ESTIMATES FROM AN ENERGY DEMAND SYSTEM: EVALUATING THE EFFECTS OF ELECTRICITY PRICE CHANGE ON CO_2 EMISSIONS AND POVERTY IN GERMANY

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Overview

In every developed country, the household sector is one of the major final energy consumers. In Germany, one of the countries with strong preferences for renewable energy and environmentally sustainable energy policies, residential demand for final energy constitutes one third of final energy consumption. Households are also the second largest contributor to CO_2 emissions (21.6% in 2013). One of the main goals of climate change mitigation policies in Germany and in the EU is to reduce the energy consumption of the residential sector. Energy and carbon taxes have been among the most important policy instruments for limiting consumption and achieving the emissions reductions targets.

The assumption that consumer response to tax and price change is the same is increasingly questioned in the literature, especially for energy goods (Ghalwash, 2007; Brockwell, 2013; Li et al. 2014; Tiezzi and Verde, 2016). The difference between the reactions to change in the energy tax as opposed to change in the producer price is known as the tax signalling effect. In order to better understand the behavioural responses, it is important to empirically investigate households' reactions to change in the energy taxes for the various energy commodities: electricity, gas, district heating, and car fuels. Such examination is particularly important in the face of increasing prices of energy goods and energy or environmental taxes.

For that purpose, we study how the changes in energy taxes and prices influence the consumption patterns of German households with the help of Demographically-scaled Quadratic Almost Ideal Demand System (DQAIDS). Moreover, by using tax simulations we study how changes in tax and price in electricity or car fuels affects households' CO_2 emissions, poverty, welfare, inequality and government's tax revenues.

Methods

For our policy analysis, we employ the estimates from a Demographically-scaled Quadratic Almost Ideal Demand System (DQAIDS) following Banks et al. (1997) and Blakow et al. (2010). Using the approach of Ghalwash (2007) and Brockwell (2013), we allow for different responses of consumer demand to energy tax and price changes. Let p_j denote the consumer price for good j. Then we separate the consumer price into producer price and energy tax: $p_j = \bar{p}_j \tau_j$ in order to be able to distinguish the signaling effect in response to tax change in comparison to changes in the producer price. To ease notation household and time period subscripts are suppressed. The estimable demansystem then takes the following form:

$$(1)\quad w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(\bar{p}_j) + \sum_{j=1}^{n} \tilde{\gamma}_{ij} \ln(\tau_j) + \left(\beta_i + \sum_{s=1}^{t} \theta_{is} z_s\right)\left(\ln(m) - \ln\left(a(\bar{p},\tau)\right) - \ln(1 + \sum_{s=1}^{t} \rho_s z_s)\right) + \left(\frac{\lambda_i}{(b(\bar{p},\tau)c(\bar{p},\tau,z))}\right)\left\{\left(\ln(m) - \ln\left(a(\bar{p},\tau)\right) - \ln\left(1 + \sum_{s=1}^{t} \rho_s z_s\right)\right)\right\}^2 + u_i$$

$i = 1, \dots, n$ denotes the number of goods included in the system; w_i stands for the expenditure share of good i in total expenditures m; $\bar{p}_j$ stands for the producer price of the jth good; τ_j represents the energy tax; $a(\bar{p},\tau)$ is the subsistence level; z_s stand for demographic variables; $s = 1, \dots, t$ denotes the number of demographic variables included in the system; $b(\bar{p},\tau)$ is the bliss level; $c(\bar{p},\tau,z)$ is a simple Coubb-Douglas price aggregator; $\alpha_i, \beta_i, \gamma_{ij}, \tilde{\gamma}_{ij}\ \rho_i, \theta_i, \lambda_i$ are the parameters to be estimated; α_0 is set at the lowest level of natural logarithm of total expenditures in the base year (2003). Several restrictions are imposed on the parameters in order to ensure adding up of the budget constraint, homogeneity of degree zero and Slutsky symmetry:

$$(2)\quad \sum_i \alpha_i = 1,\ \sum_i \beta_i = 0,\ \sum_i \lambda_i = 0,\ \ \sum_k \gamma_{kj} = 0,\ \sum_k \tilde{\gamma}_{kj} = 0,\ \sum_i \theta_{i1} = \sum_i \theta_{i2} = 0.$$

Results

We find that the German households are much more responsive to changes in the taxes of energy goods than to changes in the producer prices. Electricity is found to have rather high own price elasticity: 1 percent increase in the producer price of electricity; demand would decrease by 0.736 percent. Demand for electricity is even more responsive to changes in the energy tax on electricity: the energy tax elasticity is found to be -2.603. The same holds true for the response of car fuels demand to changes in producer price and energy tax. Demand for car fuels would decrease by 0.972 percent if producer price increases by 1 percent but would drop by 1.191 percent if energy tax increases by 1 percent. The expenditure elasticities shows that electricity and other fuels are necessity goods while car fuels are a luxury good. We find evidence that there are differences in demand responses of the various households' types. Single parent households are most responsive to electricity price changes while couples without children are most responsive to electricity tax changes. Concerning the demand for car fuels, single adult households are most responsive to price changes and households with two and more adults with children are least responsive. Single adults and couples without children have the largest consumption decreases in response to increase in the car fuels tax.

The changes in car fuels and electricity tax in our scenarios are chosen so that to represent 25 percent energy tax increase. The increase is translated into 11.6 percent increase in the price of electricity and 8.9 percent increase in the price of car fuels. If the energy tax on car fuels is increased by 0.15 euro, car fuels related emissions would decrease by 15.7 percent and electricity related emissions would decrease by 27.3 percent. The tax burdens for car fuels and electricity are higher than the status quo. Poverty decreases but households' welfare decreases on average by 1234 euros. Government energy tax revenues decrease by 10.3 percent. If the producer price of car fuels is increased, both car fuels and electricity emissions and the respective tax burdens decrease. Government tax revenues are 20.6 percent lower and the cost of living is 2.9 percent higher.

The results from the electricity scenarios confirm the results of the car fuels scenarios: namely households are much more responsive to changes in the tax than to changes in the price itself. If the electricity tax is 0.02 euro higher, electricity related emissions go down by almost two thirds. If the price increases by an equivalent amount, electricity related emissions decrease by one third. Consequently, the government tax revenues under both scenarios are lower than in the status quo. If the energy taxes on both car fuels and electricity are increased, demand for electricity will be 64.4 percent lower and demand for car fuels would be 22.6% lower than in the status quo. The electricity tax burden reduces drastically while the change in the car fuels tax burden is moderate. In the final scenario, electricity related emissions decrease by 21.5 percent and car fuels related emissions decrease by 11.3 percent in response to prices increases. Overall, due to the large tax elasticities and consequently large quantity reductions, government tax revenues decrease in all scenarios even though the tax levels are increased. The effects of the scenarios on the variables of interest differ across the household types.

Conclusions

Estimating the residential energy demand is an important part of policy design of any country. In the face of increasing energy taxes and prices, it is important to investigate the amounts of welfare and emissions changes among German households. Our estimates indicate that electricity is a necessity good while car fuels are luxury good in Germany. The price elasticities of electricity and car fuels are much lower than their tax elasticities, making us conclude that an energy tax increase would cause a much larger reduction in demand than an equivalent producer price increase. The results from the tax and price change scenarios further confirm this fact. Emissions decline is larger when the tax is increased rather than when the price is increased. Government revenues decline under all of our scenarios due to large demand responses which are overcompensating the tax or price increases.

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