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Turning lights into flights: Estimating direct and indirect rebound effects for UK households

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HIGHLIGHTS

- ► We estimate the direct and indirect rebound effects from energy efficiency improvements by UK households.
- ► We allow for the capital cost of the improvement, together with the emissions embodied in the relevant equipment.
- ► We find rebound effects to be relatively modest, in the range 5–15%.
- ► The anticipated shift towards a low carbon electricity system will lead to larger rebound effects.

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ABSTRACT

Energy efficiency improvements by households lead to *rebound effects* that offset the potential energy and emissions savings. Direct rebound effects result from increased demand for cheaper energy services, while *indirect* rebound effects result from increased demand for other goods and services that also require energy to provide. Research to date has focused upon the former, but both are important for climate change. This study estimates the combined direct and indirect rebound effects from seven measures that improve the energy efficiency of UK dwellings. The methodology is based upon estimates of the income elasticity and greenhouse gas (GHG) intensity of 16 categories of household goods and services, and allows for the embodied emissions of the energy efficiency measures themselves, as well as the capital cost of the measures. Rebound effects are measured in GHG terms and relate to the adoption of these measures by an average UK household. The study finds that the rebound effects from these measures are typically in the range 5–15% and arise mostly from indirect effects. This is largely because expenditure on gas and electricity is more GHG-intensive than expenditure on other goods and services. However, the anticipated shift towards a low carbon electricity system in the UK may lead to much larger rebound effects.

1. Introduction

Global efforts to reduce greenhouse gas (GHG) emissions rely heavily upon improving energy efficiency in all sectors of the economy. For example, the ambitious '450 scenario', published by the International Energy Agency (IEA) anticipates energy efficiency delivering as much as 71% of the global reduction in carbon dioxide emissions in the period to 2020, and 48% in the period to 2035 (IEA, 2010). The technical and economic opportunities to improve energy efficiency are particularly large in the built environment which is consequently the target of multiple policy interventions. But the energy and GHG savings from such improvements may frequently be less than simple engineering estimates suggest as a consequence of various *rebound effects*. If these effects are significant, scenarios that ignore them are likely to be flawed and to provide misleading guidance for policy-makers. But despite a growing body of evidence on the nature and importance of rebound effects (Sorrell, 2007), they continue to be overlooked by the majority of governments, as well as by international organisations such as the IEA. While the UK government is beginning to include some allowance for rebound effects within its policy guidance, only a subset of effects are addressed.

This study seeks to estimate the magnitude of rebound effects following a number of energy efficiency improvements by UK households. We focus upon measures that improve the efficiency

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of heating and lighting systems and we estimate rebound effects in terms of their effect on global greenhouse gas (GHG) emissions. We extend the existing literature by accurately quantifying both 'direct' and 'indirect' rebound effects, and by also allowing for the emissions 'embodied' in energy efficiency equipment such as insulation materials.

The following section provides a classification of rebound effects for households and an overview of the relevant empirical literature. Section 3 summarises our approach, Section 4 describes the methodology in more detail and Section 5 introduces the analytical tools employed. Section 6 summarises our specific assumptions and examines their implications for estimates of rebound effects. Section 7 presents our results and investigates the sensitivity of those results to selected assumptions. Section 8 concludes.

2. Classifying and estimatingrebound effects for households

'Rebound effects' is an umbrella term for a variety of behavioural responses to improved energy efficiency. The net result of these effects is typically to increase energy consumption and carbon/GHG emissions relative to a counterfactual baseline in which these responses do not occur. As a result, the energy and emissions' saved' by the energy efficiency improvement may be less than anticipated.

Rebound effects for households have been classified in a number of different ways. To clarify, we introduce five distinctions.

2.1. Direct versus indirect rebound effects

For households, rebound effects are commonly labelled as either direct or indirect. *Direct* rebound effects derive from increased consumption of the, now cheaper, energy services such as heating, lighting or car travel. For example, the replacement of traditional light-bulbs with compact fluorescents will make lighting cheaper, so people may choose to use higher levels of illumination or to not switch lights off in unoccupied rooms. In contrast, *indirect* rebound effects derive from increased consumption of *other* goods and services (e.g., leisure, clothing) that also require energy and GHG emissions to provide. For example, the cost savings from more energy efficient lighting may be put towards an overseas holiday. As Fig. 1 illustrates, this type of behaviour can be deliberately encouraged!

2.2. Energy versus emission rebound effects

Both direct and indirect rebound effects may be estimated in terms of energy consumption, carbon emissions or GHG emissions, but the magnitude of those effects will differ in each case. As the average carbon/GHG intensity of energy systems change, the relative magnitude of these rebound effects will also change—and in some circumstances, rebound effects may be found to be large in energy terms but small in GHG terms, or vice versa. The estimated magnitude of energy rebound effects will also depend upon how different energy carriers are aggregated—for example, on a thermal equivalent basis or weighted by relative prices (Cleveland et al., 2000).

Fig. 1. Encouragement of rebound effects.

2.3. Efficiency versus sufficiency rebound effects

Rebound effects do not result solely from cost-effective energy efficiency improvements, such as purchasing energy-efficient light bulbs, but also from energy-saving behavioural changes, such turning lights off in unoccupied rooms. These are sometimes referred to as 'sufficiency' rather than efficiency actions (Alcott, 2008; Druckman et al., 2011). But while efficiency improvements will lead to both direct and indirect rebound effects, sufficiency actions will only lead to indirect effects.

2.4. Direct versus embodied energy use and emissions

Households consume significant amounts of energy 'directly' in the form of heating fuels, electricity and fuels for private cars. But they also consume energy 'indirectly', since energy is used at each stage of the supply chain for all goods and services. For example, energy will be used to manufacture laptops in China, ship them to the UK and distribute them by road to retail outlets. This life-cycle energy use is commonly termed *embodied energy* while the associated emissions are termed *embodied emissions*. For OECD households, embodied GHG emissions frequently exceed the direct emissions associated with consumption of electricity and fuels. All of these emissions contribute to climate change, but only a portion occur within national boundaries and hence are covered by national targets on GHG emissions.

While direct rebound effects only affect direct energy use and emissions by the household, indirect rebound effects affect *both* direct and embodied energy use and emissions. For example, the savings from an energy-efficient heating system may be spent upon more heating (direct rebound, direct emissions), more lighting (indirect rebound, direct emissions) or more furniture (indirect rebound, embodied emissions).

2.5. Income versus substitution effects

As described in Annex I, both direct and indirect rebound effects may theoretically be decomposed into *income* and *substitution* effects. By making energy services cheaper, energy efficiency improvements increase the real income of households, thereby permitting increased consumption of all goods and services and increased 'utility' or consumer satisfaction. These adjustments are termed *income effects*. But since energy services are now cheaper relative to other goods and services, households may shift their consumption patterns *even if* their real income and hence utility was held constant. These adjustments are termed *substitution effects*. The change in consumption for a particular good or service is given by the sum of income and substitution effects for that good or service. The corresponding change in energy use or emissions may be estimated by multiplying the change in consumption by the energy/emission intensity of that good or service. The direct rebound effect represents the net result of the income and substitution effects for the relevant energy service, while the indirect rebound effect represents the net result of income and substitution effects for all the other goods and services purchased by the household—including other energy services.

Since the income and substitution effects for any individual good or service may be either positive or negative, the sum of the two may be either positive or negative. The consumption of any individual good or service may therefore increase or decrease