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The impact of increased efficiency in the industrial use of energy: A computable general equilibrium analysis for the United Kingdom ☆

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Abstract

The conventional wisdom is that improving energy efficiency will lower energy use. However, there is an extensive debate in the energy economics/policy literature concerning "rebound" effects. These occur because an improvement in energy efficiency produces a fall in the effective price of energy services. The response of the economic system to this price fall at least partially offsets the expected beneficial impact of the energy efficiency gain. In this paper we use an economy–energy–environment computable general equilibrium (CGE) model for the UK to measure the impact of a 5% across the board improvement in the efficiency of energy use in all production sectors. We identify rebound effects of the order of 30–50%, but no backfire (no increase in energy use). However, these results are sensitive to the assumed structure of the labour market, key production elasticities, the time period under consideration and the mechanism through which increased government revenues are recycled back to the economy.

Keywords: Energy efficiency; Rebound; Industrial energy consumption

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1. Introduction

Governments and environmental pressure groups across the world are advocating energy efficiency programs for either energy security or environmental reasons (Cabinet Office, 2001; Carbon Trust, 2003; DEFRA, 2005; EEA, 1999; Nordic Council of Ministers, 1999; Schutz and Welfens, 2000). Whilst the conventional wisdom is that improving energy efficiency will lower energy use, there is an extensive debate in the energy economics/policy literature on the actual impact of such improvements. This debate focuses on the notion of "rebound" effects, according to which the expected beneficial impacts on energy intensities are partially offset as a consequence of the economic system's responses to the fall in the effective price of energy services that accompany the improvement in energy efficiency. The "Khazzoom–Brookes postulate" (Saunders, 1992) asserts an extreme form of this: that improvements in energy efficiency can actually increase the demand for energy, a phenomenon initially identified by Jevons (1865) and now known as "backfire".

There is general agreement that some degree of rebound is to be expected, so that if, for example, a 5% improvement in energy efficiency in a particular use will generate energy savings of 3%, rebound would be 40%.[1] Of course, the key question is the pragmatic one: how big is this rebound effect likely to be? Empirical work has concentrated on measuring rebound effects in consumer services (Dufournaud et al., 1994; Greening et al., 2000; Small and Van Dender, 2005; Zein-Elabdin, 1997). Moreover, existing studies generally focus on the "direct" rebound effects. This restricts the analysis solely to the energy requirements to provide the consumer services to which the efficiency improvement directly applies. Less frequently studied are the "indirect" and "economy-wide" effects that are associated with the relative price, output and income effects that will affect the consumption and production in other energy using industries. This decomposition of rebound into direct, indirect and economy-wide effects is first made by Greening et al. (2000), who also point to a shortage of empirical studies on the "non-direct" rebound effects.

A recent UK House of Lords (2005, p. 29) report sums up the present position as follows:

> Absolute reductions in energy consumption are thus possible at the microeconomic level. However, this does not mean that an analogy can be made with macroeconomic effects. Apart from anything else, the substitution effects observable at the macroeconomic level cannot be replicated by households, where demand for a range of goods is relatively inelastic… a business on the other hand, could respond to cheaper energy by deliberately increasing consumption — using a more energy intensive process, which would allow savings to be made elsewhere, for instance in manpower.

The House of Lords report seems to be making two points here. First, that energy savings in production sectors are likely to have stronger indirect and economy-wide impacts than energy saving in consumption activities. Second, that energy substitution possibilities might be substantially greater in production than consumption.

In this paper we wish to tackle the question: how large are the rebound effects likely to be for general improvements in energy efficiency in production activities in a developed economy?

[1] We express rebound as a percentage, calculated as: (1 − (the actual percentage reduction in energy use) / (the imposed percentage change in energy efficiency)) × 100. Therefore if, for example, there is no change in energy use following an improvement in energy efficiency, so that the actual percentage reduction in energy use is zero, rebound would be 100%. If energy use actually increases after the improvement in efficiency, the reduction in energy use would be assigned a negative value and rebound would be greater than 100%. Such a value indicates backfire.