Direct and Indirect Energy Rebound Effects in German Households: A Linearized Almost Ideal Demand System Approach

Hendrik Schmitz[1], *Reinhard Madlener*[**]

Executive summary

Improvements in energy efficiency are often considered to be effective and cost-efficient for mitigating both energy consumption and greenhouse gas (GHG) emissions. However, these advances are prone to triggering rebound effects – behavioral changes that stem from the decreased price of an energy service due to the increased efficiency, leading to an increased demand for that specific service. Direct rebound effects are a standard reaction to a price decrease and are easily explained by basic microeconomics. They consist of an income effect and a substitution effect. Additionally, there exist indirect rebound effects. These occur when an efficiency increase related to one good or service increases the demand for other goods and services. For example, buying a more fuel-efficient car can cause a number of different reactions: driving more frequently and longer distances in the new car is a direct energy rebound effect, whereas using some or all of the monetary savings to undertake more trips by airplane would be an indirect effect.

The magnitude of rebound effects has implications for energy policy: namely, the higher a rebound effect is, the less effective efficiency improvements are in achieving environmental goals, because more of the potential savings remain unrealized due to higher consumption. Since these improvements are sometimes induced by government activity, for example in the form of mandatory efficiency standards or research funding for efficiency technologies, rebound effects should be taken into account when evaluating these policy measures *ex ante* and *ex post*. Conversely, due to the close relationship between price elasticities and rebound, high rebound effects suggest that households are highly price-sensitive with regard to the demand for energy. High price sensitivity increases the effectiveness of price-based measures, such as taxes on energy consumption. Our research question is the following: what is the magnitude of direct and indirect rebound effects for energy carriers used by German households?

In this paper, we derive emission rebound effects for different energy fuels used by German households, taking into account indirect effects stemming from embodied emissions from non-energy related goods. We also explicitly include energy efficiency in our estimations, which reduces bias in rebound estimates compared to the literature that uses only price elasticities as estimates for the rebound effect. For this, we use aggregate expenditure and price data for German consumer goods and services from 1970-2017 in order to estimate expenditure

1 Institute for Future Energy Consumer Needs and Behavior (FCN), E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany. E-Mail: HSchmitz@eonerc.rwth-aachen.de, corresponding author.

** Institute for Future Energy Consumer Needs and Behavior (FCN), E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany. E-Mail: RMadlener@eonerc.rwth-aachen.de.

elasticities as well as own- and cross-price elasticities. From these elasticities, we can derive rebound estimates. By also including efficiency as explicit variables, we manage to reduce bias in these estimates. In addition to our base model, we select three different ways to model energy efficiency: (i) time trends, (ii) price growth rates, and (iii) cumulated price increases and decreases to reflect asymmetric price reactions.

Depending on the model specification, we find a total rebound effect ranging from 6.4% to 20.3% for ‘Electricity’, 7.3% to 9.8% for ‘Gas’, -6.6% to 3.4% for ‘Liquid Fuels’, 47.0% to 64.1% for ‘Other fuels’, and 59.0% to 121.1% for ‘Vehicle fuels’. Substitution effects are mostly negative for ‘Electricity’, ‘Gas’, and ‘Liquid Fuels’, whereas they are positive for ‘Other fuels’ and ‘Vehicle fuels’. This might be caused by the relative emission intensities of these goods. Compared to income effects, substitution effects are smaller in magnitude for ‘Electricity’, and roughly of the same size for ‘Gas’, ‘Liquid fuels’, and ‘Vehicle fuels’, but considerably larger for ‘Other fuels’. This shows that studies which only focus on income effects paint an incomplete picture and that they risk substantially misrepresenting the magnitude of total rebound effects. Our results are sensitive to the exact model specification, the breakdown of commodity groups, the emission intensities of the different goods and services, and especially to the base year for the expenditure shares. Therefore, any credible attempt of estimating the magnitude of rebound effects needs to be precise on the exact methodology and data used in order to allow direct comparisons with other studies.

Keywords Rebound effects, LAIDS, Energy efficiency, Germany.