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Energy efficiency as an instrument of regional development policy? The impact of regional fiscal autonomy

Gioele Figus[a], Patrizio Lecca[b], Peter McGregor[c] and Karen Turner[d]

ABSTRACT

This paper analyses the system-wide impact of increased household energy efficiency in a regional context, using Scotland as an example. It shows that household energy efficiency improvements typically deliver a 'double dividend' of a regional economic stimulus and reduction in energy use. However, the trade-off between the two is sensitive to the degree of regional fiscal autonomy, and so is likely to vary across regions. The use of taxation to support the implementation of energy-efficiency improvement programmes negatively impacts competitiveness, unless workers are willing to accept lower after-tax wages to fund public spending on improving household energy efficiency.

KEYWORDS

energy efficiency; regional development policy; energy rebound; regional fiscal autonomy; general equilibrium

JEL C68, D58, Q43, Q48

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INTRODUCTION

Many regional governments have ambitious plans for household energy efficiency (e.g., the Energy Efficient Scotland policy programme, labelled Scotland's Energy Efficiency Programme (SEEP) at the time of the research; Scottish Government, 2017). However, while traditionally improvements in energy efficiency have been proposed as climate tools to reduce energy use and associated emissions, there is a recent tendency to consider energy efficiency as a means of stimulating economic development.[1] The aim of this paper is to analyse the economy-wide impacts of increasing household energy efficiency in a *regional* context, accounting both for 'costs', particularly in terms of rebound in energy use[2] and for the potential benefits of energy efficiency. The Scottish government, and many other regional and local governments, has *multiple* policy objectives, including sustainable economic growth, which itself reflects a positive weighting on both greater economic activity and lower carbon emissions. Accordingly, when assessing the impact of policies, including those relating to energy efficiency, it is appropriate to reflect these wider objectives. The focus should, therefore, not be exclusively on the impact on energy use. Indeed, we explore the potential of household energy-efficiency improvements to be effective instruments of regional development policy, as well as contributing to limiting carbon emissions.[3]

We analyse the impact of increases in regional household energy efficiency using our computable general equilibrium (CGE) model of Scotland. This is a purpose-built, energy-economy-environment model of Scotland that tracks the effects of policies on a range of non-energy as well as energy policy goals. In particular, it allows an assessment of the impact on economic development. The regional context is critical for the analysis. First, the model is calibrated to a social accounting matrix for Scotland, and so embodies the importance of interregional and international trade flows to a small, open region. Second, we reflect the openness of regional labour markets through the influence of migration flows. Third, we capture alternative degrees of regional fiscal autonomy to reflect the asymmetric nature of devolution among UK regions, so

CONTACT

[a] **(Corresponding author)** gioele.figus@strath.ac.uk
Centre for Energy Policy, University of Strathclyde, Glasgow, UK; and Fraser of Allander Institute, University of Strathclyde, Glasgow, UK.
[b] patrizio.lecca@ec.europa.eu
Joint Research Centre, European Commission, Seville, Spain.
[c] p.mcgregor@strath.ac.uk
Department of Economics, Fraser of Allander Institute, University of Strathclyde, Glasgow, UK.
[d] karen.turner@strath.ac.uk
Centre for Energy Policy, University of Strathclyde, Glasgow, UK.

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that the relevance of the analysis is not restricted to Scotland. Fourth, we recognize the potential regional differentiation of attitudes towards 'green' taxation and public spending, and assess their significance for the success of regional policies aimed at enhancing household energy efficiency.

We find that energy-efficiency improvements typically yield a 'double dividend'[4] of increased regional economic activity and reduced energy use, although the trade-off between the two is sensitive to the degree of regional fiscal autonomy. Furthermore, the economic development effects of energy-efficiency changes are permanent, unlike the effects of any transitory increase in spending or taxation that may accompany the implementation of energy efficiency changes.

The paper is organized as follows. The next section reviews the literature. The third section describes the CGE model used for the analysis. The fourth section discusses the simulation scenarios. The fifth section considers the impact of a government expenditure-funded increase in household energy efficiency. Here we consider two cases. First, a block-grant fiscal arrangement under which the budget constraint of any devolved government does not vary with regional economic activity. This effectively characterizes the current position of UK regions other than Scotland. Second, we explore the impact of an expenditure-financed increase in household energy efficiency in the presence of a significant degree of fiscal autonomy. This is consistent with the new fiscal arrangements being implemented for Scotland (and planned for Wales and Northern Ireland).[5] The sixth section uses SEEP as an example to assess the impact of a potentially tax-funded increase in household energy efficiency. Here we consider how regions with different environmental attitudes may react to the introduction of a temporary tax to fund energy-efficiency programmes. The seventh section discusses the results and concludes.

LITERATURE REVIEW

Using CGE frameworks, studies focused on assessing rebound from energy-efficiency increases in production have already underlined how a more efficient use of energy can deliver significant economic benefits. For example, Allan, Hanley, McGregor, Swales, and Turner (2007), Broberg, Berg, and Samakovlis (2015), Grepperud and Rasmussen (2004), Glomsrød and Wei (2005), Hanley, McGregor, Swales, and Turner (2009), Turner (2009) and Yu, Moreno-Cruz, and Crittenden (2015) find that improving energy efficiency in production leads to a productivity-led expansion. The findings are quite intuitive because in these studies energy is one of the production inputs along with capital, labour and materials.

However, CGE studies focused on the economy-wide effects of increased household energy efficiency find that energy-efficiency increases in household consumption can also stimulate the macro-economy (e.g., Duarte, Feng, Sanchez-Choliz, Sarasa, & Sun, 2015; Dufournaud, Quinn, & Harrington, 1994; Figus, Turner, McGregor, & Katris, 2017; Lecca, McGregor, Swales, & Turner, 2014). Duarte et al. (2015) investigate different energy-savings policies, including increased energy-efficiency improvements, in Spain. However, that study is quite specific to the Spanish economy characterized by very different energy needs compared with Scotland and focuses mostly on the effectiveness of energy-saving policies on CO_2 emissions.

Lecca, McGregor et al. (2014) studies the economic impact of an across-the-board 5% improvement in the energy efficiency of a UK household. They consider an efficiency improvement to reflect an increase in the value of energy expressed in efficiency units, meaning that households can consume the original 'pre-efficiency' bundle of goods (energy and non-energy) but using less physical energy. This stimulates the wider economy through an increase in aggregate demand because households respond to the lower energy price by consuming more energy in efficiency units, but also increasing their non-energy consumption.[6] However, while in studies focused on industrial energy use, such as Allan et al. (2007) and Turner (2009), the economic expansion is driven by an increase in competitiveness, in Lecca, McGregor et al. (2014) the demand-led growth puts upward pressure on consumption prices and so decreases competitiveness, partially crowding out exports.[7]

Our own regional CGE initially builds on the national case in Lecca, McGregor et al. (2014). In this respect, we provide some comparable simulations to allow a focus to be made on differences between the regional and national cases, reflecting differences in the degree of openness of goods and labour markets in the regional case. However, the primary objective is to compare the impact of household-efficiency changes under alternative degrees of regional fiscal autonomy. On this basis, we contrast the energy savings–economy trade-off for expenditure-financed increases in household energy efficiency under varying degrees of fiscal autonomy. We also consider the broad nature of programmes under the SEEP as an illustrative case study of a regional household energy-efficiency initiative. Finally, we assess the likely impact of a tax-financed increase in household energy efficiency, a policy action that becomes feasible under regional fiscal autonomy.

THE CGE MODEL

We use the AMOS ENVI CGE model for Scotland.[8] The regional focus of AMOS ENVI is reflected in two main characteristics. First, it allows for flow migration to reflect the free circulation of workers within the UK territory.[9] Second, it considers that regional government expenditure depends on a system of block-grant transfers from the national government, and it is therefore fixed. This assumption is relaxed further below to assess the impact of fiscal autonomy.

Consumption

Consumption is modelled to reflect the behaviour of a representative household that maximizes its discounted intertemporal utility, subject to a lifetime wealth constraint. The solution of the household optimization problem gives the optimal time path for consumption of the bundle of goods C_t.

Within each period consumption, C_t, is allocated between energy goods EC and non-energy goods NEC so that:

$$C_t = [\delta^E(\gamma EC_t)^{(\varepsilon-1/\varepsilon)} + (1-\delta^E)NEC_t^{(\varepsilon-1/\varepsilon)}]^{(-\varepsilon/\varepsilon-1)} \tag{1}$$

where ε is the elasticity of substitution in consumption. It measures the ease with which consumers can substitute energy goods for non-energy goods and is based on the most recent econometric estimation carried out by Lecca, McGregor et al. (2014), taking the value of 0.35 for the short run and 0.61 for the long run.[10] $\delta \in (0,1)$ is the share parameter; and γ is the efficiency parameter of energy consumption. Energy consumption includes electricity, gas, oil and coal. We assume that the individual can consume goods produced both domestically and imported, where imports are combined with domestic goods under the Armington assumption of imperfect substitution (Armington, 1969).

Production and investment

The production structure is represented by a nested constant elasticity of substitution (CES) production function where capital and labour are combined to form value added, and energy and materials are combined into intermediate inputs. The combination of intermediate inputs and value added forms gross output. Domestic and imported goods are combined under the Armington assumption (Armington, 1969).[11]

The demand functions for capital and labour are obtained from the first-order conditions of the CES production function. Following Hayashi (1982), the optimal time path of investment is derived from maximizing the value of firms, V_t, subject to a capital accumulation function $\dot{K}_t$, so that:

$$\text{Max } V_t \sum_{t=0}^{\infty}\left(\frac{1}{1+r}\right)^t [\pi_t - I_t(1+g(x_t))] \quad \text{subject to } \dot{K}_t = I_t - \delta K_t \tag{2}$$

where π_t is the firm's profit; I_t is private investment; r is a discount factor; $g(x_t)$ is the adjustment cost function, with $x_t = I_t/K_t$; and δ is depreciation rate. The solution of the problem gives the law of motion of the shadow price of capital, λ_t, and the adjusted Tobin's q time path of investment (Hayashi, 1982).

The labour market, wage bargaining and migration

Wages are determined within the region in an imperfect competition setting, according to the following wage curve:

$$\ln\left[\frac{w_t^b}{cpi_t}\right] = \varphi - \epsilon \ln(u_t) \tag{3}$$

where:

$$w_t^b = \frac{w_t}{1+\tau_t}$$

where the bargaining power of workers and, hence, the real consumption wage is negatively related to the rate of unemployment (Blanchflower & Oswald, 2009). In equation (3), (w_t^b/cpi_t) is the real after-tax consumption wage; φ is a parameter calibrated to the steady state; ε is the elasticity of the wage rate with respect to the rate of unemployment, u, and it takes the value of 0.113 (Layard, Nickell, & Jackman, 1991); and τ_t is the income tax rate which is fixed in the default setting.

Since regions are much more open systems than nations, the assumption of a fixed working population, as used in national CGE modelling analysis, such as by Lecca, McGregor et al. (2014), is inappropriate in a regional context. For this reason, we introduce the following migration function:

$$nim_t = \varsigma - v^u[\ln(u_t) - \ln(\bar{u}^N)] + v^w[\ln(w_t^b/cpi_t) - (\bar{w}^N/\overline{cpi}^N)] \tag{4}$$

where nim_t is the instantaneous rate of net migration; ζ is a parameter calibrated to ensure zero migration in the first period; and v^u and v^w are elasticities that measure the response to the differences in logs between regional and national unemployment and real wage rates and are equal to 0.06 and 0.08 respectively (Layard et al., 1991). In equation (4), net migration flows are positively related to the difference between the log of regional and national real wages and negatively related to the difference between the log of regional and national unemployment rates (Layard et al., 1991).

The social wage

We explore a special case where workers reflect the amenity value of public expenditure in the wage-bargaining process. We call this the social wage. This is implemented by augmenting equation (3) so that:

$$\ln\left[\frac{w_t^b}{cpi_t}\right] = \varphi - \epsilon \ln(u_t) + \alpha\beta \ln(1-\tau_t) \tag{3a}$$

where $\alpha \in (0, 1)$ represents the extent to which public consumption is reflected in the wage determination; and $\beta \in (0, 1)$ is the relative valuation of public goods. Accordingly, equation (4) is augmented as follows:

$$nim_t = \varsigma - v^u[\ln(u_t) - \ln(\bar{u}^N)] + v^w[\ln(w_t^b/cpi_t) - \beta\ln(1-\tau_t) - (\bar{w}^N/\overline{cpi}^N)] \tag{4a}$$

When $\alpha = 0$ and $\beta = 0$, workers and migrants do not value any increase in government expenditure and expressions (3a) and (4a) reduce to their standard forms in (3) and (4). When the two parameters equal 1, wage bargaining and gross migration respond to the *gross* of tax wage (Lecca, McGregor, Swales, & Yin, 2014). Essentially this reflects a situation where workers attribute the same value, at the margin, to the consumption of public and private goods. This implies that the amenity value of government expenditure is independent of its composition. However, in the present context, it is as if workers and migrants within the region are sufficiently concerned about the environment that they are willing to accept a reduced take-home pay in exchange for a government-funded increase in household energy efficiency.

The government

The government operates according to the following budget constraint where the fiscal deficit (FD) is given by government income (GY) minus expenditure (GEXP):

$$\mathrm{FD}_t = \mathrm{GY}_t - \mathrm{GEXP}_t$$

where:

$$\mathrm{GY}_t = \left(d^g \cdot \sum_i rk_{i,t} \cdot K_{i,t} + \sum_i IBT_{i,t} + \bar{\tau}_t \cdot \sum_j L_{j,t} \cdot w_t \ + \overline{FE} \cdot \varepsilon_t \right) \quad (5)$$

$$\mathrm{GEXP}_t = \sum_i \bar{G}_{i,t} \cdot Pg_t + \sum_{\mathrm{dngins}} \overline{TRG}_{\mathrm{dngins},t} \cdot Pc_t$$

where GY is the sum of the share d_g of capital revenue that is transferred to the government; *IBT* is indirect business taxes; *L* is revenues from labour income at a rate of τ;[12] and *FE* is foreign remittances times the fixed exchange rate ε. *GEXP* includes government spending on goods and services *G* plus transfers (*TRG*) to other non-governmental domestic institutions (dngins), which are fixed in real terms.

Data and calibration

The structural parameters of the model are derived from the 2009 Social Accounting Matrix (SAM)[13] for Scotland (Emonts-Holley & Ross, 2014), which incorporates the 2009 Scottish Input–Output tables. The Scottish SAM reports information about economic transactions between industries and other aggregate economic agents, namely the Scottish household, the Scottish government and corporate sectors, and accounts for imports and exports to the rest of the UK (RUK) and the rest of the world (ROW). For this paper, we aggregate the SAM to 21 industries,[14] including four energy sectors, gas, electricity, coal and refined oil. Other parameters required to inform the model, such as elasticities and share parameters, are either exogenously imposed, based on econometric estimation or best guesses, or calibrated.

We calibrate the model to be initially in steady-state equilibrium (Adams & Higgs, 1990). Following any disturbance, the model solves a sufficiently long number of periods (years) to allow the economy to reach a new steady-state equilibrium. Results are reported for two conceptual periods: the short run (SR), where population and capital stocks are fixed; and the long run (LR), which corresponds to the new steady-state equilibrium characterized by no further changes in sectoral capital stocks and population. We also report period-by-period adjustments.

SIMULATION SCENARIOS

The simulations reflect two main scenarios. First, in the absence of specific information on the scale of efficiency stimuli attributable to regional initiatives such as SEEP, we simulate an illustrative 5% increase in household energy efficiency.[15] The simulations are carried out assuming a block-grant regional fiscal regime. Here the only way of funding an increase in household energy efficiency within the region through increased government expenditure is to switch public spending from other uses. In general, the composition of these changes in public spending will differ and this may impact the macro-economy. However, for simplicity, and in absence of better information, here we adopt the assumption that the reallocation of public spending has no effect on aggregate demand;[16] not only is the total of public spending unchanged but also its macroeconomic impact.[17] Any such impact would in any case be purely transitory since funding simply applies to the implementation phase (e.g., installing insulation). However, the associated efficiency gain is effectively permanent (over the lifetime of the accommodation).

We then consider the same public expenditure-financed increase in household energy efficiency, i.e., the 5% stimulus, and assess the impact of greater regional fiscal autonomy on the improvements in both energy use and the economy. Here we investigate the cases where recycled tax revenues are used either to increase government spending or to reduce the income tax rate.

Second, we consider SEEP as an example of a government-funded energy-efficiency programme,[18] but assume that the spending necessary to implement the programme is additional to the current level of government spending. This option is only available to regional governments with devolved fiscal powers. While we know the public expenditure associated with SEEP, as yet there is little evidence about the success of pilot projects and the likely scale of the stimulus to energy efficiency. Accordingly, we first assess the increase in efficiency that would have to be secured to render the programme self-funding (in present value terms).[19]

Using this result, we explore the impact of a tax-financed SEEP-like project since such financing becomes feasible under fiscal autonomy. This raises additional complications, notably the adverse supply-side impacts of a rise in the income tax rate. These could, however, be partially or even wholly offset if Scottish taxpayers' preference for 'green' policies leads them to accept a loss in take-home pay, given their perception of the wider benefits of an improvement in household energy efficiency.

IMPACT OF AN ILLUSTRATIVE 5% EXPENDITURE-FINANCED INCREASE IN HOUSEHOLD ENERGY EFFICIENCY

The block-grant fiscal regime

This section presents simulation results for an illustrative 5% increase in household energy efficiency funded by a

Table 1. Impact of a 5% increase in household energy efficiency.

Time period	Short run (SR)	Long run (LR)
Gross domestic product (GDP)	0.04	0.17
Consumer price index (CPI)	0.08	0.00
Unemployment rate	−0.24	0.00
Total employment	0.06	0.18
Nominal gross wage	0.11	0.00
Real gross wage	0.03	0.00
Households consumption	0.30	0.42
Investment	0.15	0.17
Export	−0.12	0.00
Non-energy output	0.07	0.19
Energy output	−0.41	−0.41
Energy use	−0.89	−0.57
Energy demand by industries	−0.22	−0.24
Household energy consumption	−2.70	−1.47
Household consumption of non-energy	0.49	0.54
Government expenditure	–	–
Fiscal deficit	−53.66	−165.48
Economy-wide rebound	27.65	53.48

Note: Values are the percentage change from baseline values.

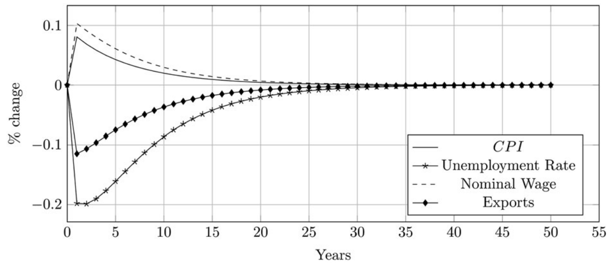

Figure 1. Period-by-period adjustment of the consumer price index (CPI), unemployment rate, nominal wage and exports.

reallocation of government spending. Recall that we assume that the temporary rise in government expenditure necessary to fund the efficiency improvement is compensated by a reduction in expenditure elsewhere and that this switch has no effect on aggregate demand. This implies that total government expenditure remains unchanged, as shown in Table 1. Variations in tax revenues accrue to Westminster.

Table 1 summarizes SR and LR results of simulations. Following the energy-efficiency improvement, household energy consumption decreases by 2.70%, while household consumption increases by 0.30%. The higher consumption puts upward pressure on the consumer price index (CPI), making domestic products more expensive and reducing international competitiveness. On the other hand, this shift in demand stimulates non-energy sectors, so that total investment increases by 0.15% and the output of non-energy producers rises by 0.07%. This impacts the labour market, where total employment increases by 0.06%, unemployment rate decreases by 0.24% and the real wage is 0.03% higher.

The initial drop in the unemployment rate and rise in the real wage triggers net in-migration of workers from the rest of the UK. This puts downward pressure on wages, and increases the unemployment rate according to the wage setting curve (equation 3). This can be seen in Figure 1 where we plot the time paths of the nominal wage, unemployment, CPI and exports. The real wage falls and the unemployment rate increases until they both approach their baseline levels, as the labour market reaches its LR equilibrium. Similarly, the CPI returns to its base-year value, allowing exports to increase again until original competitiveness is completely restored.[20] This is a crucial result. It shows that, in a regional economy with free movement of workers and flow migration, the negative effect on competitiveness implied by the constraint on labour supply disappears in the LR.

Restored LR competitiveness contributes additional momentum to the economic stimulus. In the LR, gross domestic product (GDP) increases by 0.17%,[21] and the output of non-energy sectors is 0.19% higher. However, because these activities use energy as an input in production, industrial energy use falls by 0.24% mostly due to the 1.47% reduction in household energy demand and consequent contraction in energy-supplying sectors.[22]

The zero variation in prices over the LR indicates the presence of a pure demand response to the introduction of the energy-efficiency improvement, similar to what we would expect in an input–output modelling framework (McGregor, Swales, & Yin, 1996).[23] The economic expansion observed in this scenario is entirely demand driven. It is important to note that the increase in household energy efficiency generates a double dividend of reduced energy use and increased economic activity.

The fiscal autonomy regime

Under fiscal autonomy, tax revenues accrue to the *regional* government. This is already true for income taxes in Scotland and will shortly be true for Wales and, for corporation tax, Northern Ireland. Other regional economies of the UK remain subject to a strict budget constraint as in the block-grant regional fiscal regime considered in the previous section. We illustrate the key principles by focusing on the simple case where the regional government maintains a fixed deficit according to equation (5).

To illustrate the implications of this assumption, we repeat the simulations of scenario 1, which reflects a 5% increase in households' energy efficiency in the presence of endogenous migration.[24]

We explore three sub-scenarios, FIXGOV, FIXBAL and TAX. The FIXGOV scenario replicates the results of scenario 1 by assuming fixed government expenditure with tax revenues accruing to Westminster. In the FIXBAL case, we assume that tax revenues are devolved and the Scottish government maintains a given fiscal deficit by varying public expenditure in response to any changes in tax revenues. In the TAX scenario, we assume that any stimulus to the economy, and to tax revenues, is used to reduce the income tax rate so as to maintain a fixed fiscal balance.

FIXGOV results are reported in the first column of Table 2. The economic stimulus from the improved household energy efficiency generates additional tax revenues. The Scottish government's 'notional' fiscal deficit improves in both the SR and LR, but this simply results in increased transfers to Westminster.[25]

In the FIXBAL case, the additional income is used to increase the Scottish government's current expenditure by 0.06% in the SR and 0.24% in the LR. The additional resources recycled within Scotland in the form of additional public spending further stimulate the economy. For this reason, GDP increases by more than in the FIXGOV case in both the SR (by 0.05%) and the LR (by 0.26%). Similarly, we observe a greater increase in industries' employment, investment and output. However, the greater economic expansion is also associated with a smaller reduction in energy use.

Finally, in the TAX case, the results of which are reported in the third major column of Table 2, the government uses the additional resources to reduce the income tax rate. In this case, we have a simultaneous demand-and-supply stimulus.

First, a tax reduction increases households' disposable income so that consumption rises by 0.40% in the SR and 0.66% in the LR. Second, the reduced taxation increases the post-tax real consumption wage. This puts downward pressure on wage bargaining, reducing the price of labour and stimulating employment and production. The lower labour cost improves competitiveness so, in contrast to the other cases, export demand increases in the LR.

Because production is stimulated by the lower price of labour, industries produce more output, increasing the use of other inputs, including energy. For this reason, the reduction in total energy use is substantially lower than in the FIXGOV case, especially in the LR (0.36% as against 0.57%). However, in all these cases, we still observe a 'double dividend', but the bigger the stimulus to the economy, the smaller the reduction in energy use.

IMPACT OF TAX-FUNDED 'SEEP' ENERGY-EFFICIENCY PROGRAMMES

The above section suggests that an increase in household energy efficiency delivers an economic stimulus and a reduction in energy use, and is therefore a desirable policy. However, problems may arise when the reallocation of government spending from certain areas to others has significant macroeconomic impacts, or is considered unacceptable by the electorate. For this reason, this section focuses on the impact of tax-funded energy-efficiency programmes, where the spending to implement the increased energy efficiency is additional to the current level of government spending. We use SEEP as an example.

Table 2. Impact of a 5% increase in household energy efficiency under alternative fiscal regimes.

	FIXGOV		FIXBAL		TAX	
Time period	**SR**	**LR**	**SR**	**LR**	**SR**	**LR**
Gross domestic product (GDP)	0.04	0.17	0.05	0.26	0.05	0.39
Consumer price index (CPI)	0.08	0.00	0.10	0.00	0.11	−0.08
Unemployment rate	−0.24	0.00	−0.31	0.00	−0.34	0.00
Total employment	0.06	0.18	0.08	0.27	0.09	0.39
Nominal gross wage	0.11	0.00	0.14	0.00	0.12	−0.19
Nominal after tax wage	0.11	0.00	0.14	0.00	0.14	−0.08
Real gross wage	0.03	0.00	0.04	0.00	0.01	−0.11
Real after-tax wage	0.03	0.00	0.04	0.00	0.04	0.00
Household's consumption	0.30	0.42	0.35	0.48	0.40	0.66
Investment	0.12	0.17	0.17	0.23	0.22	0.38
Exports	−0.12	0.00	−0.14	0.00	−0.15	0.14
Non-energy output	0.07	0.19	0.09	0.27	0.09	0.39
Energy output	−0.41	−0.41	−0.41	−0.37	−0.40	−0.22
Energy use	−0.89	−0.57	−0.87	−0.51	−0.85	−0.36
Energy demand by industries	−0.22	−0.24	−0.22	−0.19	−0.21	−0.03
Household's energy consumption	−2.70	−1.47	−2.65	−1.41	−2.60	−1.26
Government expenditure	–	–	0.06	0.24	–	–
Fiscal deficit	−53.66	−165.48	–	–	–	–
Income tax rate	–	–	–	–	−0.10	−0.45
Economy-wide rebound	27.65	53.48	29.01	58.14	30.69	70.61

Note: SR, short run; LR, long run.

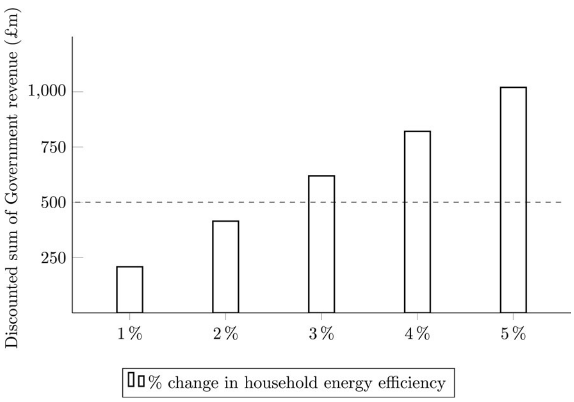

Figure 2. Discounted sum of government revenues over 20 years.

How much efficiency do we need to make SEEP a self-funded project?

SEEP is a 20-year programme in which the Scottish government commits to make an initial investment of £500 million in energy efficiency (Scottish Government, 2017).[26] Pilots to assess the impact of such expenditure on efficiency are still running, so it is currently not possible to quantify this effect. Instead, we explore by how much efficiency would have to increase in order to make the project self-funding over its lifespan.

Using the model with fixed government expenditure, we calculate the discounted sum[27] of government revenues over 20 years from the introduction of the household energy-efficiency improvements for energy efficiency increases of 1–5%.

It is clear from Figure 2 that under current assumptions that SEEP would break even with an increase in household energy efficiency of approximately 2.5%; a SEEP project that stimulates a 2.5% increase in household energy efficiency would be self-funding over 20 years.

Impact of a tax-financed increase in household energy efficiency

Assuming that SEEP does deliver the breakeven 2.5% energy-efficiency stimulus, we assess the economy-wide impact of such a project over its lifespan. This is set here in circumstances where the initial spending of £500 million is funded through an increase in the income tax rate.

We assume that the £500 million expenditure is additional to the current level of government spending, G, and that it is spread evenly over the first five years of the project. Given that we do not know which sectors directly benefit from this spending, we assume that in each year the £100 million is distributed according to the government's initial shares of consumption from the data set, δ_i^g. This implies that, for years 1–5, expression (5) is replaced by:

$$\overline{\text{FD}}_t = \text{GY}_t - \text{GEXP}_t \tag{5a}$$

$$\text{GEXP}_t = \sum_i \bar{G}_{i,t} \cdot Pg_t + \sum_i \delta_i^g 100m + \sum_{\text{dngins}} \overline{TRG}_{\text{dngins},t} \cdot Pc_t$$

Since both the fiscal deficit and government expenditure, G, are fixed, government income needs to vary by adjusting the income tax rate, τ, to allow for the additional spending. In year 6, equation (5a) is replaced by (5), the income tax rate returns to its baseline value, the fiscal deficit is still constant and G is endogenously determined.

Table 3 summarizes key results for this scenario. We focus on the first and second columns – the period during which the additional government spending takes place. The additional spending of £100 million requires the income tax rate to increase by 0.2%. This puts upward pressure on the nominal wage through equation (3). In the SR, the real gross wage increases by 0.08% while the real after-tax wage is 0.03% higher.

The higher wage adversely impacts production. This exacerbates the reduction in competitiveness caused by the increased domestic demand. On the other hand, the additional government spending further increases aggregate demand. Overall, the stimulus from the increased household energy efficiency and additional government spending dominates the negative impact of the income tax and GDP increases by 0.04% in the first period and 0.06% in year 5. From year 6, the income tax rate returns to the baseline value and ultimately the observed impacts are purely driven by the permanent increase in household energy efficiency.

Impact of a tax-financed increase in household energy efficiency with a 'social wage'

We compare the above results with two alternative scenarios. The first assumes a 2.5% increase in household energy efficiency under fiscal autonomy where the fiscal deficit is held constant through endogenous adjustments of government expenditure. Essentially, this replicates the previous FIXBAL scenario, but for a 2.5% rather than a 5% increase in household energy efficiency, and assumes that the implementation of the energy-efficiency improvement is funded via a neutral reallocation of current government spending. We refer to this as the SEEP-FIXBAL case.

Second, we replicate the above analysis, but now assume that the 'social wage' labour market closure is applicable. This is implemented by setting α and β to unity in equations (3a) and (4a). In this case, workers value the consumption of additional public expenditure as much as their private consumption; they are willing to accept lower real wages in exchange for the benefits of the increased energy efficiency (including the reduction in energy use and in carbon emissions). We call this case SEEP (social wage).

The time path of GDP for each of the three cases is plotted in Figure 3.[28] First, compare the SEEP-FIXBAL and SEEP cases. In the SEEP-FIXBAL case – the solid line – GDP adjusts smoothly towards the LR, as neither government expenditure nor aggregate demand are impacted by the implementation phase. The SEEP case outperforms the SEEP-FIXBAL case in the first and second years due to the additional government spending. However, as the rise in the income tax rate increasingly

Table 3. Impact of a 2.5% increase in household energy efficiency funded via an increase in the income tax rate.

Time period	Short run (SR)	5	10	15	20	Long run (LR)
Gross domestic product (GDP)	0.04	0.06	0.09	0.11	0.12	0.13
Consumer price index (CPI)	0.08	0.06	0.02	0.01	0.00	0.00
Unemployment rate	−0.24	−0.10	−0.07	−0.04	−0.02	0.00
Total employment	0.06	0.09	0.11	0.12	0.13	0.14
Nominal gross wage	0.15	0.12	0.03	0.01	0.01	0.00
Nominal after-tax wage	0.10	0.07	0.03	0.01	0.01	0.00
Real gross wage	0.08	0.06	0.01	0.00	0.00	0.00
Real after-tax wage	0.03	0.01	0.01	0.00	0.00	0.00
Household consumption	0.13	0.16	0.22	0.23	0.24	0.25
Investment	0.05	0.06	0.11	0.12	0.12	0.12
Exports	−0.10	−0.09	−0.03	−0.02	−0.01	0.00
Non-energy output	0.05	0.08	0.11	0.12	0.13	0.14
Energy output	−0.13	−0.25	−0.23	−0.21	−0.20	−0.19
Energy use	−0.24	−0.32	−0.29	−0.28	−0.27	−0.26
Energy demand by industries	−0.06	−0.16	−0.13	−0.11	−0.10	−0.10
Household energy consumption	−0.74	−0.77	−0.74	−0.73	−0.72	−0.71
Government expenditure	0.32	0.32	0.12	0.12	0.12	0.12
Fiscal deficit	0.00	0.00	0.00	0.00	0.00	0.00
Income tax rate	0.20	0.21	–	–	–	–

impacts competitiveness, the GDP growth slows down until period 5 where GDP is slightly higher in the SEEP-FIXBAL case. From year 6 onwards, GDP starts rising faster until it approaches the SEEP-FIXBAL case.

In the social wage case, the distortionary impact of the increased income tax rate on the wage is neutralized by workers' (and migrants') willingness to accept a lower take-home pay to allow increased spending on energy efficiency. For this reason, from years 1 to 5, GDP is boosted by the additional £100 million of public spending per year. In year 6, the additional government spending is exhausted and the proportionate increase in GDP is around 0.04% lower than in year 5. However, it still remains above the SEEP-FIXBAL and the SEEP cases. Note that here we only report the adjustment path for 20 years, as this is the lifespan of the energy-efficiency project. However, the three cases converge to the same long-run equilibrium subsequently, since ultimately this is driven solely by the same permanent increase in household energy efficiency. Between period 6 and the attainment of the long-run

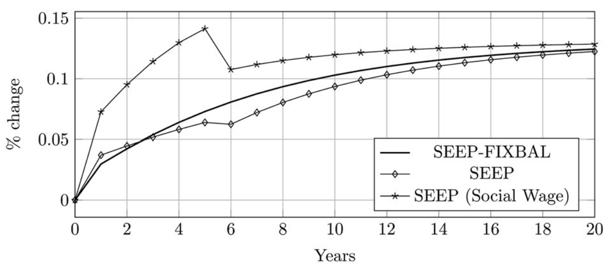

Figure 3. Time path adjustment of gross domestic product (GDP) under different government budget assumptions.

equilibrium, the results reflect a combination of the permanent stimulus to efficiency and the 'legacy effects' of transitory changes in government spending and tax rate changes.

CONCLUSIONS

The results show that improving household energy efficiency does indeed have positive impacts on the host regional economy, and such initiatives therefore have the *potential* to be instruments of regional development policy as well as climate change tools. Such initiatives are typically associated with a double dividend of reduced energy use and increased economic activity. However, the size of the impact varies with the degree of regional fiscal autonomy, the chosen method of financing and the 'tastes' of the host region's population for 'green' policies, in terms of their willingness to accept a reduction in the take-home wage in exchange for government-funded increased energy efficiency.[29] While we use Scotland as an example, the modelling results emulate a range of fiscal powers currently possessed by regions of the UK and regions in other countries.

When the increase in efficiency is funded via regional government expenditure reallocation, differences in results are driven by the specific fiscal regime of the region. Under a block-grant-type fiscal regime, a 5% household energy efficiency increase delivers a long-run rise in GDP of 0.17% with a reduction in total energy use of 0.57%.

Under fiscal autonomy, regional governments have the power to recycle additional tax revenues either to increase current spending or to reduce the income tax rate. If spending is increased, this further stimulates demand and delivers a long-run GDP increase of 0.26%, while total energy use falls by 0.51%. When the additional tax revenues are used to reduce the income tax rate, there is a supply-side response because the real net-of-tax wage increases, but the nominal wage falls. In this case, GDP increases by 0.39% in the long-run. However, total energy use falls by only 0.36%. In all these cases the energy-efficiency improvements are funded via current government spending reallocation, which is assumed to leave aggregate demand unaffected, and therefore the transitory change in government demand has no impact on the results.

When an energy-efficiency programme (such as SEEP) is financed via an increased income tax rate, we have different short- to medium-term impacts. In fact, income tax variations have negative supply-side effects reflected in a small loss of competitiveness. This is because at higher tax rates workers put more upward pressure on wages, thereby increasing the cost of producing goods in the region. These impacts dominate the positive stimulus from the additional government spending.

However, in the case where workers have 'green' tastes and attribute the same marginal value to the government programme and to private consumption, the distortionary impact of the tax on competitiveness disappears. We then observe positive transitory legacy impacts due to the increase in government demand. This is because workers are willing to accept lower wages in exchange for the increased energy efficiency and associated reduced energy use and emissions.

Overall, the analysis implies that regional governments should consider household energy-efficiency-increasing initiatives as potentially important instruments of regional development policy, as well as of policies aimed at delivering energy (and emission) savings. Furthermore, the efficacy of household-efficiency enhancements in stimulating economic development typically increases with the degree of regional fiscal autonomy. However, this arises partially at the expense of a corresponding decline in their efficacy as a source of energy savings. Future research should examine the nature of this trade-off for particular policy interventions in different regional cases. It should allow for potentially differentiated impacts of changes in the composition of government expenditure on the aggregate economy and on any amenity value associated with them.

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NOTES

1. For example, in September 2016 the Scottish government announced a post-European Union referendum stimulus package that included, among other items, additional spending on energy-efficiency measures (see https://news.gov.scot/news/capital-spending-boost).
2. Rebound occurs when the potential energy savings from an increase in energy efficiency are bigger than the actual energy savings. This paper calculates the rebound effect as: (1 – (AES/PES))100, where AES is actual energy savings; and PES is potential energy savings (for details, see Figus, Lecca, McGregor, & Turner, 2017).
3. The Scottish government has recently designated improved energy efficiency within homes and the non-domestic building stock as part of the National Infrastructure Priority. This reflects an increasing awareness of the role that energy efficiency might play in stimulating the regional economy.
4. The double-dividend argument can be decomposed into a number of multiple benefits as intended by the International Energy Agency (IEA) (2014).
5. The Welsh Assembly will have the power to set an income tax rate from April 2019, and the Northern Ireland Executive will be able to set the corporation tax rate from April 2018.
6. Similar results are found in Figus, Turner, et al. (2017) where the distributional impact of household energy-efficiency improvements is assessed.
7. Figus, Lecca, et al. (2017) show that if the CPI is adjusted to reflect the price of energy in efficiency units, there is actually an improvement in competitiveness.
8. AMOS is the acronym for a micro–macro model of Scotland. ENVI indicates a version of this model developed for the analysis of energy/environmental impacts of a range of policies and other disturbances.
9. Of course, the database of the model reflects the characteristics of a regional economy: in particular, the Scottish economy is highly open with respect to trade.
10. Figus, Lecca, et al. (2017) discuss the implications of using different estimated elasticities.

11. See Figure A2 in Appendix A in the supplemental data online for a schematic representation of the production structure.
12. Which is the same as that in equation (3).
13. While the 2009 national accounts may not fully reflect the current economic situation in Scotland, evidence suggests that economic structure changes little over comparatively short periods of time.
14. See Table B1 in Appendix B in the supplemental data online for the full list of sectors included in the model.
15. This also allows a comparison of the results with the UK case in Lecca, McGregor et al. (2014).
16. We could, in principle, capture any reallocation effects if we had sufficient data. For example, see Hermannsson et al. (2013) on balanced expenditure multipliers applied in a higher education institutions (HEIs) context.
17. We assume that general current public spending has no supply-side impact effects.
18. We do not intend to provide an exhaustive analysis of the impact of SEEP because: (1) SEEP focuses on both residential and commercial energy-efficiency improvements while we only focus on residential; and (2) although the analysis uses a Scottish model, it aims to emulate the likely impact of energy-efficiency programmes in regions with similarly devolved fiscal powers.
19. Of course, policy efficacy is concerned with much more than 'breaking even' in public finance terms, and should reflect the wider considerations we have already emphasized, including impacts on the economy and energy use.
20. Figus, Lecca, et al. (2017) show that if the CPI used to deflate the real wage is adjusted to include the price of energy in efficiency units, we observe an increase in competitiveness due to the reduction in the nominal wage.
21. In a comparable UK study by Lecca, McGregor et al. (2014), GDP increases by 0.10%. However, the fall in total energy use is correspondingly less in the Scottish case (–0.57% as against –0.70% for the UK). This reflects the structural differences between the UK and Scotland as captured by the models databases. We have isolated these by examining the impact of the same shock in AMOS ENVI under an assumption of zero labour mobility. Unsurprisingly, Scottish trade flows prove more sensitive to competitiveness changes, but the migration effect is much more important quantitatively. Space restrictions preclude a detailed treatment, but this available in Figus, Lecca, et al. (2017).
22. In an alternative scenario with no migration, we find that energy used by industries falls by 0.3% and household energy consumption by 1.48%.
23. Again, this will not be the case if we use a quality-adjusted CPI, as explained by Figus, Lecca, et al. (2017), as there will be supply responses through the real wage.
24. For simplicity, we use the SR elasticity for the short run and the LR elasticity for the long run.
25. The negative sign indicates that the deficit has fallen.
26. Again, this includes energy-efficiency improvements in residential and non-residential buildings. However, here we focus on the impact of energy-efficiency improvements only in residential energy use.
27. We use a discount factor of 3.5%, as recommended by the *Green Book* of HM Treasury (2013).
28. We have run the same 2.5% increase in household energy efficiency assuming a Barnett-type closure (SEEP-FIXGOV). Results are compatible with those presented in Table 2, in that the more efficient use of energy delivers a positive but smaller increase in GDP (0.8% in year 20) than the SEEP-FIXBAL case.
29. The size of these effects also varies with the degree of openness of the host economy, as our earlier comparison with the national results reported by Lecca, McGregor et al. (2014) clearly indicates.

ORCID

Gioele Figus http://orcid.org/0000-0002-2642-5504
Patrizio Lecca http://orcid.org/0000-0002-1053-3869
Peter McGregor http://orcid.org/0000-0003-1221-7963

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