanwhile it peaked at 27 euro in April 2019.)

Moreover, we account for situations of market power in the different countries. We expect a situation of market power if the share of forecasted (day-ahead) load net of forecasted renewables generation on the available production of the remaining power generation plants is at least 90 percent. This involves about 11 percent of total hours in Switzerland and 3 percent in France and the German/Austrian bidding zone.

[18] The depicted merit orders are based on artificial commodity prices. When computing the merit orders used to identify price-setting cases in the respective hours we employ actual commodity prices.

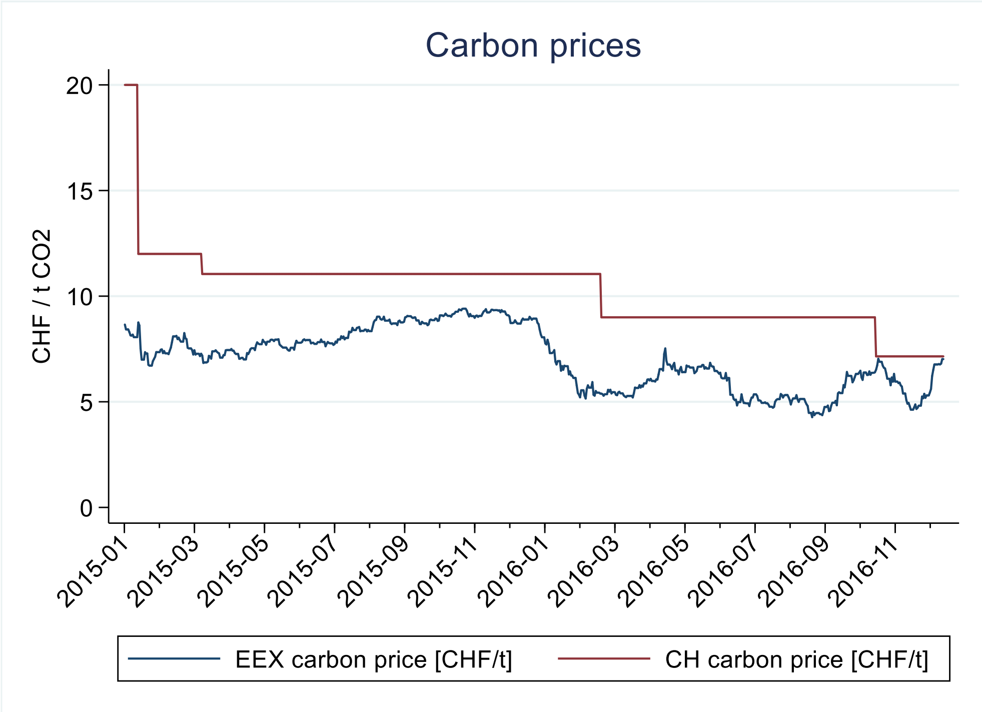

Figure 11: Carbon prices

Sources: EEX, SFOE

Finally turning to the monthly analysis, our dataset is less comprehensive. Monthly consumption data is also taken from Swissgrid, who kindly provided us with monthly average data dating back to 2011. As for the hourly case, the data comprises total energy consumption of aggregated cantons. We therefore can only rely on 72 observations (6 years and 18 combined cantons). Figure 12 shows the development at the canton level. Besides the known level differences, seasonal patterns with increased consumption in winter are visible. Similar to the hourly analysis, we cannot reliably distinguish the sectors' consumption and analyze the aggregated demand attributing price reactions to more flexible users. We thus also employ the Swiss electricity spot price (as monthly mean). Figure 13 plots the development showing seasonality and a decreasing trend. Summary statistics are presented in Table 4.

Table 4 also entails information on the excluded instrument (spot prices in the German/Austrian bidding zone as the strongest determinant of Swiss prices given unavailability of price-setting commodity information, which is only available since 2015 from ENTSO-E). As control variables we employ temperatures (and their squares) as well as interactions of industry sites and gross value added next to the number of houses with electric heating to proxy demand while maintaining a parsimonious number of variables given the small sample size.

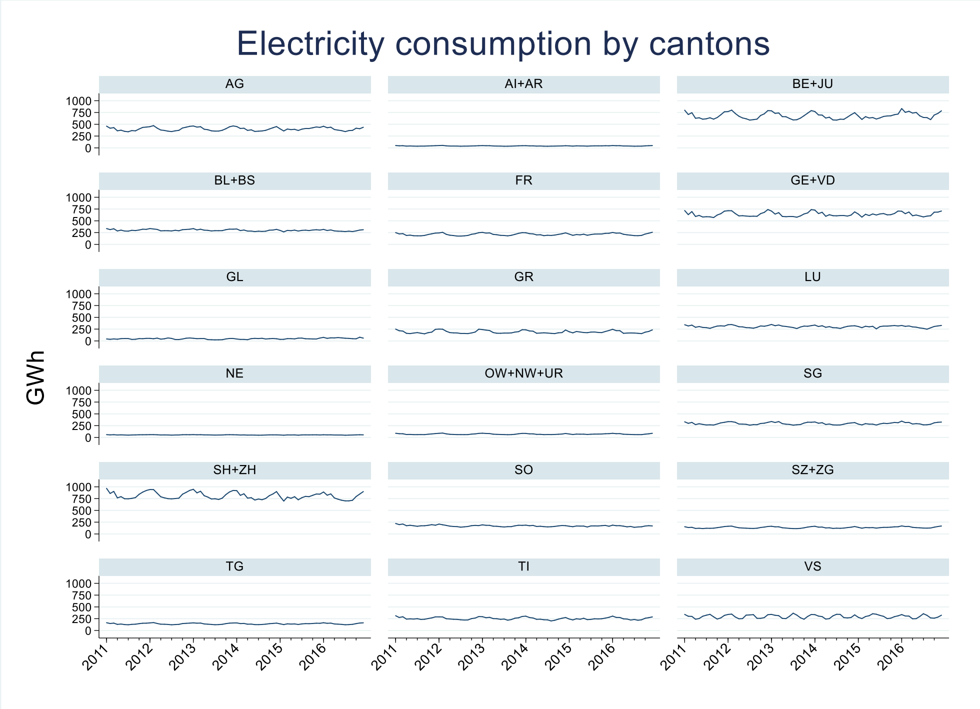

Figure 12: Electricity consumption by canton (monthly)

Source: Swissgrid

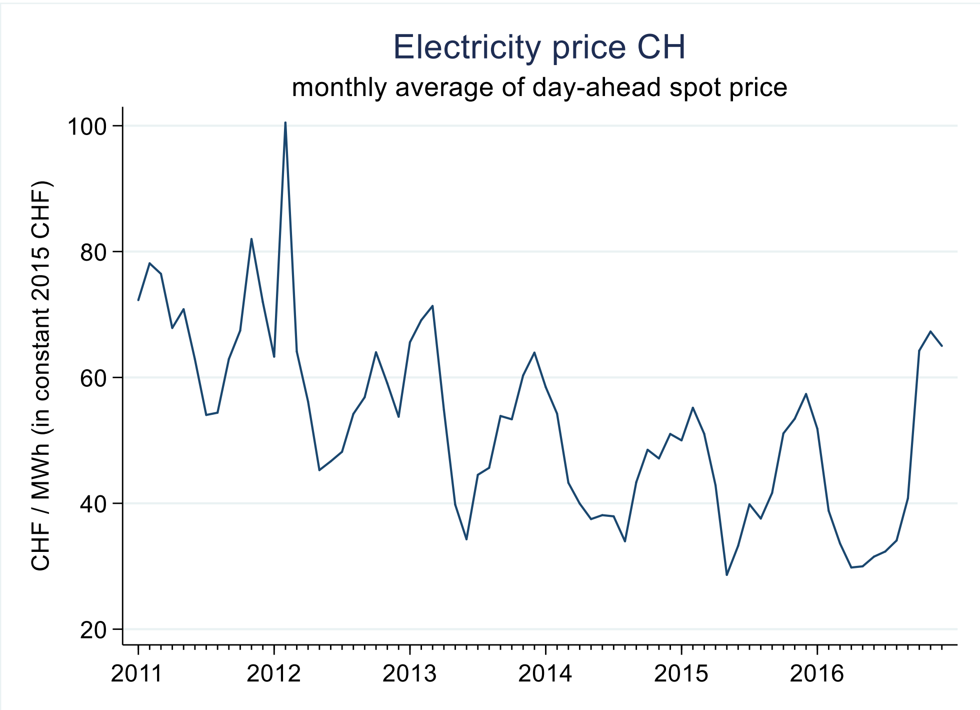

Figure 13: Electricity price in Switzerland (monthly)

Source: epex spot

Table 4: Summary statistics (monthly)

Variable	Effective Obs.	Mean	Std. Dev.	Min	Max	Unit, Source, Notes
Elec. price CH (monthly mean)	72	52.57	14.41	28.63	100.51	CHF/MWh; epex spot: day-ahead spot price
Elec. price AT/DE (monthly mean)	72	44.49	11.22	26.35	69.41	CHF/MWh; epex spot: day-ahead spot price in German/Austrian bidding zone
Elec. consumption	1296	280.56	220.6	23.21	967.38	GWh; Swissgrid
Temperature (monthly mean)	1224	9.09	6.59	-7.14	23.2	°C; MeteoSwiss
Sites industry	108	5012.07	3749.57	550	13758	Federal Statistical Office; yearly values
Gross value added (manufac-turing)	432	738.97	536.05	85.47	2009	CHF; Federal Statistical Office; quarterly va-lues
Houses with electric heating	108	9185.17	8556.74	860	29090	Federal Statistical Office; yearly values

Notes: Monetary values in constant 2015 CHF. Effective observations show how many individual values are available for cantons over the years 2011-2016.

4 Results

In this section we describe and discuss our estimation results and provide robustness checks.

4.1 Yearly results

In the following we dwell on results regarding electricity consumption of households, industry and services. We subsequently turn to gas consumption results.

Table 5 presents the results of our estimation regarding annual electricity consumption of households. We provide OLS results as well as IV-GMM results to highlight differences arising from a possible endogeneity of prices (but only consider the unbiased IV results for interpretation in any case).[19] The comparison of OLS and IV-GMM suggests a possible endogeneity bias indicated by the diverging coefficients. The quality of the excluded instrument (lagged annual average of the spot price in the German/Austrian bidding zone) is acceptable passing the weak ID test. The overall fit of the model is also strong indicated by a relatively high R^2. Still, the results do not indicate any statistically significant price elasticity (i.e. the coefficient of the (logged) price is not different from 0 at any conventional statistical significance level (as indicated by the low t statistic)). In contrast, the price coefficient also shows a counter-intuitive sign.

The other control variables instead show the expected signs in case they are statistically significant. More residents imply higher electricity consumption (a 1 percent increase in the number of resident increases electricity consumption by 0.85 percent). The same holds true for the unemployment rate as residents then have higher present times at home. In addition, more heating degree days and more houses with electric heating systems increase electricity consumption (yet, to a lesser extent than the respective variables in the gas analysis). An increased presence of houses with heat pumps decreases electricity consumption. This seems unusual at first sight but might be explained by a greater ecological awareness of owners who might either have a generally or energy-efficient renovation-related reduced electricity consumption, or might also rely on renewable energy sources fueling the heat pump. In contrast to gas consumption, we find a positive trend suggesting the increased deployment of more electric gadget (as e.g. electric vehicles).

[19] As prices are a function of supply and demand, a simple regression of quantity on prices and demand-side related explanatory variables might lead to biased parameter estimates. Instrumenting equilibrium prices with supply-side related variables (i.e. commodity prices) helps to circumvent the correlation between equilibrium prices and demand variables.

Table 5: Estimation results – yearly, electricity, households

Dependent variable:	**OLS**		**IV-GMM**	
Log electricity consumption of household sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	0.063	[1.47]	0.200	[1.63]
Log residents	0.648**	[2.42]	0.851***	[2.71]
Log share of residents aged 65 years and above	-0.527*	[-1.72]	-0.418	[-1.37]
Log income	0.010	[0.61]	0.015	[0.73]
Log unemployment rate	0.079**	[2.46]	0.070***	[3.09]
Log houses with heat pumps	-0.075	[-1.68]	-0.073**	[-1.99]
Log houses with electric heating	0.571***	[4.01]	0.576***	[4.26]
Log heating degree days	0.116***	[5.52]	0.116***	[5.22]
Trend	0.017***	[2.83]	0.012*	[1.73]
Obs.	130		130	
R^2 (within)	0.76		0.73	
First Stage F-Test (Price)	-		10.03	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic exceeds the weak ID critical values from Stock-Yogo (15%: 8.96) suggesting that price is identified by the instrument (lagged price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table 6 contains the results for the industry sector. The comparison of OLS and IV-GMM results also indicates an endogeneity bias. This especially concerns the price coefficient which turns more negative while still being statistically insignificant (even though the IV quality is acceptable). In contrast, all control variables are significant. Increased numbers of industry sites and employees increase consumption (the negative interaction indicates that there is a diminishing effect of more employees given a certain number of sites). Industry consumption is also depending on economic activity as well as heating degree days indicating the multi-purpose use of electricity in this sector. In contrast to the household sector, we find a negative trend suggesting, e.g., an increased deployment of economic technologies.

In Table 7 we show results for the services sector. We also find an endogeneity bias which results in a negative price coefficient which turns out to be statistically significant (yet, only at the 10 percent significance level; the IV quality is also acceptable for identification). This implies that the services sector has a somewhat price elastic electricity demand. A price increase of one percent implies a demand reduction of 0.187 percent, which however is relatively low. The remaining control variables also show expected signs with comparable implications as in the industry sector. Noteworthy, there is no dependency on the economic development and also no time trend while consumption is also affected by heating degree days suggesting the importance of electricity as a means for heating (yet at a low magnitude).

All in all, there seems to be an indication that only the services sector has a weakly price sensitive electricity demand. For robustness checks we also repeat the analyses using consumption figures derived from the original methodology of Eymann et al. (2014). Table A-4 and Table A-5 in the appendix provide the IV-GMM results for the respective sectors. Regarding the industry and services sector we obtain comparable results; yet, there are no significant price effects. Regarding the household sector, we obtain a statistically significantly negative price coefficient indicating a price elasticity of -0.177. This finding might be due to the neglected consumption related to (water) heating in Eymann et al. (2014). In addition, we check robustness with respect to a different consideration of the share of electric heating. We repeat our analyses using the lower and upper bound of the range suggested by the literature (Nipkow and Togni, 2009). The coefficients of our initial results (Table 5) are placed in the middle in terms of effects suggesting that a more pronounced consideration of heating consumption reduces price-sensitivity of electricity demand. It is therefore important to rely on authentic figures regarding heating demand when investigating electricity demand. Accordingly, we favor the results of our derivation over those using the method of Eymann et al. (2014) even though this implies an indication of rather price inelastic electricity demand of households.

Table 6: Estimation results – yearly, electricity, industry

Dependent variable:	**OLS**		**IV-GMM**	
Log electricity consumption of industry sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	-0.036	[-0.19]	-0.077	[-0.26]
Log sites	3.637**	[2.26]	3.580**	[2.20]
Log sites * log employees	-0.381**	[-2.60]	-0.377***	[-2.58]
Log employees	2.687**	[2.55]	2.661**	[2.44]
Log gross value added	1.196**	[2.30]	1.162***	[2.66]
Log heating degree days	0.073**	[2.54]	0.071**	[2.46]
Trend	-0.036***	[-2.87]	-0.035***	[-3.39]
Obs.	156		156	
R^2 (within)	0.38		0.38	
First Stage F-Test (Price)	-		7.04	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic exceeds the weak ID critical values from Stock-Yogo (20%: 6.66) suggesting that price is identified by the instrument (lagged price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table 7: Estimation results – yearly, electricity, services

Dependent variable:	**OLS**		**IV-GMM**	
Log electricity consumption of services sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	0.032	[0.88]	-0.187*	[-1.66]
Log sites	1.752***	[3.48]	1.721***	[3.19]
Log sites * log employees	-0.154***	[-4.10]	-0.159***	[-3.92]
Log employees	2.715***	[6.70]	2.525***	[5.86]
Log gross value added	-0.098	[-0.47]	-0.136	[-0.68]
Log heating degree days	0.139***	[9.13]	0.122***	[6.47]
Trend	-0.016***	[-3.95]	-0.009	[-1.64]
Obs.	156		156	
R^2 (within)	0.57		0.47	
First Stage F-Test (Price)	-		6.74	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic does not exceed the weak ID critical values from Stock-Yogo (20%: 6.66) suggesting that price is only weakly identified by the instrument (lagged price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Turning to gas consumption, Table 8 presents the results of our estimation regarding annual gas consumption of households. We provide OLS results as well as IV-GMM results to highlight differences arising from a possible endogeneity of prices (but only consider the unbiased IV results for interpretation in any case). Obviously, the bias due to endogeneity is not very strong as the estimated parameters are fairly comparable across methods. The overall fit of the model is strong indicated by a high R^2. The F-statistic of the first-stage regression (i.e. basically regressing price on instruments) is also high exceeding the weak ID critical values from Stock-Yogo suggesting that price is identified by the excluded instruments (lagged TTF gas prices).

Despite these good prerequisites, we do not find any indication of elastic demand. The coefficient of the (logged) price variable is not statistically significantly different from 0 at the usual statistical significance levels (as indicated by the low t statistics). Counter-intuitively, it even has a positive sign while a negative sign would naturally be expected (implying a reduced consumption when prices rise).

All other variables show expected signs though. Gas demand of households increases with higher population (a 1 percent increase in the number of resident increases gas consumption by 0.64 percent). More heating degree days as well as a higher number of houses with gas heating also increase demand (elasticities of about 0.9% in both cases). A higher number of houses with heat pumps instead decreases consumption as these users are less reliant on gas. We also observe a negative trend implying a general decrease of household consumption given that we control for other demand shifters. In contrast to these statistically significant coefficients, we do not find statistically significant effects for the share of older residents, income and unemployment rate although their coefficients show the expected positive sign.

We take from these results that Swiss households do not seem to react to gas prices and consume depending on external influences such as temperatures. Yet, this does not provide strong evidence for inelastic demand given the rather small sample size.

Table 8: Estimation results – yearly, gas, households

Dependent variable:	**OLS**		**IV-GMM**	
Log gas consumption of household sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	0.094	[1.42]	0.065	[0.93]
Log residents	0.625**	[2.31]	0.637**	[2.40]
Log share of residents aged 65 years and above	0.023	[0.14]	0.028	[0.18]
Log income	0.048	[0.37]	0.054	[0.44]
Log unemployment rate	0.032	[0.78]	0.031	[0.77]
Log houses with heat pumps	-0.091***	[-3.67]	-0.092***	[-3.84]
Log houses with gas heating	0.868***	[22.37]	0.866***	[23.37]
Log heating degree days	0.895***	[28.24]	0.890***	[36.60]
Trend	-0.011***	[-3.65]	-0.012***	[-4.12]
Obs.	115		115	
R^2 (within)	0.97		0.97	
First Stage F-Test (Price)	-		76.00	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic exceeds the weak ID critical values from Stock-Yogo (10%: 19.93) suggesting that price is identified by the instrument (lagged gas prices). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table 9 contains the results for the industry sector. Obviously, the endogeneity bias is stronger as the price coefficient turns negative when conducting IV-GMM estimation. Still, despite showing the expected sign (and a good model quality as measured by R^2 and first stage F) the coefficient is not statistically significant either. We only find statistically significant impacts of gross value added and industry production suggesting that industry gas consumption is largely driven by economic development and hardly sensitive to prices. Although a decreasing trend is suggested by the negative coefficient of the respective variable, it is not statistically significant either.

In Table 10 we find similar results for the services sector. The price coefficient is slightly negative but not statistically significant when accounting for endogeneity. In contrast to the industry sector, the services sector is not sensitive to economic development but rather statistically significantly influenced by heating degree days and the number of employees highlighting the importance of gas for heating purposes in this sector. However, regarding the model quality we note that the F-statistic of the first-stage regression is quite low suggesting that the identification of price by means of excluded instruments is rather poor, which can still result in a biased price coefficient.

While these results do not suggest any price elastic consumption of all sectors, they are all based on the derived canton-level consumption figures by sector. In order to check robustness we repeat the analyses using consumption figures derived from the original methodology of Eymann et al. (2014). Table A-6 and Table A-7 in the appendix provide the IV-GMM results for the respective sectors. We obtain comparable results in terms of the coefficients' magnitude and significance. However, this also entails statistically insignificant price coefficients.

Table 9: Estimation results – yearly, gas, industry

Dependent variable:	**OLS**		**IV-GMM**	
Log gas consumption of industry sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	0.001	[0.02]	-0.090	[-1.35]
Log sites	0.213	[0.22]	0.707	[0.72]
Log sites * log employees	-0.041	[-0.35]	-0.125	[-1.08]
Log employees	0.019	[0.02]	0.663	[0.58]
Log gross value added	1.099**	[2.47]	1.335***	[3.75]
Log Swiss industry production	2.964***	[6.97]	2.394***	[6.62]
Trend	-0.001	[-0.05]	-0.007	[-0.93]
Obs.	132		132	
R^2 (within)	0.70		0.69	
First Stage F-Test (Price)	-		19.22	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic exceeds the weak ID critical values from Stock-Yogo (15%: 11.59) suggesting that price is identified by the instrument (lagged price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table 10: Estimation results – yearly, gas, services

Dependent variable:	**OLS**		**IV-GMM**	
Log gas consumption of services sector	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	0.030	[0.60]	-0.098	[-0.69]
Log sites	0.839	[0.83]	0.445	[0.34]
Log sites * log employees	-0.087	[-1.21]	-0.076	[-0.84]
Log employees	2.935***	[3.87]	4.159***	[4.91]
Log gross value added	0.396	[1.02]	-0.23	[-0.57]
Log heating degree days	0.999***	[30.57]	0.861***	[13.17]
Trend	0.013	[1.37]	-0.007	[-0.56]
Obs.	132		132	
R^2 (within)	0.88		0.79	
First Stage F-Test (Price)	-		3.94	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic does not exceed the weak ID critical values from Stock-Yogo (25%: 7.25) suggesting that price is only weakly identified by the instrument (lagged gas prices). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

4.2 Hourly results

In contrast to the yearly analyses, the focus on an hourly resolution provides more observations that can be used to derive canton-level elasticities. (In the yearly analysis we only estimated nationwide elasticities.) However, the hourly analyses are based on aggregate consumption of all sectors in the respective cantons. A separate investigation of sectoral consumption is not possible without very strong behavioral assumptions. We therefore focus on aggregate consumption at the canton level and account for inflexible consumption with the help of time dummies and control variables.

Table 11 presents the results of our three-stage least squares estimation of the system of equations comprising a consumption equation for each canton (group) as well as a price equation to account for endogeneity. Thereby we only depict the price coefficients and do not report the control variables of the consumption equations. (They include sunshine duration, temperatures and their squares, interactions of the yearly number of plants in different branches and the respective quarterly gross value added, interaction of number of residents and an off-peak dummy, at the canton-level as well as month, day, hour and day-hour dummies, which are in most cases highly significant and thus effectively controlling for demand of rather inflexible users.)

For most cantons we obtain statistically significant price coefficients indicating price elasticities of demand in ranges from -0.5 to -0.07. Thereby we treat all statistically insignificant coefficients as 0 implying inelastic demand. We also obtain a statistically significant positive coefficient for the canton Glarus. Glarus, however, represents the smallest non-grouped canton in terms of population so that this result does not appear trustworthy and will hence be disregarded and treated as inelastic. Further analyses based on these price elasticities are conducted in section 5.

Table 11: Estimation results – hourly, electricity (canton consumption equations) – congestion distinction

Canton:	AG	AI + AR	BE + JU	BL + BS	FR	GE + VD	GL	GR	LU
Log price	-0.405***	-0.378***	-0.018	-0.433***	-0.369***	-0.230***	0.553***	-0.066***	-0.177***
	[-34.14]	[-25.23]	[-1.29]	[-29.85]	[-27.87]	[-13.98]	[7.29]	[-3.73]	[-13.85]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.11	0.22	0.37	0.07	0.29	0.20	0.19	0.53	0.35

Canton:	NE	OW+NW+UR	SG	SH + ZH	SO	SZ + ZG	TG	TI	VS
Log price	-0.494***	-0.494***	-0.301***	-0.308***	-0.422***	-0.307***	-0.397***	-0.451***	-0.298***
	[-26.10]	[-26.10]	[-20.75]	[-17.75]	[-30.01]	[-17.92]	[-28.69]	[-29.87]	[-18.70]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.07	0.42	0.12	0.16	0.14	0.29	0.15	0.24	0.55

Notes: 3SLS results of system of equations with bootstrapped standard errors (100 repetitions). t statistics in brackets. Control variables (not reported): sunshine duration, temperatures and their squares, interactions of the yearly number of plants in different branches and the respective quarterly gross value added, interaction of number of residents and an off-peak dummy, month, day, hour and day-hour dummies. *,**,***: significant at 10%, 5% and 1% respectively.

The estimation of the equation-system also entails the price equation. We present the estimated parameters in Table 12. The model fit is strong (high R^2) which is also due to the inclusion of time dummies (not reported and highly significant). Most coefficients are significant and show the expected signs. When Switzerland is net-importing the Swiss electricity spot price is, on average, increased by 14 percent (=*(exp(0.134)-1)*100*). Whenever there is a congestion situation,[20] prices are also, on average, increased by about 37 percent (=*(exp(0.316)-1)*100*). Commodity prices also affect the Swiss electricity price. Increases of gas and oil prices of one percent entail electricity price increases by about 0.02 percent, respectively, while coal price have no significant effect. The effects are indeed small which can be attributed to the special situation of Switzerland. These technologies are mostly employed in neighboring countries and thus mainly affect the Swiss electricity prices in net-import situations. These situations thus entail implicit effects so that commodity price increases are not fully arriving in Switzerland. A direct effect would be anticipated for the gas price when gas plants are price setting in Switzerland, this however only comprises very few situations (3 percent of total hours). Regarding coal, the insignificance could also be explained by coal being a relatively cheap technology so that importing coal-driven electricity usually also entails lower prices.

The indirectness of effects due to import situations is also relevant for carbon prices. In contrast to commodity prices, we decided to make the effects explicit by distinguishing the respective states of congestion and market power as the carbon price effects are important for subsequent analyses.[21] Regarding Swiss carbon prices, we find that in cases of market power the pass through of price increases is higher than in more competitive cases (0.27 in contrast to 0.17; a coefficient of 1 would imply that a 1% increase in Swiss carbon prices would translate into a Swiss electricity price increase by

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[20] Congestion situations are defined as hours in which the price differentials at the Swiss-French or Swiss-German/Austrian border are greater than 1 EUR/MWh (following Heim et al, 2017).

[21] We also applied the distinction to commodity prices. As we did not obtain very different elasticities and some states were characterized by multicollinearity we opted for the present specification. In Table A-8 and Table A-9 we present the results of a specification without congestion distinction showing that the coefficients and elasticities remain very similar.

1% suggesting a cost pass through of 100%). Yet, pass through is below the actual price increases (the coefficient should be greater than 1 otherwise) which could be due to the low gas capacity in Switzerland so that producers always have to bear in mind imports and generation by large hydro-related generation.

Regarding European carbon prices we also distinguish congestion situations. We do not expect certain effects in congestion situations as in such cases the indirectness is not only biased on imports but also biased by congestion rents. In contrast, in non-congested situations the effects should be directly effective. Remarkably, we always find that price increases are more strongly passed through in market power situations for any commodity. The only exception is coal in non-congested situations which again might be due to its relative cheapness. In congested situations we also find a weakly significant negative coefficient, which might be biased by congestion rents. The strongest pass through related to market power can be observed for gas price increases in non-congested situations. The respective coefficient of 0.89 is close to one.

For robustness checks we perform IV-GMM estimation implying to estimate equation by equation (with the supply side serving as excluded instruments). Results are provided in Table A-10. The respective elasticities are lower than from the 3SLS estimation (about half the size) and we also obtain positive values for cantons that were previously characterized by low or insignificant elasticities. This can be due to the neglected cross-equation correlation so that price effects are not fully captured. We therefore adhere to the 3SLS results and take from the IV-GMM results that a price elasticity is indeed present among the flexible users in the cantons.

Table 12: Estimation results – hourly, electricity (price equations) – congestion distinction

Dependent variable:	**3SLS**	
Log Price	**Coefficient**	**t Stat**
Net import	0.134***	[10.36]
Congestion situation	0.316***	[36.50]
Log gas price	0.015***	[3.04]
Log coal price	0.013	[1.20]
Log oil price	0.022***	[3.58]
Log CH CO2 price (gas) - no market power	0.170***	[7.85]
Log CH CO2 price (gas) - market power	0.270***	[5.17]
Log EU CO2 price (gas) - congestion - no market power	0.044	[0.46]
Log EU CO2 price (gas) - congestion - market power	0.575***	[5.10]
Log EU CO2 price (coal) - congestion - no market power	-0.090*	[-1.76]
Log EU CO2 price (coal) - congestion - market power	0.426***	[5.53]
Log EU CO2 price (oil) - congestion - no market power	-0.075	[-1.34]
Log EU CO2 price (oil) - congestion - market power	0.238**	[2.49]
Log EU CO2 price (gas) - no congestion - no market power	0.215***	[11.89]
Log EU CO2 price (gas) - no congestion - market power	0.889***	[5.06]
Log EU CO2 price (coal) - no congestion - no market power	0.007	[0.29]
Log EU CO2 price (coal) - no congestion - market power	0.148	[0.58]
Log EU CO2 price (oil) - no congestion - no market power	0.027	[0.96]
Log EU CO2 price (oil) - no congestion - market power	0.350***	[4.54]
Obs.	17420	
R^2	0.99	

Notes: 3SLS results of system of equations with bootstrapped standard errors (100 repetitions). Included calendar dummies for month, day, hour and day-hour (not reported). *,**,***: significant at 10%, 5% and 1% respectively.

4.3 Monthly results

Finally, we turn to the monthly analysis. We employ a comparable approach as in the hourly case and investigate aggregate consumption of all sectors in the respective cantons. Thereby we cannot rely on an as comprehensive model in terms of included variables as the sample only covers 72 month-canton observations. We thus do not expect much significance.

Table 13 presents the results from the monthly analysis depicting only the price coefficients of the consumption equations. While the model fit is individually good, we do not find significant price coefficients (while especially temperature and time dummies turn out to be significant). (We do not obtain results for the combined canton Appenzell Inner and Ausser Rhoden as temperatures are only available for two years.) The robustness check using IV-GMM estimation by equation does neither provide significant elasticities with a robust sign (Table A-11). Our results therefore hardly provide evidence for price elastic demand in cantons at the month level.

Table 13: Estimation results – monthly, electricity

Canton:	**AG**	**AI + AR**	**BE + JU**	**BL + BS**	**FR**	**GE + VD**	**GL**	**GR**	**LU**
Log price	-0.057	-	0.012	0.006	-0.034	-0.037	-0.095	-0.009	0.057
	[-1.21]	-	[0.24]	[0.20]	[-0.79]	[-0.93]	[-0.32]	[-0.13]	[1.33]
Obs.	72	-	72	72	72	72	72	72	72
R^2	0.82	-	0.78	0.80	0.84	0.78	0.41	0.87	0.77

Canton:	**NE**	**OW+NW+UR**	**SG**	**SH + ZH**	**SO**	**SZ + ZG**	**TG**	**TI**	**VS**
Log price	0.052	0.020	0.072	0.014	0.091	-0.012	0.027	0.026	-0.058
	[1.32]	[0.34]	[1.40]	[0.36]	[1.54]	[-0.20]	[0.61]	[0.52]	[-0.57]
Obs.	72	72	72	72	72	72	72	72	72
R^2	0.74	0.83	0.78	0.84	0.74	0.82	0.81	0.80	0.72

Notes: 3SLS results of system of equations with bootstrapped standard errors (100 repetitions). t statistics in brackets. Control variables (not reported): temperatures and their squares, interaction of industrial sites and quarterly industrial gross value added, number of houses with electric heating systems, month dummies, and time trend. *,**,***: significant at 10%, 5% and 1% respectively.

4.4 Discussion

Our statistically insignificant results on household demand are not supported by the literature. In particular for the electricity sector, other studies find a statistically and economically meaningful impact of prices on demand. This accounts for the long-run as well as the short-run. Mostly based on experimental field studies, in particular short-run elasticities are unlikely to be mirrored in our data representative for the whole of Switzerland, where no highly disaggregated metering is implemented up to the current date. Due to our short investigation period and little price movements caused by balancing decreasing electricity prices and increasing state levies, we are not able to find household electricity elasticities. In addition, compared to smaller samples typically used in the literature, we attribute much of the loss in precision to unobserved cross-sectional heterogeneity. The same holds for our household gas demand elasticity estimates. Whereas there is also substantial evidence for elastic demand in the literature, we have not been able to precisely estimate a price effect on demand.

Discussing the results found in the literature in greater detail, it has to be mentioned that most studies examining Swiss price elasticity of electricity demand focus on residential demand. In this realm, they rely on more disaggregate data at the household level (as opposed to our canton focus). For example, Filippini (2011) uses Swiss city-level data for the period 2000-2006 finding short-run own price elasticities between -0.7 (off-peak) and -0.9 (peak), and long-run values (i.e. accounting for a changeable capital stock of households) between -1.3 (off-peak) and -2.3 (peak). In a later study, Boogen et al. (2017) use aggregate electricity consumption data at the utility level from a survey and find short-run elasticities of -0.3 and long-run elasticity of -0.6. Bonomo et al. (1998) find short-run own price elasticities between -0.67 and -0.89, and between -0.59 and -0.9 for the long run. Similarly, their analysis is based on a smaller sample of 1054 observations of Swiss households of the years 1991 and 1992. Spierer (1988) finds a long-run elasticity of -0.5 for Swiss households based on the period 1960-1984. Dennerlein and Flaig (1987) find short-run elasticities between -0.2 and -0.4 for Swiss households based on the period 1975-1984, and between -0.4 and -0.6 for the long run. In an update of this study, Dennerlein (1990) finds a long-run elasticity of -0.7. Again, in two earlier studies Fillipini (1995a, 1995b) examines households of 21 (and 40) Swiss cities in 1987-1990 and finds short-run elasticities between -1.92 (peak) and -0.71 (off-peak) for Swiss households. This contrasts the findings by the same author (Fillipini 1999), who examines households of 40 Swiss cities in the period of 1987-1990 and finds short-run elasticities of approximately -0.3 for Swiss households controlling for two-part tariffs. Zweifel et al. (1997) find long-run elasticities between -0.25 and -0.4 for about 1300 Swiss households based on the period 1987 -1990.

With regard to household gas demand elasticities, authors typically find lower values which particularly holds for short-run elasticities. This is plausible given that in most cases major investments are necessary to reduce in particular heating demand. Demand reactions are visible rather in the longer term. Bernstein and Griffin (2005) find a short-run elasticity of -0.12 and a long-run elasticity of -0.36 of residential gas demand in the US. Asche et al. (2008) analyze the residential natural gas demand in 12 European countries during the period from 1978 to 2002. For Switzerland they find a short-run elasticity of -0.11 and a long-run elasticity of -0.76. Labandeira et al. (2017) conduct a meta-analysis and report an average short-run elasticity of -0.18 and a long-run elasticity of -0.68 based on 230 papers.

Regarding elasticities for industry electricity demand we were only able to find international evidence. Firms are found to have similarly low demand elasticities in the short-run. In the longer-run, elasticities are more heterogeneous and depend much on the flexibility of the firms' production technologies and options with regard to mobility. For example, Kamerschen and Porter (2004) find elasticities between -0.34 and -0.55 based on US firms. Also focusing on the US, Bernstein and Griffin (2005) find a short-run elasticity of -0.21 and a long-run elasticity of -0.97 while Paul et. al (2009) find short-run elasticities between -0.11 and -0.29, and between -0.16 and -0.4 for the long run. Bae (2009) additionally distinguishes between high-load consumers and finds that those that are more mobile (i.e. might change their sites) have a higher elasticity of -3.8 while less mobile ones have an elasticity of -1.27. Firms with lower load have an elasticity of -1.1. With regard to industry gas demand elasticities, we were not able to find any (representative) public studies.

Summing up, with regard to long-run electricity elasticities our results are clearly at the lower end for commercial customers with -0.19, with regard to all other demand elasticities, we were not able to find elasticities statistically significantly different from zero. Our short-run results for electricity demand are also somewhat in the lower range values found in the literature. In the hourly analysis, we found values between zero and -0.5 for the respective canton. This is valuable knowledge given the sparse evidence on current industry energy demand elasticities.

5 Application

The previous section did hardly indicate evidence for price-elastic electricity and gas demand in Switzerland at the year and month level. Still, this is does not imply that Swiss consumers are inelastic. Doubts on our results might be casted with regard to data quality and/or sample size. Typically, consumers are characterized by relative inert reactions to price changes at an annual level. Replacement rates of assets rather indicate reaction periods to market prices of several years, which raises issues of sufficient period length under study. On top of this, smaller customer segments are not fully liberalized yet and thus longitudinal price variation (price changes of their respective suppliers they cannot switch away from) might be insufficient to induce consumption reactions. Larger customers' indicative prices used in this study might not be representative for (unobservable) individually renegotiated prices. This raises a price measurement problem and corresponding inappropriately measured price-quantity elasticities. The only segment with weakly significant elastic reactions is commercial electricity. Due to these largely statistically insignificant price elasticities at the year and month level, we do not engage in a detailed analysis of policy effects. In case of totally inelastic demand any price-increasing policy (such as increased energy taxes) would not result in any demand reaction. While there would not be any steering effect, funding public expenditure would be possible without any distortions. However, this is highly unlikely with respect to energy demand, as the preceding discussion of the literature on energy demand elasticities has shown. Thus, in this study, we abstain from such conclusions and consider our yearly and monthly results as indicative for measurement problems and cannot derive definite conclusions about the appropriateness of measures based on data at the year and month level.

We therefore focus on the cantonal price elasticities of electricity demand derived from the hourly analysis. The previous section has revealed that price elasticities range from about -0.5 to -0.07. Thereby they rather capture the behavior of flexible, large customers. Smaller ones are more inelastic based on our previous findings.

To put these elasticities into perspective, we relate them to the composition of customers in the cantons. Figure 14 shows the sector shares on consumption for all (combined) cantons. These shares are computed using the previously derived annual consumption figures by canton. For instance, we see that households are more important in Grisons and Valais. In Figure 15 we plot the elasticities against the shares of individual sectors. Obviously there is a positive relationship with respect to households. A higher household share on consumption entails less price elastic consumption. The relationship is reversed for both industry and services. Thereby higher industry shares are more decisive for higher price elasticities.

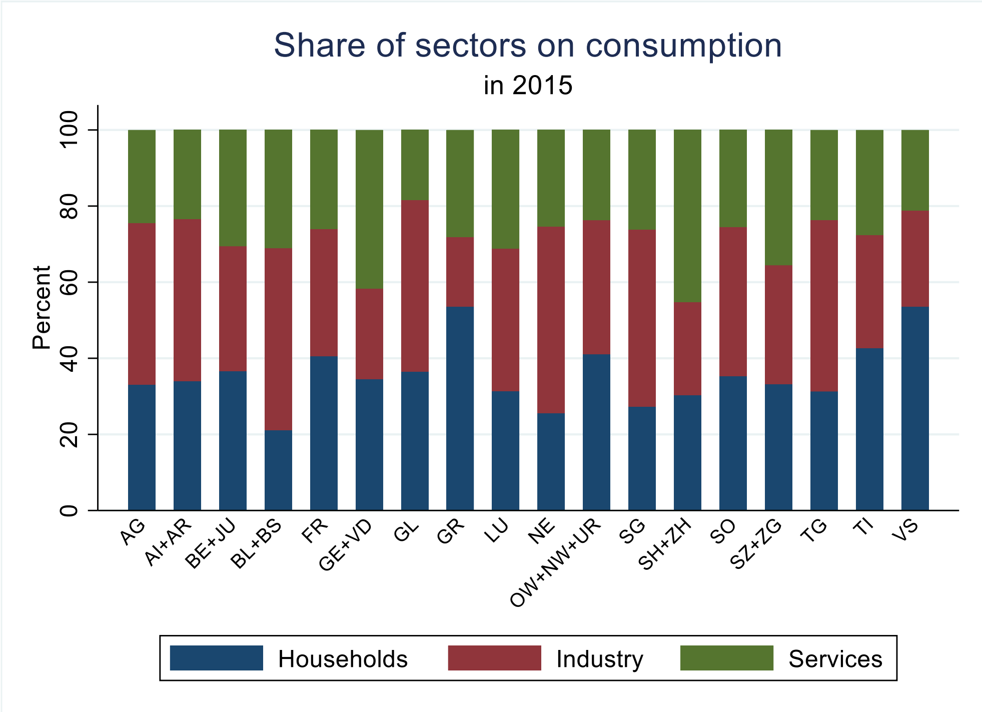

Figure 14: Sector share by canton

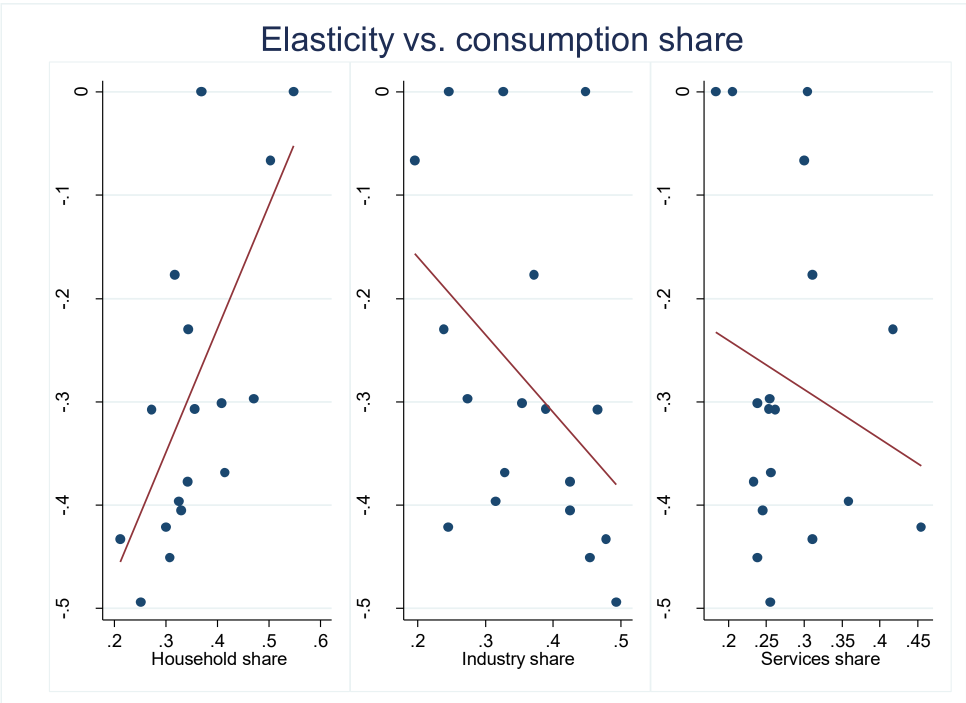

Figure 15: Elasticities and sector consumption shares

To learn about the demand reactions stemming from these elasticities, we investigate how an increase in carbon prices would affect the cantons. Carbon prices are an interesting study subject as Switzerland will abandon its own emission trading scheme and participate in the European emission trading scheme in 2020. To get an idea of the effects we distinguish between increases at the national and the European level. We subsequently simulate a common carbon price to depict a common emission trading scheme.

Our simulation draws on market fundamentals derived from the previous hourly estimation. In particular, we employ the estimated effects and realizations of variables included in our hourly regression of the system of equations (Table 11 and Table 12) to analyze consumption changes due to a change in carbon prices. Thereby carbon prices only act on commodity prices. An increased price of a ton CO2 in the European emission trading scheme increases the prices of coal, gas and oil used in European fossil-fuel fired plants which, in turn, affects the Swiss electricity price through imports (by means of the relationships estimated in Table 12). Likewise, an increased price of a ton CO2 in the Swiss emission trading scheme only affects Swiss plants taking part in the emission trading scheme (these are only gas-fired plants). Note that simulating a Swiss carbon price is thus independent from the Swiss CO2 levy (96 CHF per ton CO2 in 2018) which already makes fossil fuels more expensive but does not apply to Swiss fossil-fuel fired plants who instead participate in the Swiss emission trading scheme. Simulations are thus keeping the CO2 levy constant.

In our simulations we increase carbon prices and compute the increases in the Swiss electricity price. This increase then serves as a base for computing demand reactions using the canton-level elasticities as derived from Table 11.

First, we assume an increase in Swiss carbon prices by 10 CHF per ton CO2. We use the parameters of the price equation (Table 12) to compute new Swiss electricity prices. Based on the hourly price increases we then compute demand reaction using the canton-level elasticities. The resulting demand reaction are depicted in Figure 16. Reactions are rather small and only reach up to -0.2 percent because the respective electricity price increase only amounts to 0.42 percent. The strongest reactions take place in cantons with high shares of industry and services (e.g. Neuchâtel and Basel) while cantons with high household shares or fewer large industrial customers are less affected. Note that there are no reactions in those cantons for which we did not find statistically negative elasticities.

Second, we assume an increase in European carbon prices by 10 euro per ton CO2. In the same manner we compute demand reactions to respective electricity price increases. Figure 17 plots the demand reactions resulting from a roughly 9 percent electricity price increase. The magnitude of demand reactions is greater compared to the Swiss case since European carbon prices are more often decisive for the Swiss electricity price when fossil fuel technologies are price setting in the neighboring countries. Consumption is reduced by up to about 4.5 percent. The reactions are thereby distributed across cantons as in the Swiss case.

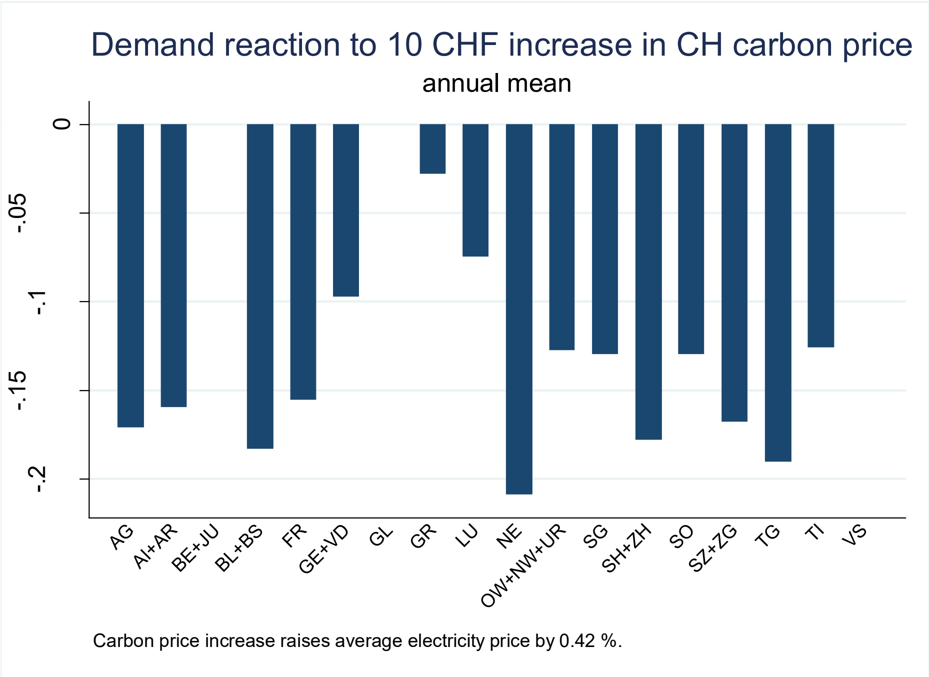

Figure 16: Demand reaction to CH carbon price increase

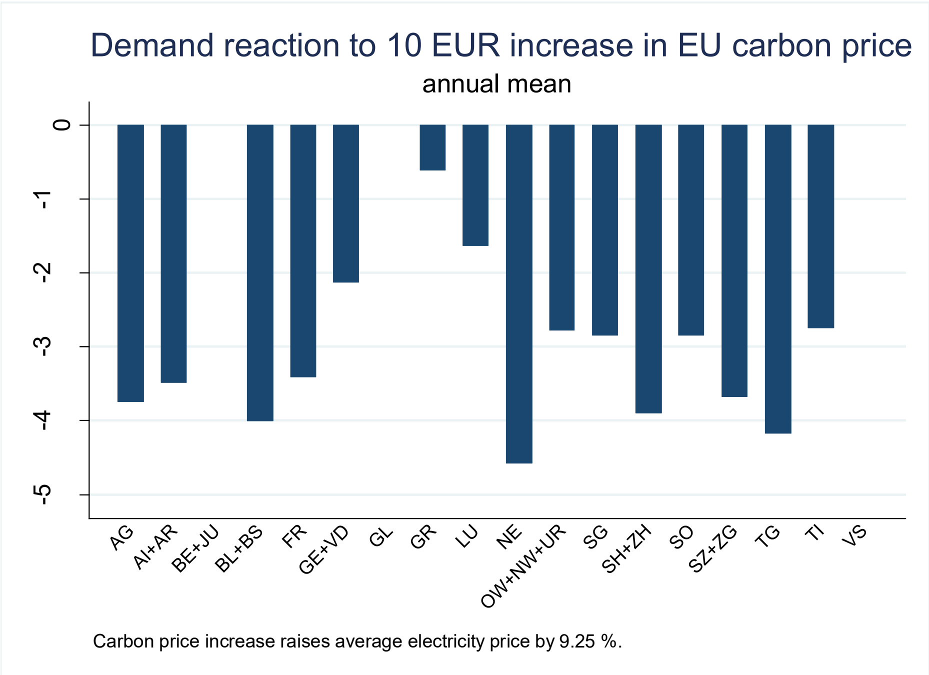

Figure 17: Demand reaction to EU carbon price increase

Finally, we simulate the effects of a common emission trading scheme. For this we do not model relative price increases in every hour but presume a common carbon price of 25 euro per ton CO2 in every hour. This value is based on the recent peak in the European carbon price (27 euro in April 2019) marking a possible renaissance of the European emission trading scheme resulting from the foreseeable shortening of certificates. Such an increase entails an increase in the Swiss electricity price by about 15 percent (based on our estimated parameters). This price increase in turn entails demand reductions by up to 7 percent as depicted in Figure 18. Again, cantons with high industry and services shares are more affected then cantons with higher household shares.

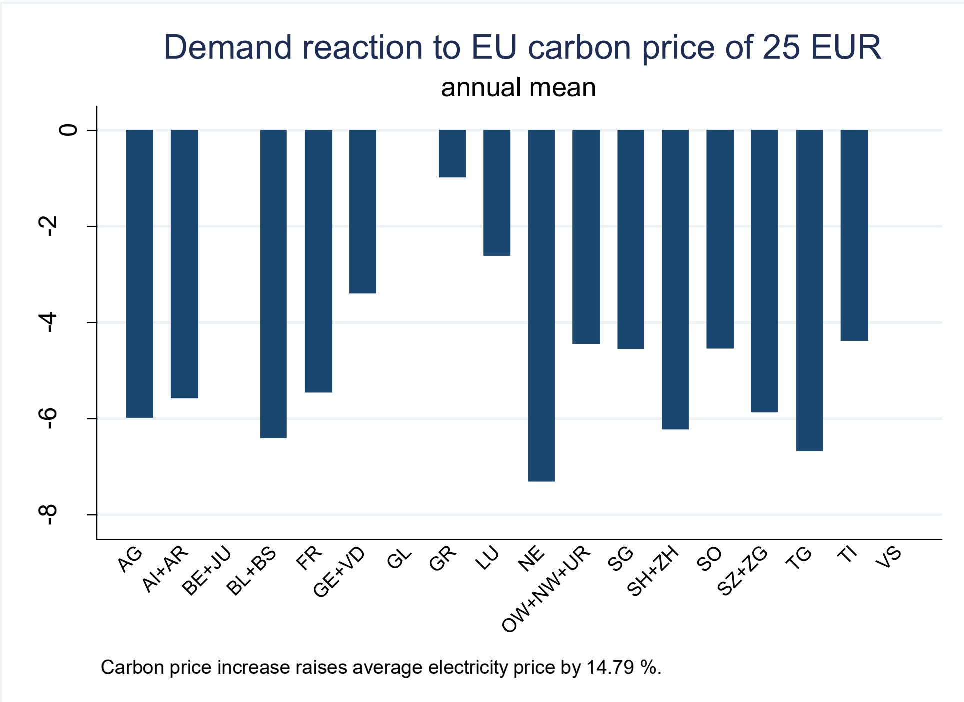

Figure 18: Demand reaction to common EU carbon price of 25 EUR / t CO2

6 Conclusion

In this paper, we have investigated price elasticities of electricity and gas demand in Switzerland. Building on a rich dataset comprising canton-level information for the years 2011 to 2016, we estimate structural single-equation and system-equation models. Thereby, we model demand as a function of price, business cycle, income, houses with different heating systems, temperature, sunshine hours and time amongst others, and supply as a function of input prices as well as import, congestion and market power situations generation capacities amongst others.

We do not find strong evidence for price elastic gas or electricity demand at the year level for any sector. Only commercial electricity customers show weak statistical evidence of elastic behavior. Furthermore, there is no evidence for price elastic electricity demand at the month level. Being contrary to previous studies we attribute these findings to the rather small sample size, measurement problems and incomplete liberalization of retail markets that does not seem to allow precisely identifying demand reactions regarding prices. Further research is needed either at a more disaggregate level or using longer time periods which entails consulting different (private) data sources.

Our hourly analysis, in contrast, builds on more detailed data resulting in significant canton-level price elasticities of electricity demand ranging from about -0.5 to -0.07. The hourly analysis is based on aggregate canton consumption without any distinction by sectors. By netting out demand of rather inelastic users we attribute these elasticities to flexible, large customers. Finding more elastic demand when focusing on more flexible users is in line with the market structure of the Swiss electricity sector in which rather the very large customers are reacting to spot prices. Elasticities are larger in cantons with higher industry shares.

We use these fundamental market characteristics to analyze demand reactions. Thereby we focus on carbon prices representing an interesting study subject as Switzerland will abandon its own emission trading scheme and participate in the European emission trading scheme in 2020. In our hourly analysis we also estimate a comprehensive price equation taking into account commodity prices whenever a respective fossil-fuel fired plant is price setting in neighboring countries. This allows us to compute counterfactual prices related to an increased carbon price. Simulating a common emission trading scheme and a common carbon price of 25 euro per ton CO_2 we find possible demand reductions of up to 7 percent aggregated over an entire year. Cantons with higher shares of industry are more affected than cantons with higher household shares.

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A Appendix

A.1 Approximation of annual canton-level consumption

The approximation's starting point is the overall energy statistic published by the Swiss Federal Office of Energy.[22] It contains an allocation of the nationwide consumption of different energy sources by the customer groups households, industry, services, transportation and statistical difference. These yearly figures are then distributed among cantons with the help of several canton-level characteristics. The procedure of Eymann et al. (2014) and our modifications are described in the following.

A.1.1 Households

Eymann et al. (2014) base their approximation on the canton-level statistic on buildings published by the Federal Statistical Office.[23] It contains a distinction by single- and multi-family houses and by heating energy source. With the help of nationwide information on the energy reference area by single-/ multi-family houses[24] they determine an equivalence measure for multi-family houses (multi-family houses have an energy reference area 2.72 times as large as single-family houses) and then calculate total numbers by canton distinguished by heating energy source. Accordingly, canton shares are derived to allocate nationwide household consumption among cantons.

For gas consumption, the plain figure from the overall energy statistic is allocated using these canton shares. For electricity consumption, Eymann et al. (2014) additionally distinguish between heating and other purposes. For heating, they cite Nipkow and Togni (2009) and assume that 9 percent of Swiss electricity consumption is due to residential electric heating and accordingly allocate this amount using the canton shares. The remaining electricity consumption of households is then allocated with the help of different shares derived from a consideration of the typical electricity consumption of occupants. Based on Swiss figures provided by Nipkow (2013) they compute the typical yearly electricity consumption for the nationwide average of occupants per single-family house and per multi-family house,[25] respectively, and likewise compute an equivalence measure for multi-family houses.

We deviate in several aspects from Eymann et al. (2014). First, we employ a canton-level statistic on buildings from a different statistic allowing the simultaneous distinction of buildings by type of building and heating energy source.[26] Together with also included information on building age and hot water generation this allows us to exploit more canton-level variation and to get more accurate approximations.

Second, in order to maintain consistency within these statistics we do not label all buildings with a single dwelling as single-family houses in contrast to Eymann et al. (2014). We only consider the official number of single-family houses and treat other houses with a single dwelling but secondary residential

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[22] Cf. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/overall-energy-statistics.html, last accessed on April 29, 2019.
[23] Cf. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.3982429.html, Table "je-d-09.02.00-07", last accessed on April 29, 2019.
[24] Cf. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/energieverbrauch-nach-verwendungszweck.html, Table "Entwicklung Energiebezugsflächen EBF", last accessed on April 29, 2019.
[25] Thereby, they resort to a different source and take the share of population living in houses or in flats (https://ec.europa.eu/eurostat/web/products-datasets/product?code=ilc_lvho01, Table ilc_lvho01, last accessed on April 29, 2019).
[26] Cf. https://www.pxweb.bfs.admin.ch/pxweb/en/px-x-0902010000_102/-/px-x-0902010000_102.pxl, "Housing by Canton, building category, type of heating, hot water, energy source and period of construction", last accessed on April 29, 2019.

use as a part of a multi-family house, which rather seems to comply with the typical conception of such dwellings.

Third, before allocating the nationwide household (gas and electricity) consumption among cantons we deduct the canton-level consumption related to hot water generation. As the aforementioned official statistic also provides canton-level information on the energy source used for hot water generation distinguished by the type of building we can also account for this part of residential consumption. The approximation is based on the canton-level average number of occupants per type of building (single-/ multi-family houses) multiplied by the number of respective buildings with hot water generation (distinguished by energy source) and by the average energy consumption per person related to hot water consumption. Thereby, we start from an average hot water consumption per person in Switzerland of 46.8 liters (Freiburghaus, 2015) multiplied by 350 days and by the energy needed to heat water from 10°C to 60°C (50 x 4187 Joule). This amount is then corrected by the efficiency factor of gas- or electricity driven boilers (84% and 99%, respectively[27]).

Fourth, for allocating residential energy consumption related to heating we account for the buildings' heating energy requirements. For this, we additionally consider the size of dwellings and the age of buildings in combination with the heating degree days of the respective years. Specifically, we assume a certain heating load by building age (70 W/m² if constructed before 1970; 50 W/m² if constructed between 1970 and 2000; 30 W/m² if constructed after 2000[28]) which is multiplied by a measure for the energy reference area in the individual cantons. The latter is approximated by the average size of dwellings by type of building[29] and a conversion factor (single-family houses: 1.30; multi-family houses: 1.38 (Office of the Environment and Energy of the Canton of Lucerne, 2013)) multiplied by the number of dwellings by type of building with electricity (or gas) heating. This amount is then multiplied by (24 times) the number of heating degree days in the cantons and divided by the annual use efficiency of the heating system. The latter is dependent on the type of energy source and the age of boiler (approximated by building age): 95% for electricity and gas (condensing, i.e. after 2000), and 85% for gas (non-condensing, i.e. before 2000) (SFOE and Minergie, 2007).

Based on these canton-level heating energy requirements we compute canton shares used to allocate the residential energy consumption related to heating. For gas, this comprises nationwide gas consumption of households (taken from the overall energy statistic) deducted by the aforementioned residential consumption related to hot water generation. For electricity, we follow Eymann et al. (2014) and also assume that 9 percent of the nationwide electricity consumption is due to residential electric heating and accordingly allocate this amount using the just derived canton shares.

Fifth, the residual electricity consumption is allocated with the help of canton-level (instead of nationwide) averages of occupants per single-family house and per multi-family house.[30] The residual electricity consumption thereby comprises the nationwide electricity consumption less residential energy consumption related to heating and to hot water generation. Canton shares used for allocation are derived in the same manner as Eymann et al. (2014) by employing the Swiss figures provided by

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[27] Cf. VDI standard 2067: Economic efficiency of building installations – Effective energy demands for heating drinking water.
[28] Cf. SFOE and Minergie (2007); http://www.energie.ch/heizung, last accessed on April 29, 2019.
[29] Cf. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.6286409.htmlhttps://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.3982429.html, Table je-d-09.03.02.28, last accessed on April 29, 2019 – appended by information on type of building and previous year kindly provided by Federal Statistical Office.
[30] Cf. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.6087026.htmlhttps://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.3982429.html, Table cc-d-01.02.02.04, last accessed on April 29, 2019 – appended by information on type of building kindly provided by Federal Statistical Office.

Nipkow (2013). Yet, we use occupant averages at the canton level to derive the typical residual electricity consumption by type of building.

Finally, for any gas consumption we disregard cantons that are not connected to gas infrastructure (Uri, Obwalden, Nidwalden). Note that this correction is also applied when we derive canton-level consumption replicating the method of Eymann et al. (2014).

A.1.2 Industry and services

Eymann et al. (2014) base their approximation on the energy consumption statistics in the industry and services sectors published by the Swiss Federal Office of Energy.[31] This publication comprises information on energy consumption by branch of economic activity (distinguished by energy source). It is based on a representative sample of firms. Entailing information on the number of employees of these firms, it allows computing the average consumption per employee by branches. Eymann et al. (2014) relate this information to canton-level numbers of firms by economic activity[32] to derive weights used for allocating the nationwide energy consumption of the sectors industry and services, respectively.

We apply the same methodology and sources as Eymann et al. (2014) but deviate slightly when assigning the branches of economic activity to specific economic activities. The publication by the Swiss Federal Office of Energy only provides figures on the aggregated level of the branches of economic activity. Yet, the Swiss Federal Office of Energy also provides a clear assignment to the General Classification of Economic Activities.[33] In contrast to Eymann et al. (2014) we apply this assignment to maintain consistency within the statistical sources. Table A-1 provides an overview.

Moreover, as we cover a longer time period as Eymann et al. (2014) we need to account for a change in the official publication of the energy consumption statistics in the industry and services sectors. There was a switch from reporting full time equivalents to the number of employees. But both can be captured by the statistic on canton-level numbers of firms by economic activity. Again, we also disregard cantons that are not connected to gas infrastructure (Uri, Obwalden, Nidwalden).

[31] Cf. https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/sector-statistics.htmlhttps://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/energy-statistics/overall-energy-statistics.html, last accessed on April 29, 2019.
[32] Cf. https://www.pxweb.bfs.admin.ch/pxweb/en/px-x-0602050000_102/-/px-x-0602050000_102.pxhttps://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.3982429.html, "Workplaces and employees by canton, economic activity and size", last accessed on April 29, 2019.
[33] Cf. https://www.bfs.admin.ch/bfs/en/home/statistics/industry-services/nomenclatures/noga/publications-noga-2008.html, last accessed on April 29, 2019.

A.1.3 Transportation

Eymann et al. (2014) relate the nationwide transportation energy consumption solely to rail traffic stating that it is the largest consumer. Thereby, they also refer to Swiss Federal Railways asserting that one quarter of consumption is due to freight traffic and the rest due to passenger traffic. Hence, they allocate 25% of nationwide electricity consumption related to transportation among cantons by shares derived from full time equivalents in the industry sector. The remaining nationwide electricity consumption related to transportation is allocated based on shares derived from the daily distance travelled by person in trains taken from the micro census on mobility and transport 2010 (multiplied by the cantons' population). [34]

Regarding gas consumption related to transportation, Eymann et al. (2014) allocate the nationwide figure with the help of canton shares derived from the daily distance travelled by person in cars. Yet, before that they consider the gas consumption of compressor stations in Switzerland, which is also displayed in the overall energy statistic. The allocation is based on shares derived from residual gas consumption in the cantons.

We deviate in several aspects from Eymann et al. (2014). First, we employ more recent information from the micro census on mobility and transport 2015 which also entails canton-level information (instead of the earlier, more aggregated information at the NUTS-2 regions). [35] This affects the derivation of canton shares for the allocation of nationwide electricity consumption related to passenger traffic. Here, we have to rely on the daily distance travelled by person in public transport as trains are no longer displayed separately. The allocation of nationwide electricity consumption related to freight traffic is also conducted using full time equivalents in the cantons' industry sector.

Second, we disregard the gas consumption of compressor stations, which basically only comprises a single station in Lucerne. Third, the allocation of nationwide gas consumption related to transportation is based on the cumulated daily distance travelled by person in public transport and in cars to account for the stock of natural gas vehicles. The stock is rather low with 12,912 in 2016.[36] While the minority is due to busses (190 in 2016), their kilometrage is usually higher so that the accumulation seems justified.

A.1.4 Statistical difference

The overall energy statistic also contains the item "statistical difference". Regarding electricity consumption, Eymann et al. (2014) relate the respective nationwide figure solely to agriculture (which is suggested by the Swiss Federal Office of Energy) and allocate it among the cantons with the help of canton-level information on the full time equivalents in the agricultural sector. Regarding gas consumption, Eymann et al. (2014) allocate the "statistical difference" based on weights that they compute from the already allocated (residual) gas consumption in the cantons. We do not deviate from these approaches.

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[34] Cf. https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases.assetdetail.su-d-11.04.03-MZ-2010-T00.html, Table su-d-11.04.03-MZ-2010-T00, last accessed on April 29, 2019.
[35] Cf. https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/personenverkehr/verkehrsverhalten/tabellen-2015/kantone.html, Tables su-d-11.04.03-MZ-2015-A3 for each canton, last accessed on April 29, 2019.
[36] Information provided by VSG (Verband der Schweizerischen Gasindustrie).

A.2 Tables

Table A-1: Assignment branch – economic activity

Branch	Sector	Economic activities (cf. footnote 33)	Assignment by Eymann et al. (2014)
Manufacture of foods	industry	10, 11, 12	10, 11, 12
Manufacture of textiles and leather	industry	13, 14, 15	13, 14, 15
Manufacture of paper and print	industry	17, 18	17, 18
Manufacture of chemical and pharmaceutical products	industry	20, 21	20, 21
Manufacture of cement	industry	23	Treated separately
Manufacture of other non-metallic mineral products	industry	23	23
Manufacture of basic metals	industry	24	24
Manufacture of non-ferrous metals	industry	24	24
Manufacture of fabricated metal products, computer and electrical equipment	industry	25, 26, 27	25, 27
Manufacture of machinery	industry	28	28
Other industries	industry	7, 8, 9, 16, 22, 29, 30, 31, 32	7, 8, 9, 16, 22, 29, 30, 31, 32
Construction	industry	41, 42, 43	41, 42, 43
Wholesale and retail trade	services	45, 46, 47, 95	45, 46, 47, 95
Accommodation	services	55, 56	55, 56
Financial and insurance activities	services	64, 65, 66	64, 65, 66
Public administration	services	84	84
Education	services	85	85
Human health and social work activities	services	75, 86, 87, 88	75, 86, 87, 88
Other services	services	33, 36, 37, 38 , 39, 49, 50, 51, 52, 53, 58, 59, 60, 61, 62, 63, 68, 69, 70, 71, 72, 73, 74, 77, 78, 79, 80, 81, 82, 90, 91, 92, 93, 94, 96	59, 60, 61, 62, 63, 68, 69, 70, 71, 72, 73, 74, 77, 78, 79, 80, 81, 82, 90, 91, 92, 93, 94, 96

Table A-2: Electricity consumption by canton and sector

in GWh		own approach						via Eymann et al (2014)					
Canton	Year	Total	Households	Industry	Services	Traffic	Other	Total	Households	Industry	Services	Traffic	Other
AG	2011	-	-	1,942.2	1,000.6	249.9	63.2	4,559.5	1,269.0	2,002.6	980.9	243.8	63.2
AG	2012	4,605.9	1,343.6	1,932.8	1,013.1	253.1	63.3	4,600.4	1,299.6	1,995.8	994.7	247.0	63.3
AG	2013	4,637.0	1,379.4	1,903.4	1,032.2	257.6	64.4	4,635.4	1,337.5	1,965.1	1,017.1	251.3	64.4
AG	2014	4,477.6	1,353.8	1,801.5	1,006.0	251.9	64.5	4,474.6	1,306.2	1,867.5	990.7	245.7	64.5
AG	2015	4,550.9	1,398.5	1,793.8	1,033.2	260.7	64.8	4,538.2	1,340.3	1,863.6	1,018.1	251.3	64.8
AG	2016	4,550.0	1,431.4	1,758.9	1,030.0	267.2	62.5	4,524.1	1,365.3	1,829.8	1,008.8	257.6	62.5
AI	2011	-	-	37.8	21.8	6.3	6.5	113.7	40.9	37.7	22.2	6.4	6.5
AI	2012	105.3	32.4	38.0	22.1	6.3	6.5	116.0	42.1	38.4	22.6	6.5	6.5
AI	2013	111.7	33.0	40.0	25.6	6.3	6.7	123.2	43.2	40.8	25.9	6.5	6.7
AI	2014	106.0	27.4	41.0	24.9	6.2	6.4	121.9	42.0	41.9	25.2	6.4	6.4
AI	2015	108.1	28.5	40.8	25.3	6.9	6.6	123.7	43.4	41.6	25.6	6.6	6.6
AI	2016	107.8	29.3	40.0	24.9	7.1	6.6	123.3	44.1	40.8	25.2	6.7	6.6
AR	2011	-	-	137.1	71.8	20.5	10.4	372.1	128.0	140.2	72.5	21.1	10.4
AR	2012	348.5	114.5	130.6	72.8	20.4	10.3	368.3	130.5	133.3	73.3	20.9	10.3
AR	2013	360.2	117.4	136.3	75.6	20.6	10.3	380.6	133.8	139.3	76.2	21.1	10.3
AR	2014	355.2	113.9	137.9	73.1	20.1	10.1	375.9	130.3	141.2	73.7	20.6	10.1
AR	2015	363.7	116.3	140.2	74.3	22.4	10.4	382.6	132.7	143.3	75.1	21.1	10.4
AR	2016	360.2	117.8	136.1	73.2	22.9	10.3	378.8	134.5	138.6	74.0	21.5	10.3
BE	2011	-	-	2,078.2	2,045.1	398.5	210.5	7,221.8	2,479.5	2,079.6	2,044.8	407.4	210.5
BE	2012	7,076.3	2,341.1	2,081.3	2,043.5	401.4	209.0	7,277.6	2,531.6	2,084.5	2,042.2	410.3	209.0
BE	2013	7,194.6	2,386.9	2,096.3	2,094.7	405.6	211.0	7,417.5	2,593.2	2,105.4	2,093.2	414.7	211.0
BE	2014	7,004.0	2,357.0	2,039.2	2,009.7	394.7	203.4	7,197.6	2,529.9	2,052.5	2,008.4	403.5	203.4
BE	2015	7,141.1	2,409.1	2,046.4	2,043.5	436.3	205.8	7,318.6	2,603.2	2,057.4	2,040.6	411.6	205.8
BE	2016	7,131.3	2,434.9	2,020.3	2,029.4	443.8	203.0	7,335.1	2,655.3	2,029.9	2,028.4	418.6	203.0
BL	2011	-	-	871.6	477.6	109.4	19.3	2,038.2	538.5	906.9	466.7	106.8	19.3
BL	2012	1,970.1	538.4	828.6	475.1	109.4	18.7	2,005.4	551.1	862.5	466.4	106.7	18.7
BL	2013	1,938.2	549.6	793.8	464.3	110.8	19.7	1,977.4	565.9	825.9	458.0	108.1	19.7
BL	2014	1,804.1	495.7	723.4	458.1	107.9	19.1	1,858.0	531.5	751.5	450.7	105.2	19.1
BL	2015	1,795.3	476.7	720.0	468.3	111.0	19.3	1,871.2	534.4	748.6	461.6	107.3	19.3
BL	2016	1,747.5	458.5	696.7	459.5	113.4	19.3	1,840.3	536.2	722.3	452.8	109.7	19.3
BS	2011	-	-	1,386.5	691.8	80.1	0.5	2,480.3	241.1	1,486.0	674.3	78.3	0.5
BS	2012	2,418.2	289.3	1,356.3	690.7	81.3	0.5	2,455.5	242.1	1,456.6	676.8	79.4	0.5
BS	2013	2,280.8	293.5	1,219.3	685.5	82.0	0.5	2,308.4	243.5	1,309.1	675.1	80.2	0.5
BS	2014	2,070.1	282.7	1,035.8	670.8	80.2	0.6	2,088.6	235.0	1,113.6	661.1	78.4	0.6
BS	2015	2,073.9	292.1	1,020.8	663.4	97.2	0.5	2,078.3	241.5	1,099.9	655.7	80.7	0.5
BS	2016	2,017.3	299.7	967.5	650.6	99.2	0.3	2,017.1	246.3	1,044.1	643.9	82.5	0.3
FR	2011	-	-	620.0	448.0	113.8	52.6	1,965.3	723.0	621.9	451.3	116.4	52.6
FR	2012	1,939.8	704.5	611.8	454.0	116.3	53.2	1,987.5	741.6	616.3	457.5	118.9	53.2
FR	2013	1,977.8	722.7	609.0	472.2	119.4	54.5	2,028.0	760.9	615.3	475.2	122.1	54.5
FR	2014	1,944.4	710.0	606.8	457.2	117.6	52.9	1,994.3	744.5	616.8	459.9	120.2	52.9
FR	2015	1,964.5	732.0	604.2	470.4	103.8	54.0	2,029.3	766.0	613.4	472.8	123.2	54.0
FR	2016	1,981.8	746.2	611.7	464.0	106.7	53.2	2,047.9	780.5	621.5	466.2	126.5	53.2
GE	2011	-	-	694.8	1,442.2	131.4	9.9	2,592.5	398.2	601.6	1,457.6	125.2	9.9
GE	2012	2,939.1	671.6	679.8	1,444.6	132.5	10.5	2,585.0	406.6	583.5	1,458.1	126.4	10.5
GE	2013	2,802.8	692.0	633.1	1,332.4	134.8	10.5	2,432.9	417.2	535.9	1,340.8	128.5	10.5
GE	2014	2,708.8	668.9	600.1	1,296.6	132.8	10.5	2,339.5	406.3	491.4	1,304.6	126.6	10.5
GE	2015	2,713.4	700.1	582.5	1,305.1	115.3	10.4	2,333.1	417.4	463.1	1,312.4	129.8	10.4
GE	2016	2,720.2	718.5	572.8	1,300.7	117.7	10.6	2,329.6	425.5	452.8	1,308.4	132.4	10.6
GL	2011	-	-	145.2	54.6	16.8	6.1	358.8	125.6	154.9	54.9	17.2	6.1
GL	2012	336.9	114.2	144.2	55.5	16.8	6.2	360.7	127.2	154.3	55.8	17.2	6.2
GL	2013	344.1	115.6	145.6	59.5	17.0	6.4	369.0	129.5	155.9	59.8	17.4	6.4
GL	2014	339.2	111.8	148.5	56.3	16.6	6.1	365.2	125.8	159.6	56.8	17.0	6.1
GL	2015	339.3	116.5	144.1	58.9	13.7	6.1	367.3	128.3	156.6	59.2	17.1	6.1
GL	2016	338.5	115.6	144.8	58.1	13.9	6.1	370.3	130.8	157.7	58.3	17.4	6.1
GR	2011	-	-	326.1	477.7	72.6	40.9	1,804.3	870.6	336.2	482.0	74.5	40.9
GR	2012	1,786.6	862.8	323.5	487.0	72.8	40.5	1,828.8	888.2	334.2	491.2	74.7	40.5
GR	2013	1,812.8	869.0	324.1	505.6	73.4	40.6	1,871.7	911.3	335.0	509.5	75.3	40.6

GR	2014	1,809.0	910.3	309.6	478.0	71.3	39.8	1,807.9	893.0	320.4	481.6	73.2	39.8
GR	2015	1,787.3	892.6	306.1	468.3	80.8	39.4	1,829.9	927.3	317.3	471.5	74.4	39.4
GR	2016	1,783.8	889.7	312.0	459.7	82.3	40.1	1,850.1	948.3	322.8	463.1	75.8	40.1
JU	2011	-	-	264.1	104.0	32.8	18.2	563.5	199.9	206.9	105.1	33.5	18.2
JU	2012	595.8	169.0	270.3	104.5	33.5	18.5	571.4	204.2	209.2	105.4	34.1	18.5
JU	2013	585.9	174.2	250.9	107.8	34.3	18.7	555.6	209.7	183.6	108.6	34.9	18.7
JU	2014	576.9	165.5	256.8	103.0	33.6	18.0	545.9	200.5	189.5	103.6	34.3	18.0
JU	2015	572.9	168.5	253.5	103.6	29.0	18.4	542.7	203.5	181.8	104.2	34.9	18.4
JU	2016	574.7	171.7	252.4	103.0	29.2	18.3	544.3	205.8	181.4	103.7	35.2	18.3
LU	2011	-	-	945.3	751.4	145.0	86.2	2,733.6	753.0	995.5	752.6	146.2	86.2
LU	2012	2,746.7	785.3	966.5	763.0	146.6	85.3	2,787.5	770.2	1,020.5	763.6	147.8	85.3
LU	2013	2,803.4	802.4	969.0	796.3	148.9	86.8	2,844.6	788.6	1,023.1	795.9	150.1	86.8
LU	2014	2,733.6	777.3	951.6	775.5	145.8	83.5	2,781.5	767.7	1,007.2	776.1	147.0	83.5
LU	2015	2,767.9	796.8	950.1	792.4	143.1	85.6	2,825.3	786.6	1,009.6	793.2	150.3	85.6
LU	2016	2,777.1	808.0	948.7	789.2	146.2	85.1	2,833.5	799.5	1,006.2	789.1	153.5	85.1
NE	2011	-	-	597.9	298.1	80.0	13.9	1,102.1	290.1	414.3	302.3	81.6	13.9
NE	2012	1,289.3	291.6	597.4	305.6	81.0	13.7	1,111.2	296.8	408.7	309.5	82.6	13.7
NE	2013	1,288.0	299.9	587.1	305.1	82.0	13.9	1,114.6	304.0	404.7	308.5	83.6	13.9
NE	2014	1,250.1	293.2	567.4	296.0	79.9	13.6	1,081.1	296.8	389.9	299.4	81.4	13.6
NE	2015	1,253.7	301.3	576.8	298.8	62.7	14.1	1,096.9	305.5	392.1	302.5	82.7	14.1
NE	2016	1,226.7	307.5	551.3	291.0	62.8	14.2	1,077.6	312.9	372.6	294.8	83.1	14.2
NW	2011	-	-	103.1	67.6	15.9	7.8	307.4	105.3	109.9	68.3	16.1	7.8
NW	2012	302.5	105.4	105.0	68.1	16.2	7.8	312.3	107.3	112.2	68.7	16.3	7.8
NW	2013	319.6	107.1	114.6	73.3	16.6	8.0	331.1	109.5	122.9	74.0	16.7	8.0
NW	2014	318.7	107.5	116.8	70.6	16.2	7.7	327.5	106.5	125.8	71.2	16.3	7.7
NW	2015	318.9	108.0	117.1	72.8	13.5	7.5	333.9	110.0	126.6	73.3	16.5	7.5
NW	2016	314.9	107.3	114.8	71.8	13.6	7.5	332.9	112.3	124.1	72.3	16.7	7.5
OW	2011	-	-	98.1	60.0	15.0	10.1	309.9	118.0	105.6	61.1	15.1	10.1
OW	2012	293.3	110.6	96.2	61.2	15.1	10.2	312.3	120.5	104.0	62.3	15.2	10.2
OW	2013	300.0	112.7	97.2	64.6	15.3	10.2	319.9	123.3	104.9	66.0	15.5	10.2
OW	2014	301.3	114.3	100.9	61.3	15.0	9.9	317.2	120.3	109.3	62.6	15.1	9.9
OW	2015	303.9	113.2	101.2	62.1	17.4	10.0	322.4	123.2	110.2	63.6	15.4	10.0
OW	2016	302.9	111.3	102.9	60.8	17.8	10.1	326.4	125.8	112.3	62.4	15.7	10.1
SG	2011	-	-	1,597.9	870.3	199.1	69.9	3,704.3	914.0	1,650.4	866.1	203.9	69.9
SG	2012	3,665.0	907.4	1,612.6	874.1	201.3	69.6	3,748.4	934.4	1,667.7	870.6	206.1	69.6
SG	2013	3,729.2	934.4	1,617.4	903.0	203.7	70.6	3,813.2	961.5	1,675.5	897.1	208.6	70.6
SG	2014	3,628.5	905.1	1,581.2	873.7	198.0	70.4	3,719.7	937.0	1,644.6	865.0	202.8	70.4
SG	2015	3,691.2	935.3	1,590.0	895.7	200.2	70.1	3,778.8	960.6	1,657.2	884.8	206.2	70.1
SG	2016	3,708.9	950.1	1,597.2	890.0	204.3	67.4	3,799.1	978.1	1,666.4	876.9	210.3	67.4
SH	2011	-	-	294.3	133.0	31.6	11.0	629.8	160.2	296.5	129.8	32.3	11.0
SH	2012	627.3	163.5	286.3	134.2	32.0	11.4	627.7	163.4	289.1	131.1	32.7	11.4
SH	2013	621.3	167.1	271.5	138.6	32.4	11.6	621.5	167.7	273.2	135.7	33.2	11.6
SH	2014	588.0	162.6	249.1	133.8	31.2	11.3	587.9	163.6	249.9	131.1	32.0	11.3
SH	2015	598.6	166.8	250.1	134.1	36.2	11.4	594.1	167.5	251.2	131.4	32.7	11.4
SH	2016	595.7	170.3	243.9	132.9	36.9	11.6	589.9	169.9	244.6	130.5	33.3	11.6
SO	2011	-	-	652.1	408.1	107.4	26.0	1,728.3	575.1	630.3	387.2	109.8	26.0
SO	2012	1,755.7	571.7	642.2	407.6	108.7	25.5	1,726.6	587.8	615.0	387.2	111.1	25.5
SO	2013	1,803.7	583.2	662.6	422.1	109.9	25.9	1,785.3	603.0	639.8	404.5	112.2	25.9
SO	2014	1,757.6	568.9	644.0	413.2	106.9	24.7	1,737.9	588.0	621.1	395.0	109.2	24.7
SO	2015	1,788.4	585.6	649.0	422.8	105.6	25.4	1,774.2	602.9	629.8	405.1	111.0	25.4
SO	2016	1,782.3	598.2	629.4	421.9	107.3	25.4	1,767.0	613.5	610.3	404.9	112.8	25.4
SZ	2011	-	-	271.0	240.8	55.5	26.1	964.5	359.9	280.3	242.3	55.9	26.1
SZ	2012	943.8	344.3	273.0	244.2	56.3	26.0	979.7	367.9	283.1	245.9	56.7	26.0
SZ	2013	980.6	351.5	283.5	262.0	57.1	26.5	1,019.6	377.3	294.8	263.5	57.5	26.5
SZ	2014	947.5	341.8	269.8	254.5	55.3	26.2	992.5	368.1	285.7	256.6	55.8	26.2
SZ	2015	971.3	355.6	269.2	260.0	59.9	26.5	1,007.6	377.9	283.8	262.2	57.1	26.5
SZ	2016	970.2	356.4	268.3	257.8	61.2	26.6	1,013.5	385.4	283.0	260.1	58.3	26.6
TG	2011	-	-	699.9	357.5	99.9	53.9	1,735.0	486.6	734.9	357.3	102.4	53.9

TG	2012	1,674.8	470.2	682.6	366.9	101.3	53.8	1,742.5	500.3	717.8	366.8	103.8	53.8
TG	2013	1,698.3	485.0	678.8	377.0	102.9	54.6	1,768.9	517.8	713.7	377.4	105.5	54.6
TG	2014	1,694.5	475.0	700.6	365.5	100.6	52.8	1,767.8	506.0	739.9	366.0	103.1	52.8
TG	2015	1,722.4	491.9	709.2	371.7	94.9	54.7	1,805.9	521.1	751.5	372.8	105.9	54.7
TG	2016	1,755.3	503.4	731.0	370.6	97.4	52.9	1,843.6	532.4	779.2	370.6	108.6	52.9
TI	2011	-	-	872.4	770.4	73.9	18.1	3,364.6	1,627.9	873.7	775.6	69.4	18.1
TI	2012	3,025.0	1,274.6	872.6	784.5	75.0	18.4	3,405.6	1,652.4	875.8	788.6	70.4	18.4
TI	2013	3,011.0	1,257.2	867.1	792.4	76.0	18.3	3,425.1	1,665.5	873.2	796.8	71.3	18.3
TI	2014	2,958.5	1,237.7	852.5	775.9	74.2	18.2	3,346.9	1,620.0	858.2	780.8	69.6	18.2
TI	2015	2,983.3	1,227.7	854.3	794.2	88.8	18.3	3,388.5	1,637.5	862.2	799.3	71.1	18.3
TI	2016	2,944.7	1,201.5	844.8	790.9	89.6	17.9	3,371.4	1,633.7	851.9	796.2	71.7	17.9
UR	2011	-	-	66.5	48.7	13.6	9.6	263.4	121.3	69.7	49.0	13.7	9.6
UR	2012	231.9	99.6	60.9	48.3	13.5	9.6	259.4	124.0	63.7	48.4	13.6	9.6
UR	2013	244.9	101.5	64.9	55.1	13.7	9.7	273.4	126.8	67.8	55.3	13.8	9.7
UR	2014	233.5	99.0	60.8	51.1	13.3	9.3	261.3	123.7	63.6	51.4	13.4	9.3
UR	2015	241.3	103.5	60.5	52.7	15.7	8.9	267.0	128.2	63.2	53.1	13.5	8.9
UR	2016	237.7	102.6	59.0	51.5	15.8	8.8	266.8	131.1	61.4	51.9	13.7	8.8
VD	2011	-	-	1,107.1	1,604.9	205.9	78.6	4,478.2	1,498.6	1,078.0	1,626.8	196.2	78.6
VD	2012	4,616.2	1,587.4	1,108.0	1,632.6	209.2	79.0	4,541.3	1,535.2	1,074.1	1,653.6	199.4	79.0
VD	2013	4,593.0	1,647.4	1,088.4	1,563.7	213.9	79.5	4,490.3	1,572.2	1,052.6	1,582.1	203.9	79.5
VD	2014	4,450.8	1,595.8	1,050.7	1,516.9	210.0	77.4	4,359.6	1,532.6	1,013.5	1,536.0	200.1	77.4
VD	2015	4,556.6	1,654.5	1,044.6	1,539.3	239.4	78.8	4,421.1	1,573.7	1,005.1	1,558.3	205.3	78.8
VD	2016	4,577.3	1,692.0	1,036.0	1,525.7	244.9	78.7	4,434.4	1,601.2	998.8	1,545.9	209.9	78.7
VS	2011	-	-	835.4	589.4	94.8	56.9	3,265.8	1,624.0	892.1	602.2	90.5	56.9
VS	2012	2,939.9	1,411.8	779.4	596.6	95.6	56.5	3,254.6	1,665.7	832.9	608.1	91.3	56.5
VS	2013	2,992.8	1,450.5	761.2	627.9	97.1	56.0	3,308.6	1,707.0	814.2	638.7	92.8	56.0
VS	2014	2,882.6	1,418.0	718.9	595.4	95.0	55.3	3,202.5	1,679.4	770.7	606.4	90.7	55.3
VS	2015	3,010.3	1,514.0	716.2	597.4	125.4	57.1	3,262.0	1,732.8	770.5	608.5	93.0	57.1
VS	2016	2,990.0	1,518.0	698.0	588.6	128.0	57.4	3,274.2	1,771.6	751.1	599.2	94.9	57.4
ZG	2011	-	-	329.1	379.6	47.9	10.8	930.3	215.7	267.0	388.5	48.3	10.8
ZG	2012	1,010.5	251.8	318.6	381.1	48.0	10.9	929.3	219.6	261.9	388.4	48.4	10.9
ZG	2013	1,032.9	256.5	321.6	394.5	49.2	11.1	944.0	224.2	258.1	401.2	49.6	11.1
ZG	2014	1,011.8	251.4	312.3	388.9	48.2	11.0	926.2	218.5	251.5	396.6	48.6	11.0
ZG	2015	1,025.4	260.1	310.9	400.1	42.9	11.4	941.0	224.5	247.7	407.7	49.7	11.4
ZG	2016	1,032.2	265.2	315.6	396.0	44.4	11.0	945.4	228.5	250.8	403.8	51.4	11.0
ZH	2011	-	-	1,964.2	3,811.5	644.4	71.7	8,549.9	2,077.9	1,947.4	3,803.0	650.0	71.7
ZH	2012	8,867.6	2,355.4	1,967.1	3,822.3	651.7	71.1	8,618.6	2,123.0	1,952.8	3,814.4	657.4	71.1
ZH	2013	8,935.0	2,423.5	1,953.1	3,825.9	661.3	71.2	8,671.1	2,172.9	1,941.2	3,818.6	667.1	71.2
ZH	2014	8,674.1	2,362.8	1,864.0	3,730.5	647.2	69.6	8,403.2	2,113.0	1,844.0	3,723.7	652.9	69.6
ZH	2015	8,774.2	2,453.8	1,859.0	3,778.7	612.2	70.6	8,523.2	2,171.1	1,841.5	3,772.4	667.6	70.6
ZH	2016	8,806.5	2,530.8	1,830.5	3,749.3	626.0	69.9	8,518.3	2,209.3	1,809.3	3,747.1	682.7	69.9

Table A-3: Gas consumption by canton and sector

in GWh		own approach						via Eymann et al (2014)					
Canton	Year	Total	Households	Industry	Services	Traffic	Other	Total	Households	Industry	Services	Traffic	Other
AG	2011	-	-	1,036.0	325.1	15.3	-	2,316.2	767.2	1,051.4	318.4	33.8	145.4
AG	2012	2,384.3	782.3	1,075.4	376.8	14.6	135.2	2,513.5	872.5	1,095.5	369.1	32.2	144.3
AG	2013	2,543.3	832.1	1,210.1	465.4	15.0	20.8	2,672.0	935.4	1,232.2	458.4	23.8	22.3
AG	2014	2,280.9	678.6	1,207.1	375.7	14.4	5.1	2,401.9	762.6	1,230.9	370.2	32.8	5.4
AG	2015	2,368.5	740.6	1,178.6	426.7	14.8	7.9	2,477.4	814.8	1,201.9	420.8	31.5	8.3
AG	2016	2,459.9	780.5	1,204.6	453.3	14.1	7.4	2,550.8	848.1	1,228.7	444.6	21.6	7.8
AI	2011	-	-	19.8	6.3	0.4	-	32.5	3.6	19.8	6.4	0.7	2.0
AI	2012	37.1	7.1	20.4	7.1	0.4	2.1	35.2	4.7	20.6	7.2	0.7	2.0
AI	2013	43.4	7.8	25.0	9.8	0.4	0.4	42.1	6.0	25.3	10.0	0.6	0.4
AI	2014	43.3	7.3	27.4	8.1	0.4	0.1	43.9	7.2	27.7	8.2	0.7	0.1
AI	2015	43.8	9.5	24.7	9.1	0.4	0.1	43.2	8.3	24.9	9.1	0.7	0.1
AI	2016	44.4	11.6	22.7	9.7	0.4	0.1	42.5	9.4	22.8	9.8	0.5	0.1
AR	2011	-	-	62.3	25.6	1.4	-	207.1	102.4	62.7	25.9	3.1	13.0
AR	2012	236.4	128.4	64.2	29.0	1.3	13.4	227.5	117.3	64.8	29.4	3.0	13.1
AR	2013	254.9	139.8	75.6	36.0	1.4	2.1	242.7	125.8	76.3	36.4	2.2	2.0
AR	2014	225.9	112.8	81.9	29.4	1.3	0.5	219.8	103.9	82.7	29.7	3.0	0.5
AR	2015	243.7	123.4	84.5	33.7	1.3	0.8	236.3	113.2	85.3	34.2	2.9	0.8
AR	2016	255.1	130.2	87.1	35.8	1.2	0.8	246.8	120.1	87.8	36.3	1.9	0.8
BE	2011	-	-	1,023.3	682.3	27.3	-	3,103.7	1,150.4	1,022.8	683.1	52.6	194.8
BE	2012	3,270.2	1,217.9	1,061.2	779.8	25.7	185.5	3,398.2	1,312.0	1,060.9	780.3	50.0	195.0
BE	2013	3,528.8	1,291.3	1,210.9	971.3	26.4	28.9	3,657.8	1,404.1	1,212.4	972.0	38.9	30.5
BE	2014	3,158.7	1,092.9	1,249.1	784.5	25.2	7.0	3,238.9	1,143.6	1,252.2	785.5	50.4	7.3
BE	2015	3,276.8	1,160.2	1,194.4	888.0	23.3	10.9	3,364.4	1,224.6	1,195.1	888.4	44.9	11.3
BE	2016	3,319.0	1,185.3	1,153.8	947.8	22.1	10.0	3,419.1	1,276.5	1,151.7	949.3	31.1	10.5
BL	2011	-	-	488.6	158.2	6.8	-	1,366.9	610.5	498.2	154.6	17.8	85.8
BL	2012	1,567.5	810.4	481.9	179.9	6.4	88.9	1,516.6	742.7	493.3	176.5	17.1	87.0
BL	2013	1,793.9	1,026.8	531.0	214.9	6.6	14.7	1,667.5	886.1	543.2	212.2	12.1	13.9
BL	2014	1,585.5	892.1	508.4	175.2	6.3	3.5	1,515.6	802.1	519.4	172.7	17.9	3.4
BL	2015	1,669.5	957.2	502.0	199.2	5.6	5.5	1,590.0	859.1	512.7	196.9	16.0	5.4
BL	2016	1,773.5	1,032.7	521.5	208.6	5.3	5.3	1,649.8	896.6	532.2	206.1	9.8	5.1
BS	2011	-	-	941.4	237.7	4.6	-	1,827.9	489.4	972.1	232.3	19.3	114.8
BS	2012	2,409.0	1,035.8	959.7	272.5	4.3	136.6	1,942.4	547.1	998.3	267.4	18.1	111.5
BS	2013	2,449.3	1,084.8	1,020.8	319.2	4.5	20.0	1,977.3	574.3	1,060.7	314.8	11.1	16.5
BS	2014	2,082.3	897.9	917.4	258.1	4.2	4.6	1,730.8	501.5	952.9	254.9	17.6	3.9
BS	2015	2,230.3	972.1	963.1	284.8	2.8	7.4	1,833.2	530.4	1,000.1	282.2	14.3	6.2
BS	2016	2,492.5	1,066.0	1,116.2	300.1	2.7	7.5	2,016.9	546.2	1,159.0	297.8	7.7	6.2
FR	2011	-	-	345.5	150.9	7.9	-	693.1	136.6	347.2	152.3	13.5	43.5
FR	2012	654.3	90.2	345.4	174.0	7.6	37.1	740.2	161.4	347.7	175.8	12.9	42.5
FR	2013	726.8	99.8	393.0	220.3	7.8	5.9	818.7	182.9	396.3	222.0	10.7	6.8
FR	2014	696.1	86.0	422.8	178.2	7.6	1.6	778.1	155.4	427.8	179.5	13.6	1.7
FR	2015	717.8	101.9	400.8	204.5	8.3	2.4	811.8	183.9	404.7	205.8	14.7	2.7
FR	2016	745.7	114.4	405.9	215.2	7.9	2.2	849.6	209.6	409.6	216.5	11.3	2.6
GE	2011	-	-	339.6	468.0	10.6	-	1,532.3	620.5	318.6	473.2	23.7	96.2
GE	2012	2,420.5	1,391.8	345.0	536.4	10.0	137.3	1,702.8	722.2	318.0	542.2	22.7	97.7
GE	2013	2,467.5	1,485.1	358.1	593.9	10.3	20.2	1,734.0	776.8	328.2	597.8	16.8	14.5
GE	2014	2,015.5	1,171.4	348.4	481.3	9.9	4.5	1,455.4	632.1	314.1	484.2	21.8	3.3
GE	2015	2,197.3	1,310.7	337.3	536.2	5.8	7.3	1,541.7	678.9	302.7	538.8	16.1	5.2
GE	2016	2,296.7	1,360.0	353.9	570.4	5.5	6.9	1,618.6	710.1	320.1	573.3	10.1	5.0
GL	2011	-	-	73.7	17.5	1.1	-	142.3	37.7	75.8	17.6	2.2	8.9
GL	2012	142.8	38.9	74.9	20.0	1.0	8.1	151.9	43.4	77.6	20.1	2.1	8.7
GL	2013	155.3	41.0	86.3	25.8	1.0	1.3	164.7	46.5	89.4	25.9	1.6	1.4
GL	2014	151.6	32.4	97.3	20.6	1.0	0.3	162.0	37.7	100.9	20.8	2.2	0.4
GL	2015	156.1	36.5	94.1	24.1	1.0	0.5	165.5	40.6	97.9	24.2	2.2	0.6
GL	2016	154.6	36.5	91.1	25.7	0.9	0.5	165.1	42.6	94.7	25.8	1.5	0.5

GR	2011	-	-	175.8	138.3	5.2	-	465.2	109.5	178.5	138.9	9.1	29.2
GR	2012	512.1	144.1	178.2	155.9	4.9	29.0	502.4	127.0	181.5	156.4	8.5	28.8
GR	2013	565.8	150.7	204.9	200.6	5.0	4.6	557.9	136.2	208.7	201.4	7.0	4.7
GR	2014	510.7	138.7	205.9	160.3	4.7	1.1	491.9	111.6	209.7	160.9	8.6	1.1
GR	2015	522.9	140.1	197.0	178.9	5.0	1.7	510.6	120.1	200.6	179.6	8.5	1.7
GR	2016	546.5	145.3	204.6	190.3	4.7	1.6	533.0	125.9	208.0	191.2	6.4	1.6
JU	2011	-	-	109.7	35.6	2.0	-	180.3	33.2	96.2	36.1	3.4	11.3
JU	2012	207.8	31.6	121.8	40.7	1.8	11.8	198.9	38.8	104.1	41.2	3.3	11.4
JU	2013	205.7	34.2	117.6	50.3	1.9	1.7	194.9	43.9	96.1	50.8	2.6	1.6
JU	2014	200.0	26.4	130.7	40.6	1.8	0.4	189.6	36.1	108.9	40.9	3.3	0.4
JU	2015	198.9	27.6	123.8	45.2	1.7	0.7	190.4	39.0	102.2	45.5	3.1	0.6
JU	2016	198.5	28.7	119.7	47.9	1.6	0.6	190.4	41.1	98.2	48.3	2.3	0.6
LU	2011	-	-	485.7	247.7	10.5	-	1,147.6	310.0	497.1	248.2	20.2	72.0
LU	2012	1,081.7	222.4	513.7	287.1	9.9	48.6	1,261.1	353.0	528.9	287.6	19.2	72.4
LU	2013	1,192.9	235.7	576.3	361.9	10.2	8.8	1,356.7	375.7	592.6	361.9	15.1	11.3
LU	2014	1,103.8	191.6	608.0	292.5	9.7	1.9	1,246.8	305.7	625.7	292.9	19.7	2.8
LU	2015	1,145.8	207.0	594.5	332.4	8.8	3.1	1,293.2	326.2	611.9	332.8	17.9	4.4
LU	2016	1,157.8	218.0	575.2	353.0	8.4	3.2	1,298.8	338.7	590.5	353.1	12.5	4.0
NE	2011	-	-	249.1	102.1	4.8	-	679.8	316.3	206.7	103.8	10.3	42.7
NE	2012	962.9	514.1	269.3	120.3	4.5	54.6	755.0	363.8	215.6	122.3	9.9	43.3
NE	2013	1,005.8	551.5	297.0	144.4	4.7	8.2	795.4	395.0	240.1	146.3	7.4	6.6
NE	2014	893.1	468.9	300.7	117.0	4.4	2.0	701.8	327.7	244.2	118.5	9.9	1.6
NE	2015	936.5	502.9	294.3	132.2	4.0	3.1	743.7	358.2	239.5	134.0	9.5	2.5
NE	2016	958.0	532.9	279.9	138.4	3.8	2.9	757.2	380.9	227.2	140.3	6.5	2.3
NW	-	-	-	-	-	-	-	-	-	-	-	-	-
OW	-	-	-	-	-	-	-	-	-	-	-	-	-
SG	2011	-	-	766.9	285.9	12.9	-	2,084.5	861.8	777.1	284.6	30.2	130.9
SG	2012	2,228.7	950.8	811.7	327.5	12.2	126.4	2,302.6	990.0	825.4	326.2	28.9	132.2
SG	2013	2,409.7	1,047.7	919.0	410.8	12.5	19.7	2,461.4	1,076.7	934.8	408.2	21.2	20.5
SG	2014	2,124.9	826.3	952.0	329.9	11.9	4.7	2,216.6	885.4	969.9	326.9	29.4	5.0
SG	2015	2,260.0	934.8	929.8	376.9	10.9	7.5	2,314.4	960.0	947.0	373.0	26.7	7.8
SG	2016	2,291.5	961.5	913.7	399.0	10.3	6.9	2,361.4	1,013.5	929.4	393.9	17.4	7.3
SH	2011	-	-	152.9	43.0	2.1	-	433.8	205.5	153.6	41.9	5.6	27.2
SH	2012	487.3	254.0	154.4	49.3	2.0	27.6	469.3	233.7	155.3	48.0	5.3	26.9
SH	2013	498.2	267.0	162.7	62.4	2.0	4.1	483.0	251.0	163.3	61.1	3.7	4.0
SH	2014	425.0	213.4	158.6	50.1	1.9	0.9	419.8	205.5	159.0	49.1	5.2	0.9
SH	2015	456.3	232.6	164.3	56.1	1.9	1.5	448.1	221.6	165.1	55.1	4.8	1.5
SH	2016	484.4	248.1	173.8	59.2	1.8	1.5	470.5	232.8	174.9	58.3	3.1	1.4
SO	2011	-	-	285.4	135.4	7.1	-	964.1	481.2	279.0	128.3	15.0	60.5
SO	2012	996.7	482.9	296.2	154.3	6.7	56.5	1,056.1	548.5	286.9	145.8	14.3	60.6
SO	2013	1,060.1	510.3	342.2	192.0	6.9	8.7	1,126.9	589.9	333.2	183.8	10.7	9.4
SO	2014	926.3	409.4	352.7	155.6	6.6	2.1	992.1	482.9	343.6	149.1	14.3	2.2
SO	2015	973.2	443.6	343.9	176.6	5.9	3.2	1,043.5	521.0	336.2	169.9	12.9	3.5
SO	2016	989.0	469.8	322.6	188.0	5.6	3.0	1,054.7	547.4	314.2	181.2	8.7	3.2
SZ	2011	-	-	125.2	74.1	4.1	-	327.5	98.8	126.9	74.4	6.9	20.6
SZ	2012	333.5	93.4	131.9	85.3	3.8	18.9	363.0	115.6	134.2	85.8	6.6	20.8
SZ	2013	373.1	99.1	157.2	109.7	3.9	3.1	405.4	126.2	160.1	110.2	5.5	3.4
SZ	2014	329.8	81.6	155.1	88.6	3.8	0.7	359.8	103.9	159.4	89.1	6.7	0.8
SZ	2015	348.9	93.5	150.3	100.0	3.9	1.2	375.1	112.8	153.8	100.6	6.6	1.3
SZ	2016	355.7	96.2	148.4	106.4	3.7	1.1	384.1	119.3	151.7	107.0	5.0	1.2
TG	2011	-	-	324.3	119.6	6.8	-	1,198.7	656.0	331.0	119.7	16.6	75.3
TG	2012	1,416.3	867.4	323.7	138.5	6.4	80.3	1,311.5	749.9	331.9	138.5	15.9	75.3
TG	2013	1,478.5	919.5	366.6	173.7	6.6	12.1	1,377.6	805.0	375.5	174.0	11.5	11.5
TG	2014	1,325.7	761.4	414.4	140.6	6.3	3.0	1,251.8	666.4	425.4	141.0	16.2	2.8
TG	2015	1,410.4	825.7	414.0	159.6	6.3	4.7	1,321.9	716.3	425.1	160.3	15.8	4.4
TG	2016	1,448.9	848.5	421.2	168.8	6.0	4.4	1,366.9	750.1	433.2	168.9	10.5	4.2
TI	2011	-	-	423.4	240.8	6.9	-	998.8	254.6	423.2	242.1	16.3	62.7
TI	2012	1,003.8	208.8	452.6	279.0	6.5	56.9	1,105.6	293.1	453.3	280.1	15.6	63.5
TI	2013	1,080.2	220.3	504.2	340.2	6.7	8.8	1,198.5	329.1	505.7	341.7	12.1	10.0
TI	2014	1,004.9	188.9	529.1	278.3	6.4	2.2	1,102.7	273.6	530.8	279.6	16.2	2.5
TI	2015	1,058.4	198.8	536.5	313.7	5.9	3.5	1,169.3	296.3	539.3	315.1	14.6	3.9

TI	2016	1,093.4	205.5	544.7	334.3	5.6	3.3	1,209.2	312.5	547.3	335.8	9.8	3.7
UR	-	-	-	-	-	-	-	-	-	-	-	-	-
VD	2011	-	-	577.9	544.8	16.8	-	2,699.8	1,365.0	572.2	553.4	39.7	169.5
VD	2012	3,035.0	1,621.2	592.0	633.8	15.8	172.2	3,026.9	1,587.5	583.3	644.0	38.4	173.7
VD	2013	3,239.4	1,797.1	666.9	732.5	16.4	26.5	3,184.6	1,730.1	657.1	742.5	28.3	26.5
VD	2014	2,757.7	1,462.9	682.4	590.5	15.8	6.1	2,748.2	1,433.4	672.2	598.3	38.1	6.2
VD	2015	2,968.7	1,610.8	659.2	671.3	17.5	9.9	2,937.4	1,560.2	648.9	679.8	38.6	9.9
VD	2016	3,118.0	1,709.3	674.4	708.1	16.8	9.4	3,071.9	1,653.0	665.1	717.5	26.9	9.4
VS	2011	-	-	494.4	180.4	7.3	-	1,218.8	430.9	509.5	184.3	17.7	76.5
VS	2012	1,125.5	371.1	480.3	203.3	6.9	63.8	1,296.1	499.6	498.3	207.2	16.6	74.4
VS	2013	1,204.5	396.0	532.0	259.5	7.2	9.9	1,379.1	540.3	551.4	263.7	12.3	11.5
VS	2014	1,066.4	321.6	529.4	206.2	6.9	2.4	1,220.7	443.0	548.7	209.5	16.8	2.7
VS	2015	1,150.9	364.2	542.4	232.4	8.2	3.8	1,298.0	478.1	562.2	236.0	17.3	4.4
VS	2016	1,195.4	372.4	564.4	247.1	7.8	3.6	1,354.1	502.4	584.6	250.9	12.0	4.2
ZG	2011	-	-	147.5	113.4	3.2	-	411.3	129.7	133.2	116.0	6.6	25.8
ZG	2012	424.8	116.2	150.4	131.1	3.0	24.1	451.0	151.1	134.1	133.7	6.3	25.9
ZG	2013	461.9	122.3	169.7	163.1	3.1	3.8	488.0	163.6	149.7	165.7	4.8	4.1
ZG	2014	410.8	102.2	171.8	132.9	3.0	0.9	430.5	135.7	152.2	135.2	6.4	1.0
ZG	2015	424.5	111.3	160.9	148.3	2.6	1.4	444.9	145.3	141.8	150.5	5.8	1.5
ZG	2016	444.0	116.4	167.4	156.3	2.5	1.3	463.6	151.4	148.0	158.7	4.1	1.4
ZH	2011	-	-	960.0	1,236.9	34.9	-	4,773.1	2,215.4	955.3	1,233.9	68.9	299.6
ZH	2012	5,313.8	2,562.6	993.0	1,423.8	33.0	301.4	5,324.9	2,544.7	987.5	1,420.7	66.4	305.6
ZH	2013	5,667.7	2,749.6	1,117.4	1,720.3	33.9	46.4	5,671.9	2,746.6	1,112.2	1,717.2	48.6	47.3
ZH	2014	4,826.9	2,272.8	1,119.0	1,391.8	32.6	10.8	4,831.0	2,254.0	1,111.1	1,389.4	65.6	10.8
ZH	2015	5,228.1	2,574.0	1,045.9	1,561.6	29.2	17.4	5,215.6	2,541.1	1,037.0	1,559.1	60.8	17.5
ZH	2016	5,551.7	2,843.1	1,011.0	1,653.0	27.9	16.7	5,488.7	2,780.3	999.3	1,651.9	40.5	16.9

Table A-4: Robustness – yearly, electricity, households

Dependent variable:	Eymann		Own (6%)		Own (12%)	
Log electricity consumption of household sector	Coefficient	t Stat	Coefficient	t Stat	Coefficient	t Stat
Log price	-0.177***	[-2.73]	0.132	[1.33]	0.259	[1.39]
Log residents	-0.306	[-1.51]	0.801***	[2.98]	0.878***	[2.64]
Log share of residents aged 65 years and above	-0.115	[-1.16]	-0.341	[-1.33]	-0.525*	[-1.93]
Log income	0.001	[0.09]	0.014	[0.97]	0.017	[0.56]
Log unemployment rate	0.019	[0.98]	0.067***	[3.47]	0.074***	[2.67]
Log houses with heat pumps	-0.002	[-0.20]	-0.070*	[-1.88]	-0.076	[-1.40]
Log houses with electric heating	0.174***	[3.71]	0.501***	[4.15]	0.658***	[6.49]
Log heating degree days	0.142***	[16.01]	0.118***	[6.26]	0.116***	[5.16]
Trend	0.018***	[4.63]	0.012**	[2.07]	0.014	[1.46]
Obs.	130		130		130	
R^2 (within)	0.84		0.77		0.70	
First Stage F-Test (Price)	10.03		10.03		10.03	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistics exceed the weak ID critical values from Stock-Yogo (15%: 8.96) suggesting that price is identified by the instrument (lagged price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table A-5: Robustness – yearly, electricity, industry and services

Dependent variable:	Eymann: Industry		Eymann: Services	
Log electricity consumption	Coefficient	t Stat	Coefficient	t Stat
Log price	-0.265	[-0.88]	-0.168	[-1.47]
Log sites	4.134**	[1.99]	1.722***	[3.21]
Log sites * log employees	-0.436**	[-2.33]	-0.158***	[-3.92]
Log employees	2.869**	[2.01]	2.479***	[5.70]
Log gross value added	1.295**	[2.56]	-0.145	[-0.72]
Log heating degree days	0.056	[1.44]	0.122***	[6.65]
Trend	0.056	[1.44]	-0.008	[-1.56]
Obs.	156		156	
R^2 (within)	0.35		0.46	
First Stage F-Test (Price)	7.04		6.74	

Notes: IV-GMM results derived from two-step feasible GMM estimation. Weak ID critical values from Stock-Yogo: 15%: 8.96; 20%: 6.66. Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table A-6: Robustness – yearly, gas, households

Dependent variable:	**Eymann**	
Log gas consumption of household sector	**Coefficient**	**t Stat**
Log price	0.114	[1.60]
Log residents	-0.414	[-1.04]
Log share of residents aged 65 years and above	0.135	[0.62]
Log income	-0.032	[-0.44]
Log unemployment rate	0.108**	[2.57]
Log houses with heat pumps	0.062**	[2.48]
Log houses with gas heating	1.183***	[39.25]
Log heating degree days	0.776***	[27.07]
Trend	-0.020***	[-4.41]
Obs.	115	
R^2 (within)	0.95	
First Stage F-Test (Price)	76.00	

Notes: IV-GMM results derived from two-step feasible GMM estimation. The first-stage F-statistic exceeds the weak ID critical values from Stock-Yogo (10%: 19.93) suggesting that price is identified by the instrument (lagged gas prices). Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table A-7: Robustness – yearly, gas, industry and services

Dependent variable:	**Eymann: Industry**		**Eymann: Services**	
Log gas consumption	**Coefficient**	**t Stat**	**Coefficient**	**t Stat**
Log price	-0.082	[-1.11]	-0.104	[-0.74]
Log sites	0.150	[0.16]	0.437	[0.33]
Log sites * log employees	-0.106	[-0.97]	-0.076	[-0.82]
Log employees	0.510	[0.46]	4.115***	[4.77]
Log gross value added	1.543***	[3.85]	-0.243	[-0.59]
Log Swiss industry production	2.442***	[6.71]		
Log heating degree days			0.857***	[13.36]
Trend	-0.013	[-1.57]	-0.006	[-0.50]
Obs.	132		132	
R^2 (within)	0.66		0.78	
First Stage F-Test (Price)	19.22		3.94	

Notes: IV-GMM results derived from two-step feasible GMM estimation. Weak ID critical values from Stock-Yogo: 15%: 11.59; 25%: 7.25. Newey-West standard errors robust to heteroscedasticity and autocorrelation. *,**,***: significant at 10%, 5% and 1% respectively.

Table A-8: Robustness – hourly, electricity (canton consumption equations) – no congestion distinction

Canton:	AG	AI + AR	BE + JU	BL + BS	FR	GE + VD	GL	GR	LU
Log price	-0.410***	-0.381***	-0.018	-0.444***	-0.368***	-0.237***	0.520***	-0.0552***	-0.182***
	[-34.41]	[-25.34]	[-1.26]	[-30.38]	[-27.64]	[-14.33]	[6.80]	[-3.08]	[-14.10]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.10	0.22	0.37	0.06	0.29	0.19	0.19	0.53	0.35

Canton:	NE	OW+NW+UR	SG	SH + ZH	SO	SZ + ZG	TG	TI	VS
Log price	-0.506***	-0.506***	-0.299***	-0.320***	-0.429***	-0.314***	-0.400***	-0.462***	-0.305***
	[-26.54]	[-26.54]	[-20.50]	[-18.32]	[-30.37]	[-18.19]	[-28.76]	[-30.43]	[-19.04]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.06	0.42	0.11	0.15	0.14	0.29	0.14	0.24	0.55

Notes: 3SLS results of system of equations with bootstrapped standard errors (100 repetitions). t statistics in brackets. Control variables (not reported): sunshine duration, temperatures and their squares, interactions of the yearly number of plants in different branches and the respective quarterly gross value added, interaction of number of residents and an off-peak dummy, month, day, hour and day-hour dummies. *,**,***: significant at 10%, 5% and 1% respectively.

Table A-9: Robustness – hourly, electricity (price equation) – no congestion distinction

Dependent variable:	**3SLS**	
Log price	**Coefficient**	**t Stat**
Net import	0.134***	[10.39]
Congestion situation	0.313***	[36.58]
Log gas price	0.014***	[2.96]
Log coal price	0.011	[1.03]
Log oil price	0.022***	[3.51]
Log CH CO2 price (gas) - no market power	0.172***	[7.92]
Log CH CO2 price (gas) - market power	0.273***	[5.24]
Log EU CO2 price (gas) - no market power	0.211***	[11.71]
Log EU CO2 price (gas) - market power	0.667***	[6.98]
Log EU CO2 price (coal) - no market power	0.008	[0.34]
Log EU CO2 price (coal) - market power	0.415***	[5.58]
Log EU CO2 price (oil) - no market power	0.024	[0.87]
Log EU CO2 price (oil) - market power	0.305***	[4.87]
Obs.	17420	
R^2	0.99	

Notes: 3SLS results of system of equations with bootstrapped standard errors (100 repetitions). Included calendar dummies for month, day, hour and day-hour (not reported). *,**,***: significant at 10%, 5% and 1% respectively.

Table A-10: Robustness – hourly, electricity (canton consumption equations) – IV-GMM

Canton:	AG	AI + AR	BE + JU	BL + BS	FR	GE + VD	GL	GR	LU
Log price	-0.237***	-0.155***	0.130***	-0.112***	-0.183***	-0.099***	0.249*	0.020	-0.077***
	[-6.97]	[-4.16]	[4.40]	[-3.02]	[-5.43]	[-3.00]	[1.84]	[0.61]	[-2.80]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.41	0.48	0.36	0.46	0.53	0.36	0.25	0.54	0.48
First Stage F	43.95	45.32	45.08	45.04	45.98	45.84	44.39	44.24	45.16
p of Hansen J	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Canton:	NE	OW+NW+UR	SG	SH + ZH	SO	SZ + ZG	TG	TI	VS
Log price	-0.102**	-0.147***	-0.059	-0.138***	-0.195***	-0.145***	-0.214***	-0.053	0.042*
	[-2.19]	[-4.42]	[-1.55]	[-3.73]	[-5.44]	[-4.18]	[-5.22]	[-1.57]	[1.73]
Obs.	17420	17420	17420	17420	17420	17420	17420	17420	17420
R^2	0.46	0.57	0.38	0.50	0.31	0.55	0.47	0.46	0.58
First Stage F	45.53	44.32	43.91	43.98	44.88	44.48	43.39	42.70	44.97
p of Hansen J	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000

Notes: IV-GMM results derived from two-step feasible GMM estimation equation by equation. The first-stage F-statistic always exceeds the weak ID critical values from Stock-Yogo (10%: 21.36) suggesting that price is identified by the instruments (supply shifters as in Table 12). Overidentification test of all instruments is also passed. Newey-West standard errors robust to heteroscedasticity and autocorrelation (order 2). Control variables (not reported): sunshine duration, temperatures and their squares, interactions of the yearly number of plants in different branches and the respective quarterly gross value added, month, day, hour and day-hour dummies.
*,**,***: significant at 10%, 5% and 1% respectively.

Table A-11: Robustness – monthly, electricity

Canton:	**AG**	**AI + AR**	**BE + JU**	**BL + BS**	**FR**	**GE + VD**	**GL**	**GR**	**LU**
Log price	-0.006	-	0.062	0.040	-0.002	-0.004	-0.057	0.002	0.100*
	[-0.10]	-	[1.17]	[1.07]	[-0.05]	[-0.08]	[-0.19]	[0.03]	[1.81]
Obs.	72	-	72	72	72	72	72	72	72
R^2	0.82	-	0.77	0.79	0.84	0.79	0.42	0.87	0.77
First Stage F	44.96	-	58.29	52.90	76.82	54.04	60.12	70.08	51.19

Canton:	**NE**	**OW+NW+UR**	**SG**	**SH + ZH**	**SO**	**SZ + ZG**	**TG**	**TI**	**VS**
Log price	0.059	0.050	0.123*	0.030	0.154**	0.002	0.046	0.012	-0.074
	[1.51]	[0.71]	[1.91]	[0.65]	[1.98]	[0.04]	[0.91]	[0.24]	[-0.85]
Obs.	72	72	72	72	72	72	72	72	72
R^2	0.74	0.83	0.78	0.84	0.73	0.83	0.82	0.81	0.72
First Stage F	63.22	49.54	49.81	55.44	46.76	55.85	50.50	83.24	59.81

Notes: IV-GMM results derived from two-step feasible GMM estimation equation by equation. The first-stage F-statistic always exceeds the weak ID critical values from Stock-Yogo (10%: 16.38) suggesting that price is identified by the instrument (monthly spot price in AT/DE). Newey-West standard errors robust to heteroscedasticity and autocorrelation. Control variables (not reported): temperatures and their squares, interaction of industrial sites and quarterly industrial gross value added, number of houses with electric heating systems, month dummies, and time trend. *,**,***: significant at 10%, 5% and 1% respectively.

A.3 Figures

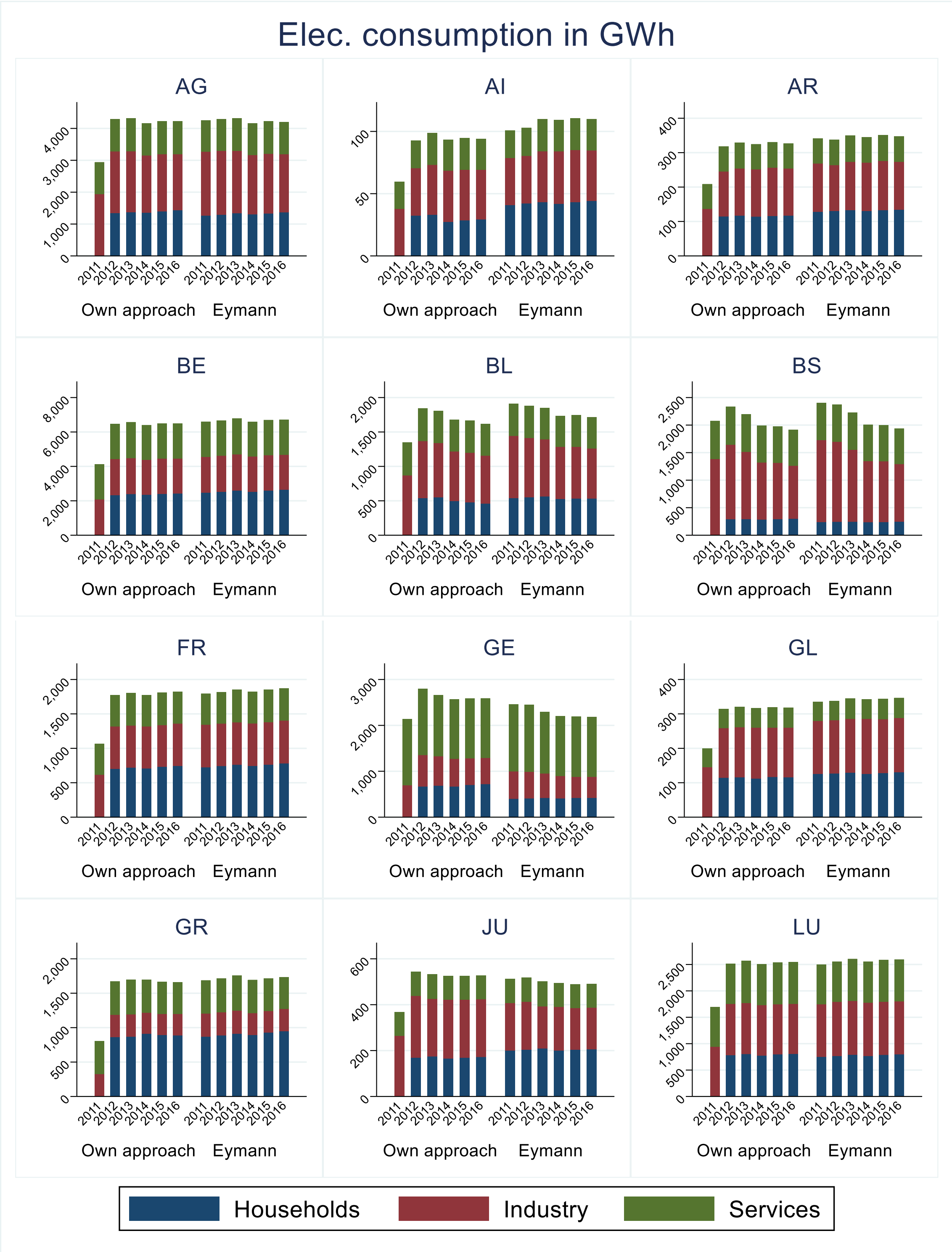

Figure A-1: Electricity consumption by canton, sector, and method (part 1)

Sources: own derivation, Eymann et al. (2014)

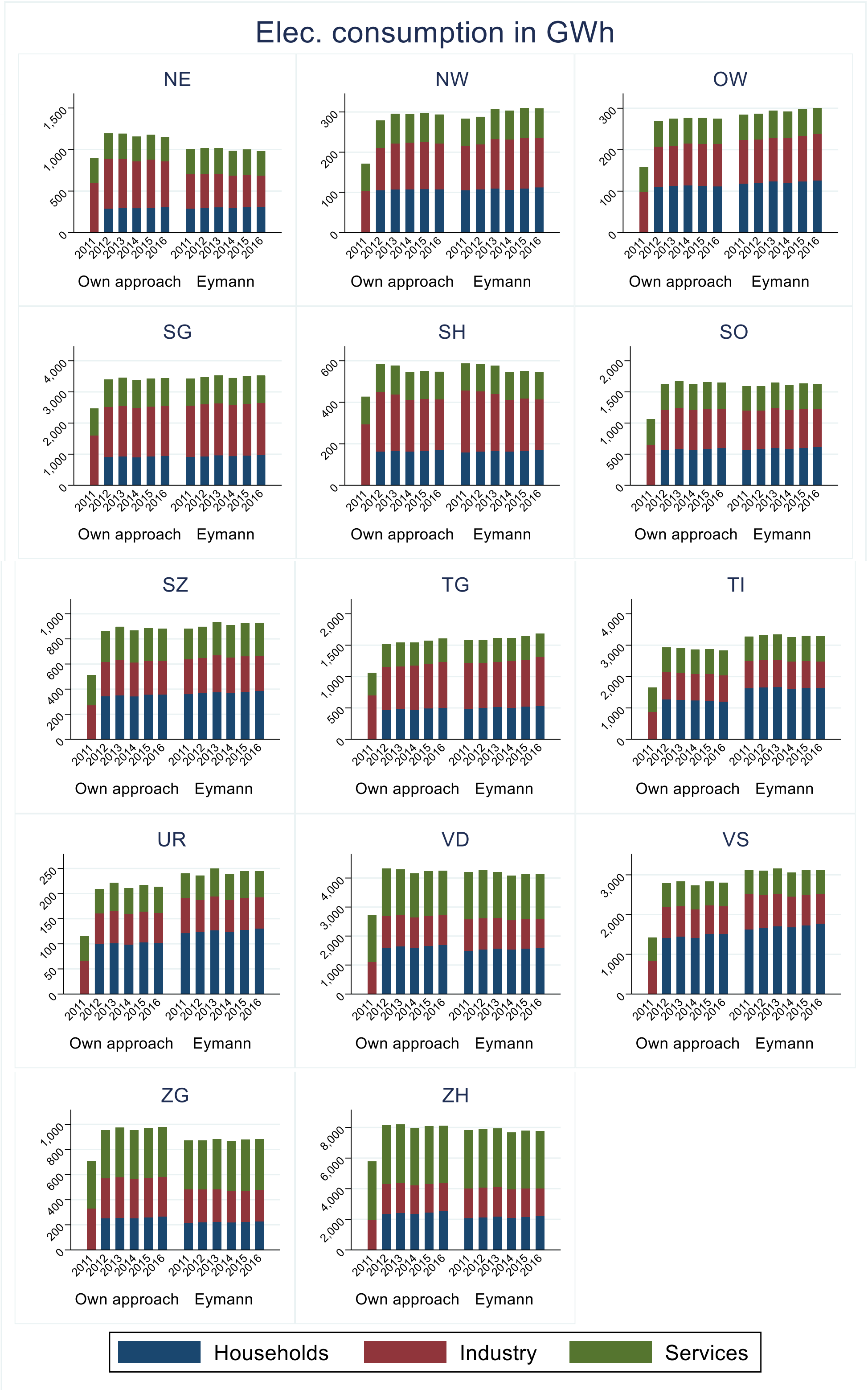

Figure A-2: Electricity consumption by canton, sector, and method (part 2)

Sources: own derivation, Eymann et al. (2014)

Figure A-3: Gas consumption by canton, sector, and method (part 1)

Sources: own derivation, Eymann et al. (2014)

Figure A-4: Gas consumption by canton, sector, and method (part 2)

Sources: own derivation, Eymann et al. (2014)

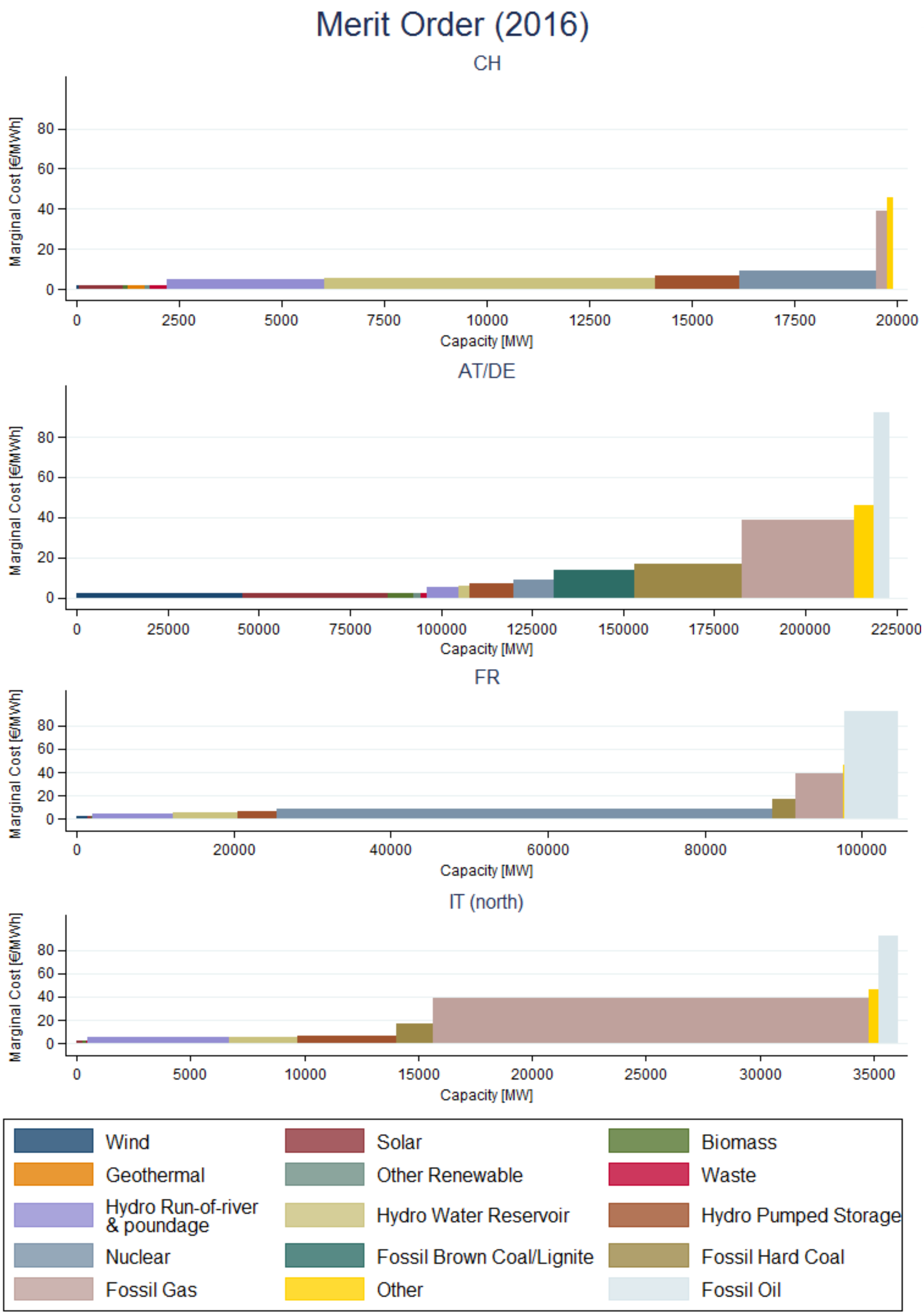

Figure A-5: Country merit-orders

Sources: ENTSO-E Transparency Platform, SFOE