Energy Policy 102 (2017) 512–528

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Price and income elasticities of residential energy demand in Germany

Isabella Schulte[a], Peter Heindl[b,*]

[a] University of Heidelberg, Germany
[b] Centre for European Economic Research (ZEW) L7 1, D-68161 Mannheim, Germany

ARTICLE INFO

JEL classification:
D12
Q41
Q54

Keywords:
Energy consumption
Price elasticities

ABSTRACT

We apply a quadratic expenditure system to estimate price and expenditure elasticities of residential energy demand (electricity and heating) in Germany. Using official expenditure data from 1993 to 2008, we estimate an expenditure elasticity for electricity of 0.3988 and of 0.4055 for space heating. The own price elasticity for electricity is −0.4310 and −0.5008 in the case of space heating. Disaggregation of households by expenditure and socio-economic composition reveals that the behavioural response to energy price changes is weaker (stronger) for low-income (top-income) households. There are considerable economies of scale in residential energy use but scale effects are not well approximated by the new OECD equivalence scale. Real increases in energy prices show a regressive pattern of incidence, implying that the welfare consequences of direct energy taxation are larger for low income households. The application of zero-elasticities in assessments of welfare consequences of energy taxation strongly underestimates potential welfare effects. The increase in inequality is 22% smaller when compared to the application of disaggregated price and income elasticities as estimated in this paper.

1. Introduction

The response of consumers to changes in prices of goods is instrumental for any ex ante assessment of the welfare consequences of taxation. In particular in the case of taxes (or subsidies) on energy or taxes on the carbon content of fossil fuels, such assessments are of importance for at least two reasons: First, they allow for an appraisal of the expected quantitative response of demand. Second, they allow for an estimation of the incidence of carbon or energy taxation. Both aspects are relevant for the design of energy and climate policy.

This paper contributes to the literature by providing detailed empirical information on energy demand of households in Germany. We use official German income and expenditure microdata at the household-level (Einkommens- und Verbrauchsstichprobe, EVS) to estimate a quadratic expenditure system (QES) and derive expenditure elasticities and price elasticities for a number of goods, including electricity, space heating, transportation, food, clothing, housing, health, mobility and education. The results are disaggregated in order to provide evidence on the demand of different household types (singles, couples, with and without children). This demographic translation is used to assess demand at the household level and it allows a cross-evaluation of the 'new OECD equivalence scale', which is used to compare income or expenditure across households of different sizes. In addition, the elasticities are estimated at different loci of the expenditure distribution (i.e. the quartile means of the total expenditure distribution) in order to provide richer information of the impact of total expenditure on energy consumption and substitution patterns. These results are eventually used to assess the incidence and welfare consequences of energy taxation in a counterfactual scenario.

Our work is related to different strands of literature and it augments a number of studies on energy consumption. In this canon of articles, evidence on energy consumption for many countries can be found. The literature - which we cannot review in full length here - ranges from macroeconomic aspects of energy consumption[1] and energy price shocks (Kilian, 2008) to the estimation of price and income elasticities of final consumption based on microdata. This article in particular is related to the estimation of price and income elasticities based on household micro-data.

Espey and Espey (2004) provide a meta-analysis of long-run and short-run price and income elasticities of residential electricity demand. One important finding of the meta-analysis, in which results from different methodological approaches are compared, is a statistically significant difference in price elasticities derived from dynamic vs. non-dynamic models. Dynamic models tend to produce smaller elasticities (p. 71).

* Corresponding author.
E-mail address: heindl@zew.de (P. Heindl).

[1] See for example with regard to the 'energy-growth nexus': Ajmi et al. (2013), Narayan et al. (2008), Narayan and Prasad (2008), Narayan and Smyth (2009).

http://dx.doi.org/10.1016/j.enpol.2016.12.055
Received 15 July 2016; Received in revised form 29 November 2016; Accepted 31 December 2016
0301-4215/

Fouquet (2014) examines the demand for energy in the United Kingdom over the past two hundred years and notes that both - the income and price elasticity of energy demand - decreased over time (p. 13). This pattern is consistent with the theory of declining marginal utility in consumption and related saturation effects (p. 18). However, other aspects, such as technological development and the emergence of energy markets also play an important role in explaining the observed trends. Another important aspect is that the demand for energy services is (among other things) contingent on national income or economic development. Thus, strong differences in price and income elasticities are to be expected for industrialised countries when compared to less advanced economies.

Narayan et al. (2007) examine the household electricity demand in the G7 countries over several decades. In a panel cointegration framework, Narayan et al. (2007) use per capita annual electricity consumption as dependent variable and per capita income as well as energy prices as explanatory variable. The authors find strong evidence for panel cointegration, which implies that there are deterministic or stochastic trends in the time-series data, for example economic trends as described by Fouquet (2014). Narayan et al. (2007) find that long-run residential demand for electricity in the G7 countries is income inelastic and price elastic. Similar approaches are used to forecast energy consumption (Pourazarm and Cooray, 2013; El-Shazly, 2013) or to assess potential energy savings (Salari and Javid, 2016).

Krishnamurthy and Kriström (2015) provide an empirical analysis of electricity demand, i.e. by estimating price elasticities for selected OECD countries based on household survey data from 2011. The sample does not include Germany, the country considered in this study, and there is no differentiation by income or size of households. However, Krishnamurthy and Kriström (2015) find rather strong differences in the price sensitivity of consumers across the considered countries. Price elasticities range from about −0.3 (South Korea, the Netherlands) up to −1.5 (Australia).

Brounen et al. (2012) examine the driving forces of residential energy use in the Netherlands with a strong focus on demographic characteristics. Their main findings are that space heating is largely determined by the characteristics of the occupied dwelling (space, age, building type) while electricity consumption is strongly driven by household composition. These results imply that equivalence scales for electricity consumption and space heating may differ because of the different driving forces of consumption. With respect to space heating Rehdanz (2007) and Meier and Rehdanz (2010) also find a strong influence of non-pecuniary variables (i.e. property ownership). Furthermore, Rehdanz (2007) shows that the actual type of heating system - in particular the type of used fuels - can have a strong influence on the price sensitivity of households.

Meier et al. (2013) investigate the relationship between household income and expenditure on energy services in the United Kingdom. As a key-result, Meier et al. (2013) find that the income elasticity of electricity and gas demand is contingent on household income. Households with low income exhibit a rather low income elasticity of energy demand (about 0.2). Households at the top end of the income distribution exhibit an income elasticity of up to about 0.6.

Over the last decades, attempts have been made to place empirical examinations of household consumption in a comprehensive theoretical framework (Deaton, 2016). These demand systems allow the estimation of income, price, and cross-price elasticities per commodity and are based on an indirect utility function. We describe the demand system applied in this article in detail in the following section. However, there are a number of relevant contributions which we want to highlight here. Baker et al. (1989) apply a two-stage model of energy demand to British expenditure data. In a first step, durable good equipment is modelled which, in a second step, determines the energy demand of households. Baker et al. (1989) emphasise that the welfare cost of subsidising or taxing fuel prices will differ substantially across households with differing income and other characteristics. This perspective on energy prices is of particular importance in relation to climate policy which may lead to increasing energy prices. Demand systems are used to assess the welfare consequences of climate policy related changes in energy prices: for instance by Labandeira et al. (2009) for the case of Spain and Pashardes et al. (2014) for the case of Cyprus. Rising energy prices lead to a regressive pattern of incidence and have a non-uniform impact on different household types (e.g. differentiated by location or demographic composition).

Kohn and Missong (2003) estimate a quadratic demand system based on German household expenditure data but do not consider energy consumption as a separate good. Instead energy consumption is comprised in the commodity group ‘housing’. Nikodinoska and Schröder (2016) estimate a demand system based on German household expenditure data to examine the consequences of car fuel surcharges and find a moderately regressive impact. Nikodinoska and Schröder (2016) also derive price and income elasticities for several types of goods but do not further investigate differences in consumption contingent on household type and composition.

Our results show that there are considerable differences in price and income elasticities of energy consumption - i.e. with regard to electricity consumption and space heating - across income levels and household types. Energy services clearly have the notion of a necessary good. Energy demand of low-income households shows a weak reaction to changes in energy prices. Energy demand of households belonging to the upper 25% of incomes is about factor three times more price-elastic when compared to households belonging to the lowest 25% of incomes.

The observed consumption and substitution patterns have several important implications. First, an increase in energy prices will cause a moderate reduction in consumption of low-income households, while households belonging to the upper brackets of the income distribution show a more pronounced change in demand. Second, a given change in energy prices, has a significantly different impact on households' welfare as a result of the price change. Welfare losses (expressed as compensating variation) tend to be large for low-income households and/or ‘small’ households (e.g. single households). Thus, a given change in energy prices will impose unequal burdens on the considered types of households, which is at odds with many principles of just taxation (Musgrave, 2002). Finally, the observed consumption patterns will have a bearing on the affordability of energy services, as low-income households face larger burdens compared to wealthier households. This, prima facie, justifies a ‘priority view’ on low-income households in the design of energy and climate policies (Parfit, 1997).

These results have some direct policy implications related to energy and climate policy in Germany. In recent years, German electricity prices have increased strongly, inter alia because of a surcharge for renewable energy promotion levied on top of the electricity price. Thus, an important part of the German ‘energy transition’ towards renewable energy is financed via the surcharge on electricity prices. While this scheme is very effective in promoting renewable energy carriers it also causes rather unequal relative burdens for different household types, which are discussed in detail in this article. One of the most salient features of this policy is, that it tends to increase economic inequality among households. Therefore policy-makers face a trade-off between effective renewable energy promotion (or other policies which might increase energy prices) and aspects of vertical equity in taxation. The results presented in this paper can be used to further investigate such trade-offs based on the price and expenditure elasticities which are reported in detail. Such ex ante assessments of the expected changes in energy demand and relative burdens can be highly useful in order to design climate and energy policies in an efficient, effective, and non-regressive manner.

The remainder of this paper is organised as follows. Section 2 presents a description of the quadratic expenditure system. Section 3 provides a detailed data description and a description of the estimation procedure. Section 4 comprises the discussion of the empirical results. Section 5 concludes.