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

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Summary

The research project investigates price elasticities of electricity demand in Switzerland. Hourly demand elasticities are derived for Switzerland using consumption data at the canton level. Special focus is put on the elasticities of households, industry and services. These elasticities are used to simulate and evaluate (regionally distinguishable) demand reactions to energy policies that influence the price of electricity. The research project also analyzes price elasticities of gas demand in Switzerland on a yearly basis.

Zusammenfassung

Das Forschungsprojekt untersucht die Preiselastizität der Stromnachfrage in der Schweiz. Mittels Schweizer Verbrauchsdaten auf kantonaler Ebene werden stündliche Nachfrageelastizitäten ermittelt. Besonderer Fokus liegt dabei auf der Unterscheidung zwischen den Sektoren Haushalt, Industrie und Dienstleistungen. Die Elastizitäten werden für eine Simulation und Bewertung von (regional unterscheidbaren) Nachfragereaktionen auf bestimmte Energiepolitiken, die den Strompreis beeinflussen (wie etwa eine Stromsteuer), verwendet. Zudem wird die Preiselastizität der Gasnachfrage in der Schweiz auf jährlicher Basis analysiert.

Résumé

Le projet de recherche étudie l'élasticité-prix de la demande d'électricité en Suisse. Les élasticités horaires de la demande sont déterminées sur la base des données de la consommation suisse au niveau cantonal. Une attention particulière est accordée à la distinction entre les secteurs des ménages, de l'industrie et des services. Les élasticités sont utilisées pour simuler et évaluer (de façon régionale) les réponses de la demande à certaines politiques énergétiques qui influencent le prix de l'électricité (par exemple une taxe sur l'électricité). En outre, l'élasticité-prix de la demande de gaz en Suisse est analysée sur une base annuelle.

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List of abbreviations

2SLS	Two-stage least squares
CO_2	Carbon dioxide
GMM	Generalized method of moments
IV	Instrumental variable
kW	Kilowatt
kWh	Kilowatt hour
MW	Megawatt
NOGA	Nomenclature Générale des Activités économiques
TSO	Transmission system operator

1 Main Idea

The research project investigates price elasticities of electricity demand in Switzerland. Based on consumption data at the canton level (hourly) demand elasticities are derived. 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. Different exogenous influences or shocks allow the estimation on a price-per-unit-of-energy basis [kWh]. We further use network-charge changes in order to derive an industry elasticity of demand for power [kW] as well as energy [kWh]. A similar investigation is carried out for price elasticities of gas demand in Switzerland – however given limited data availability, with a focus on yearly elasticities.

The identification of fundamental market data allows investigating several aspects. By means of these elasticities it is possible to evaluate demand reactions to (past) energy policies and to simulate demand reactions to energy policies that influence the price of electricity. These policies may – in accordance with SFOE – be investigated at a canton or sectoral level so that heterogeneous distributional effects, e.g. of an electricity tax, may be analyzed.

Thus, the main contribution is twofold. First, as a practical, political contribution, we determine hourly demand elasticities in a representative way for whole Switzerland (this contributes to the existing literature). We use these estimated parameters as well as market fundamentals – i.e. estimated demand and costs – to analyze future demand reactions. Thereby we can analyze welfare impacts of different energy policies. Second, as a more scientific contribution, we use hourly data on demand in the different cantons as well as the aggregated yearly demand of the cantons' customer groups as weights in estimation restrictions to finally derive hourly individual customer group elasticities. More specifically, we estimate weights for household, industry and services in each hour and each canton under the restriction that each of these groups meets its yearly demand value reported from other statistical sources.

2 Policy Relevance

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. The results of the proposed research project will give a better understanding of the behavior of Swiss electricity customers. In addition, distributional effects across cantons can be identified and the efficiency and effectiveness of different policy instruments in Switzerland can be evaluated.

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 outweigh the positive effects of saving CO_2-emissions. The same applies to the optimal dynamic taxation, i.e. the question how to determine optimal time-varying taxes, e.g. on an hourly basis. 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.

3 Methodology

We estimate structural single-equation and system-equation models in order to determine price elasticities of demand in a static partial equilibrium model. Thereby, we model demand as a function of price, network charges, business cycle, income, temperature, sunshine hours and time amongst others, and supply as a function of input prices, availability generation capacities and (cross-border-exchange-adjusted) generation from volatile renewables amongst others. We use state-of-the-art two-stage models.

By controlling for simultaneous supply and demand shocks (through instrumental variable (IV) techniques such as two-stage least squares (2SLS) as well as (system) IV-GMM methods) 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. Furthermore, we are able to identify the detailed structure at different times of the day and along different residual load levels by the inclusion of several exogenous (hour and month dummies) and endogenous (non-linear demand functions like bins and splines) interaction terms with the treatments. In addition, structural price-independent demand variation is accounted for by load profile controls.

We use these fundamental market characteristics for simulation studies. Given a certain Swiss policy option, we will calculate the corresponding demand reactions (which can be distinguished by customer group and hour of the day). Our methodological framework allows us to draw conclusions about future consumer and producer surplus impacts of different policy options for Switzerland – differentiated by canton or customer group. Shifts in taxes simply act as marginal cost add-on variations. Depending on demand and supply elasticities, a tax increase will lead to a reduction in market equilibrium quantities and a corresponding welfare loss. This additional information about allocative inefficiency in addition to production inefficiency is a major advantage over traditional system cost-minimizing models.

4 Data

We build upon both Swissgrid data for canton-level electricity demand and production, and on an existing rich and unique database on European electricity markets at ZEW, which we extend. The data set contains information on electricity wholesale and commodity (coal, gas, oil) prices, consumption, import and export data received from auction offices and TSOs and detailed information on wind and solar generation forecasts as well as the installed capacity by fuel type in most European countries and especially Swiss neighboring countries. We further use weather condition data (such as temperature, sunshine duration, and heating degree days) as exogenous market equilibrium shifters. These data are also used with respect to neighboring countries to include their influence on Swiss market equilibria. This data is available on a consistent and hourly basis since January 2015 (yearly values are available since 2011).

Customer groups are identified building on previous work by Eymann et al. (2014). They describe a procedure to approximate the shares of household, industrial and services sectors on canton-level energy demand using publicly available data. Specifically, they employ shares of single-/multi-family houses and their respective type of heating to identify the cantons' household demand. Information on nationwide demand by industry and on their respective size (number of firms and employees) in each canton is used to derive the demand of the cantons' industrial and services sectors. The selection of sectors is based on the SFOE publication "Energieverbrauch in der Industrie und im Dienstleistungssektor" comprising 19 manufacturing and services branches that translate to 85 NOGA branches. Eymann et al. (2014) estimate yearly demand values for 2011. We validate and improve this procedure updating it to the most recent data. That is, we approximate the shares of household, industrial and services sectors on canton-level electricity and gas demand for the years 2011-2016, which is used as input for the estimation of demand elasticities.

5 Work undertaken and outlook

The first months of the project time were dedicated to building a sound and rich database. Data being already present at ZEW was validated and updated. Additional data sources have been detected and the respective data retrieved and incorporated into the dataset. Special focus was put on gas data. While all main variables are available for the time period 2011-2016, some control variables regarding canton characteristics in 2016 are still not available but seem to be finally published by the end of 2018. Accordingly, the final analyses can be conducted within the project's time frame.

In 2018 two main tasks were carried out. On the one hand, canton-level consumption by customer groups was identified using the approach of Eymann et al. (2014). The replication of their approach disclosed potential for improvement which accordingly was tapped. The undertaken adjustments promise a better representation of canton-level variation. While the result of this approach yields canton-level consumption data at the year level, a further break-down to a higher time resolution is necessary in order to estimate hourly elasticities. Several methods were designed and implemented, which are based on the idea to use variation in the different sectors during the year to allocate their yearly values along the year.

The second main task was to implement the empirical approach to estimate demand elasticities and to run first regressions. The dataset allows carrying out analyses at different levels. For gas and electricity, yearly analyses can be undertaken for the years 2011-2016. In addition, for electricity analyses at the monthly level are possible for the years 2011-2016 as well as analyses at the hourly level for the years 2015-2016. While the general approach is similar for all time resolutions, we have to especially account for price-independent demand in the hourly and monthly analyses. This is mainly achieved by using load profile controls.

The implemented approach already yields plausible elasticity estimates of household demand for gas and electricity. Regarding the industry sector and the hourly estimates, refinements of the model will be implemented as the current dataset does not produce plausible findings. The models will be reevaluated once full information for year 2016 is available (the current hourly estimates are thus only based on one year). After final estimates of demand elasticities are obtained, subsequent simulation studies will be conducted to assess demand reactions to energy policies.

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