***REBOUND EFFECTS FROM EFFICIENCY IMPROVEMENT: ESTIMATING INCOME AND SUBSTITUTION EFFECTS FOR UK HOUSEHOLDS***

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## Overview

Policymakers expect improved energy efficiency to play a key role in reducing GHG emissions. However, the energy and emissions savings from such improvements may be less than simple calculations suggest, owing to a variety of mechanisms that go under the heading of *rebound effects* (Sorrell 2010).

*Direct* rebound effects result from increased demand for relatively cheaper energy services: for example, a fuel efficient car lowers the running costs and people may choose to drive further and/or more often in their fuel-efficient car. *Indirect* rebound effects result from higher demand for other (normal) goods and services, the provision of which necessarily involves energy use and GHG emissions throughout their life-cycle. For example, any savings on petrol bills may be put towards a foreign holiday, or towards the purchase of a laptop that was manufactured overseas. Re-spending therefore leads to additional energy use and emissions which offset the original energy and emission savings. Energy efficiency improvements lead to both direct and indirect rebound effects. In combination, they can be significant (Chitnis et. al. 2013).

This study estimates the combined direct and indirect rebound effects from efficiency measures affecting electricity consumption, heating fuels and road fuels for an average UK household. It departs from the previous papers by quantifying both the *income and substitution effects* from such efficiency improvements.

**Methods**

First, assuming two stage budgeting model we estimate a linear Almost Ideal Demand System (AIDS) of Deaton & Muellbauer (1980), using UK household annual time series data. The model is estimated by Iterative Seemingly Unrelated Regressions (ISUR):

 

Where *wi* is the budget share of commodity *i*, *pj* is the price of commodity *j*, *xt* is the total expenditure and Pt is the Stone price index. is the constant term,  and  are unknown parameters and  is an error term. Following Edgerton 1997, from this we obtain own-price, cross-price and income elasticities for two stage budgeting system.

Second, we assume a decrease in relevant energy price from the different measures (equal to an increase in energy efficiency) and estimate the changes in demand for different categories of goods and services. We then calculate the implications for GHG emissions and use these to estimate the rebound effects. In doing this, we disaggregate the substitution and income effects using Slutsky equation in order to estimate the contribution of each of these effects in forming total rebound effects. We estimate the rebound effects as:



Where R is the rebound effect,  is the changes in GHG emissions due to substitution and/or income effects (re-spending effect) andis the expected reduction in GHG emissions (engineering effect). Our calculations combine estimates of the GHG intensity and own-price, cross-price and income elasticities of different categories of household goods and services. The GHG intensities for different categories of goods and services are derived from an environmentally extended input output model (Druckman and Jackson 2009).

**Results**

The preliminary results show a rebound effect of 26% for measures affecting heating fuels, 17% for measures affecting electricity and 35% for measures affecting vehicle fuels. Income effect forms a larger component of the total rebound effect. However, since the substitution effect is dominated by direct emissions, total rebound is generally dominated by direct emissions as well.

**Conclusions**

Our results show that the magnitude of the rebound effect varies according to the energy efficiency measure. Rebound effects are relatively moderate for measures to improve heating and electricity efficiency, but to be significantly larger for measures to improve vehicle fuels efficiency. This difference results from the lower GHG intensity of expenditure on vehicle fuels relative to expenditure on gas or electricity.

Even though we have a rebound effect, because it is generally less than 100%, the energy-saving measures are still worthwhile. Overall, our results demonstrate the importance of taking account of rebound effects when estimating the impact of energy efficiency improvements in policy-making.

**References**

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