Economy-Wide Rebound Effects from Increased Energy Efficiency in Scottish Households

Theme: 2. Natural resources, ecosystem services and environmental quality

2.4 Economic issues in environmental quality and degradation

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Summary

This paper investigates the economy-wide impacts of a 5% improvement in Scottish household energy efficiency, focussing specifically on total energy rebound effects, both in household energy use and in total energy use across the Scottish economy. The impacts are measured through simulations using an inter-temporal dynamic single region computable general equilibrium (CGE) model. The key finding is that the economy-wide impacts of an improvement in energy efficiency in the household sector are qualitatively different to what has been found in CGE studies that focus on increased efficiency in industrial energy use, which leads to productivity-led growth. Here, we find that economic expansion resulting from increased household energy efficiency is driven by growth in domestic demand, which will crowd out export demands unless the reduced cost of living is reflected in the wage demands made by households in supplying labour services to the production side of the economy.

1 Introduction

There has been extensive investigation of the economy-wide rebound effects resulting from efficiency improvements in industrial energy use. This analysis often uses a computable general equilibrium (CGE) modelling approach(see Dimitropoulos, 2007; Sorrell, 2007, and Turner 2013 for reviews). However, very few studies have attempted to measure the economy-wide impacts of energy efficiency improvements in the household sector. Following the work of Khazzoom (1980, 1987) there have been a numbers of partial equilibrium studies (Dubin et al., 1986; Greene et al., 1999; Frondel et al., 2008; Klein, 1987, 1988; Nadel, 1993; Schwarz and Taylor, 1995; West, 2004). However, there have been very few CGE studies of increased household energy efficiency. In this paper we build on the general equilibrium analysis of Lecca et al. (2014) who examined the impacts of increased efficiency in the energy use of UK households. We focus on a regional case study within the UK, using a single region CGE model of the Scottish economy. In this abstract we present some information on our method of analysis and our provisional results. In the full paper we will extend to consider some potentially important issues. These will include whether the reduced cost of living from the efficiency improvement are reflected in household wage demands (which Lecca et al. (2014), show may cause a movement towards what we would expect to see in the case of industrial energy efficiency) and different treatments of the dynamic adjustment process (to consider the assumption that households may not be fully forward looking and rational in the their decision making). We also consider the impacts of different assumptions about labour market behaviour (in the provisional results below we assume that the total labour supply is fixed; in the full paper we will relax this assumption by examining the impacts of migration between UK regions in response to differences in relative unemployment and wage rates).

2 Method

To identify the general equilibrium impacts of energy efficiency, we use a variant of the UKENVI CGE model model Lecca et al. (2014) calibrated on a 2009 Scotland Social

Accounting Matrix (SAM) (Emonts-Holley and Ross, 2014). The SAM accounts for 25 intermediate sectors, four of which are energy sectors, and includes transactions between aggregate economic agents such as the Scottish households, the Scottish Government, and corporate sectors. The SAM accounts also for two external transactors, the rest of the UK (RUK) and the rest of the world (ROW).

Simulations are performed using the UKENVI model outlined in Lecca et al. (2014) and detailed in our full paper - where consumption and investments decisions reflect intertemporal optimization with perfect foresight agents. Households optimize their lifetime discounted utility function of consumption subject to a lifetime wealth. Once the optimal path of consumption is obtained by the solution of the intertemporal problem, the aggregated consumption is allocated within each period and between energy and non-energy goods by the following CES function:

$$C = \left[\delta^E (\gamma E_C)^{\frac{\epsilon-1}{\epsilon}} + (1-\delta^E) NE_C^{\frac{\epsilon-1}{\epsilon}}\right]^{-\frac{\epsilon-1}{\epsilon}} \tag{1}$$

In (1) NE_C is the consumption of non-energy commodities, ϵ is the elasticity of substitution between energy and non-energy commodities in consumption and $\delta^E \in (0,1)$ is the share parameter. As in Lecca et al. (2014) the long-run and the short-run elasticity of substitution are estimated using UK households consumption data from 1989 to 2008 employing the generalized maximum entropy (GME) method (Golan et al., 1996).

To calibrate the model we assume that the economy is initially in steady state equilibrium. We introduce a 5% costless and permanent increase in the efficiency of energy used in household consumption. The final paper will report results for the short-run and the long-run periods, as well as the period-by-period adjustment of some key variables, and will involve the use of different scenarios and assumptions regarding model specification. In terms of the key result of interest, we define the rebound effect as a measure of the difference between the proportionate change in the actual energy use and the proportionate change in energy efficiency. This difference is primarily driven by the fact that, *ceteris paribus*, an increase in the efficiency in a particular energy use reduces the price of energy in that use, measured in efficiency units. This reduction then leads consumers to substitute energy, in efficiency units, for other goods and services implying that the proportionate reduction in energy use is typically less than the proportionate improvement in energy efficiency. Moreover, in principle, energy use can actually rise in these circumstances, if its use is sufficiently price sensitive. This is known as backfire (Khazzoom, 1980, 1987).

In the case under consideration here, for a proportionate improvement in household energy use of here assumed to be 5% so that $\gamma = 0.05$ - rebound in the household consumption of energy, R_C, can be calculated as

$$R_C = \left[1 + \frac{\dot{E}_C}{\gamma} \right] \cdot 100 \tag{2}$$

where $\dot{E}_C$ is the proportionate change in energy use in household consumption, which may be positive or negative. Whether we are focussing on direct, indirect or economy-wide rebound here depends on how the change in household energy consumption is estimated. In CGE this changes as a result of a full range of economy-wide adjustments, not just the direct response to the change in the price of the energy service as efficiency increases. We are also interested the impact on energy use in the economy as a whole, both in consumption and production. The total rebound formulation used in this case, R_T, is given as:

$$R_T = \left[1 + \frac{\dot{E}_T}{\alpha\gamma} \right] \cdot 100 \tag{3}$$

where α is the initial share of household energy consumption in total energy use.

3 Provisional results (central case scenario)

Our results suggest that a 5% improvement in Scottish household energy efficiency would have positive effects on the Scottish regional economy. We focus here on the long-run here, but the full paper will report results for the full period of adjustment. In the long term, the Scottish GDP increases by 0.11% relative to what it would have been without the efficiency improvement. Total household consumption increases by 0.4% and aggregate investment by 0.11%, although there is some disinvestment or contraction in capacity in the energy supply sectors. There is a 0.45% drop in the unemployment rate and the average real wage increases by 0.05%. This is smaller than the rise in the nominal wage, 0.09%, due to a 0.04% increase in the consumer price index. The latter is crucial in terms of the nature of the demand-led expansion here. The rise in the price level reflects decreased competitiveness in Scottish industries and there is a crowding out of export demand, which drops by 0.06%.

Household energy consumption falls by 1.48% while industrial energy use falls by 0.3%, so that total energy use decreases by 0.61%. There is a net drop in industrial energy use for two reasons. First, contracting energy supply sectors are generally more energy-intensive than most other sectors in the Scottish economy. Second, the initial decrease in demand for energy (as efficiency increases) causes a reduction in the return on capital in energy supply so that, over time, energy suppliers reduce their capacity (Turner's (2009) disinvestment effect). As a result of the net contraction in industrial energy use, the overall economy-wide, 64.65%, is smaller than the general equilibrium household rebound effect, 70.33%.

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