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Underlying energy efficiency and technological change in the Swiss household sector

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Project goals

More than 60% of the energy end-use consumption in Switzerland originates from fossil fuels. In 2014, the residential sector consumed nearly 30% of the total final energy consumption in Switzerland and about 58% of the energy end-use consumption of households was based on fossil fuels (BFE, 2015). Improving the energy efficiency in the residential sector is therefore one of the strategies to reduce total fossil energy consumption and related CO_2-emissions in Switzerland, in order to eventually meet the energy policy goals established in the Swiss 'Energy Strategy 2050'.

When thinking about reducing the energy consumption of households, three important questions arise: (1) How large are the potentials for energy savings in the Swiss residential sector for a given level of energy services? (2) How big are the differences in the levels of energy efficiency among Swiss households and to what extent are these differences driven by energy policy measures or behavioral factors? (3) What role does technological change play for the reduction of energy consumption in Swiss households? To answer these questions it is important to remember that a household's energy demand is not a demand for energy per se but a derived demand for energy services, such as cooling, heating, cooking or lighting. A reduction in energy consumption for the production of a given level of energy services can be achieved either by improving the level of efficiency in the use of inputs (i.e. in the use of appliances), by adopting a new energy-saving technology (i.e. purchase of new appliances, investments in energy-saving renovations) or by both processes. Technological change can induce a reduction of energy consumption for a given level of energy services, provided that the inputs are used in an efficient way, i.e. given that the households are productively efficient. The total reduction in residential energy consumption is therefore a result of the interplay of technological change and a household's behavior.

The level of energy efficiency of Swiss households can be measured with a bottom-up approach, by making an on-site efficiency analysis of buildings. However, with such an economic-engineering approach, the behavioral aspects in energy use are not accounted for and it is not based on the microeconomics of production. In this project, we therefore estimate a household's level of energy efficiency with mathematical and statistical methods, accounting for total energy consumption and factors such as size and characteristics of the residence, household composition, number and type of appliances, number of energy-services consumed, as well as socio-economic and demographic variables and energy-related behavior. With this approach a 'fair' benchmarking of Swiss households with respect to their energy consumption can be performed.

The existing literature on the measurement of the level of energy efficiency in the residential sector using an economic approach is relatively small. Filippini and Hunt (2012) measure the level of energy efficiency in the residential sector in the US using aggregate (state level) data. Results of another study using disaggregated data for a sample of US households are presented in Alberini and Filippini (2015). Recently,Weyman-Jones et al. (2015) estimated an energy input demand frontier function originally proposed by Filippini and Hunt (2011) using a cross-sectional household dataset from a survey in Portugal. Thus, they are one of the first to estimate energy efficiency using stochastic frontier analysis (SFA) with disaggregated household survey data. However, the model used by Weyman-Jones et al. (2015) is relatively simple and with few explanatory variables. To our knowledge, no studies have been published on the estimation of the total residential energy demand function and on the estimation of the level of efficiency in the use of energy in Swiss households. Moreover, the relation between energy demand, technological progress and efficiency in the use of energy has not been analyzed so far for the residential sector.

The goal of the project "Underlying Energy Efficiency and Technological Change in the Swiss Household Sector" is to estimate an energy demand frontier function for a sample of Swiss households using panel data that is collected by means of a large household survey in Switzerland. The household survey is carried out in cooperation with nine Swiss utilities supplying major urban and suburban areas in different parts of Switzerland with electricity and gas. The survey will deliver data on several thousands of Swiss households. In a first step, the project aims at providing a comprehensive overview of energy consumption in Swiss households. Based on descriptive statistics, information on the size and characteristics of the residences of Swiss households, on household size and composition, energy services, appliances, sociodemographics as well as energy-related attitudes and behaviors will be provided. In a next step, the level of energy efficiency in Swiss households will be estimated with the above described econometric approach. The impact of energy policy instruments and behavioral factors on the level of efficiency in the use of energy will be analyzed. The results of this project will thus contribute to the political debate by offering an estimate of the energy saving potential in the residential sector in Switzerland using an economic rather than an economic-engineering approach. In addition, insights on the role of technological change, behavioral factors as well as energy policy measures for residential energy consumption in Switzerland will be gained.

Completed work and intermediate results

As a first step, a mathematical model of household energy demand was developed, starting from the fact that a household's energy demand is not a demand for energy per se, but rather a derived demand for energy services. The microeconomic theory of production (Huntington, 1994) was applied to establish the relation between energy demand, energy efficiency and technological change. The model is based on a household production model in which we assume that households purchase inputs such as energy and capital (i.e. appliances, electronics, light bulbs, heating and cooling systems) on the market to produce energy services. The latter appear as arguments in the household's utility function. At the same time, they are the outcome of an associated household production function. From an economic point of view, the production of energy services should be as efficient as possible, i.e. the amount if inputs used to produce these services should be minimized.

Based on the model, we conducted a systematic analysis of the relation between energy demand, energy efficiency and technological change and discussed the concepts of productive efficiency, energy efficiency, technological change and energy efficiency gap within the framework of the household production theory. This work provides the basis for the subsequent empirical analysis: the econometric estimation of a stochastic frontier function (Aigner et al. 1977) for energy demand, as introduced by Filippini and Hunt (2011).

As a second step, CEPE initiated a large household survey in cooperation with nine Swiss utilities with the aim of collecting the data needed to estimate the level of energy efficiency in Swiss households. The survey questionnaire was developed based on insights from the survey methodology literature (Dillman et al., 2009; Groves et al., 2004) as well as from earlier household surveys on residential energy consumption (Alberini et al., 2013; VSE, 2011). It was peer-reviewed by researchers and professionals in the field of household energy consumption, and finally pre-tested on a student sample (ETH Master students). The questionnaire was examined and approved by the Ethics Commission of ETH Zurich under the reference EK 2015-N-06 and implemented online with the survey software SurveyMonkey. The utilities were informed that survey participants will be asked for the permission to combine the survey data with actual electricity consumption (and gas consumption, if applicable) data

from the utilities, based on their customer number. This would allow the joint analysis of the survey data and the actual consumption data of the participating households. In exchange, CEPE promised all participating utilities to provide them with a brief report of the survey results.

The nine utilities invited either all or a subsample of their customers to take part in the online survey. If subsamples of customers were drawn, all household customers had the same probability of being in the sample (random sampling). For a majority of the customers, the invitation was sent in the form of a letter that accompanied a bi-monthly, quarterly or yearly electricity or gas bill. If the utility had access to some of their customers' e-mail addresses the letter was attached in PDF to an e-bill. Two utilities used personalized invitation letters (i.e. personal address at beginning of letter, personal customer/service number included in the letter) that were sent under separate cover. The invitation letter briefly informed the customer about the purpose and content of the study as well as about data security and usage of the data. In addition, it included a clear description how to access the online questionnaire by following a specified hyperlink. Furthermore, it was announced that all customers that complete the online questionnaire will take part in a lottery. The invitation letter also included a disclaimer with a short version of the conditions of participation, an information about the right of withdrawal from the study, as well as an e-mail address for further enquiries about the study and the questionnaire.

The total number of visits on the survey page is expected to reach about 10'000 to 12'000 by the time of closing the last survey page. Accounting for the fact that not all respondents complete the online questionnaire till the end, a total of about 7'000 to 9'000 completed questionnaires can be expected from this household survey. About 6'500 to 8'500 of the completed questionnaires can be expected to include the household's consent to the linking of the survey data to the actual consumption data of the household. Weighting techniques will be applied to establish representativeness of the collected survey data. This will prepare the ground for measuring the level of energy efficiency in Swiss households.

National cooperation

For the organization of the household survey we cooperate with nine Swiss utilities that operate in nine major urban areas in Switzerland, among them Aziende Municipalizzate Bellinzona (AMB), Aziende Industriali di Lugano (AIL), Services Industriels Lausanne (SiL), Energie Service Biel/Bienne (ESB), Energie Wasser Luzern (EWL), Stadtwerk Winterthur (SW), IBAarau, IWB Basel and Energie Wasser Bern (EWB). One of the criteria for the selection of these utilities was that they should operate mainly in urban areas in order to get a sample of households as homogeneous as possible in terms of environment. In addition, we predominantly approached multi-utilities that supply households not only with electricity but also with gas for heating, warm water and/or cooking, as this allows to expand the analysis to total energy consumption (at least for a subsample of the households). Furthermore, we wanted the utilities to represent all three major language areas of Switzerland. The final sample is expected to provide a good representation of Swiss households residing in urban and suburban areas of Switzerland, i.e. to be representative not on the regional but on the national level.

Evaluation 2015 and outlook 2016

With this report, the first milestones of the project are reached. The mathematical modelling part of the project is completed. The concepts of productive efficiency, energy efficiency, technological change and energy efficiency gap were discussed within the framework of the household production theory. The data collection has been successfully started and will be, to a large extent, completed by the end of 2015. A second round of data collection will be continued until May 2016, predominantly covering the customers of EWB Bern.

Once the first round of data collection is completed, the econometric analysis of the dataset can be started. This can be expected for January 2016, when most of the surveys are completed. The work on several scientific publications on the results of the econometric analyses has already been started and will be continued in 2016. To document the next steps, CEPE will provide BFE with intermediate reports on the ongoing work every six months, each with a different focus.

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