The economic impacts of Scottish fiscal policies and their spillover effects on the energy system

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Abstract

The energy and economic systems are inextricably intertwined. This means that fiscal interventions are likely to have a significant influence on the energy system, the neglect of which could lead to inefficiencies in the design of energy and economic policies. The importance of this in practice depends on the strength of the spill-over effects from fiscal instruments to energy policy goals. This is the focus of the present paper which employs a multi-sectoral computable general equilibrium (CGE) model to track the impacts of fiscal adjustments on key economic and energy policy goals. In particular the effect of tax and public expenditure changes are quantified and compared both with and without the imposition of a balanced budget. We are interested in identifying conditions under which a fiscal policy "double dividend" might occur. This is a stimulus to the economy accompanied by a simultaneous reduction in emissions or increase in energy productivity. Our results suggest that such an outcome is possible but these impacts depend on the public's valuation of the amenity associated with the greater public expenditure and the extent to which this is reflected in workers' wage bargaining behaviour. There are undoubtedly differential spillover effects on key elements of the energy system from tax and expenditure policies that may prove capable of exploitation through the coordination of fiscal and energy policies. Whilst it seems doubtful that fiscal policies would be formulated with a view to improved coordination with energy policies, policymakers can benefit from knowledge concerning the likely direction and scale of fiscal spillover effects to key elements of the energy system. For example, this analysis reveals the extent of any energy policy adjustment that would be required to maintain a given level of emissions.

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1. Introduction

The energy and economic systems are inextricably intertwined. While this interdependence is widely recognised, it has not featured prominently in assessments of the likely impact of economic policies, such as industrial and fiscal policies. Rather, such assessments focus on the primary economic objectives of these policies, in particular the impact on Gross Domestic Product (GDP) and employment (e.g. Cox et al., 2016; Royston et al., 2018). However, in principle, fiscal policies are likely to have a significant influence on key elements of the energy system, the neglect of which may lead to inefficiencies in the design of appropriate energy and economic policies. The importance of this in practice depends on the strength of the spill-over effects from fiscal policy instruments to energy policy goals, notably in the reduction of carbon emissions. This is the focus of the present paper.

The Scottish Government wishes to limit emissions through moderating their link to economic activity. For example, Scottish Government Energy Strategy & Climate Change Plan (2017, 2018) has in place policies and objectives to encourage a shift to renewable energy sources in electricity generation and to promote improvements in energy efficiency. However, the central interest in the present paper is on the incremental change in emissions that is likely to arise from fiscal policy actions alone. This identifies the potential additional challenge made to meeting the Government's emissions targets that is solely attributable to fiscal policy.

We approach the analysis of these issues through the use of a multi-sectoral computable general equilibrium (CGE) model for Scotland that captures the interdependence between the economy and central elements of the energy systems. This allows us to track the impact of key fiscal policy interventions on the major goals of economic and energy policies, such as these outlined in Scotland's Energy & Economic strategies (Scottish Government 2015, 2017) thereby delivering a more 'holistic' perspective on the impacts of policy actions.[1]

Ross et al. (2018a,b,c,d) analyse the potential impacts of successful UK industrial, business and innovation, and fiscal policies on the UK economic and energy systems. The present paper applies a similar approach in a Scottish context and compares the energy consequences of tax and government expenditure changes considered separately. Building on the work of Emonts-

[1] Bergman (2005) reviews the widespread use of CGE models to analyse economy-environment interactions.

Holley et al., (2016, 2019), we then analyse the impact of a rise in the average income tax rate with an imposed balanced budget, so that there are matched increases in Scottish public spending and revenues.[2]

This paper is organised as follows. Section 2 outlines the simulation strategy and key features of our energy-economy-environment model of the Scottish economy. Section 3 presents the simulation results and Section 4 provides a summary of the main conclusions.

2. Simulation strategy and the likely economic and energy impacts of fiscal policy

In order to identify the likely nature and scale of economy/energy spill-overs stimulated by fiscal policy interventions, we proceed by exploring illustrative simulations. First, we compare the impacts of achieving a given stimulus to GDP by raising government current expenditure and reducing average income tax rates. This allows identification of any differences in the pattern of spill-overs generated by the two forms of fiscal expansion. We then analyse the consequences of a 5% increase in the average income tax rate subject to an imposed balanced budget; the increase in income tax revenues are here matched by a corresponding change in current government expenditure.[3]

These simulations are undertaken using AMOSENVI, an energy-economy-environment computable general equilibrium (CGE) model of Scotland. This model was purpose-built to capture the interdependence of the energy and non-energy sub-systems. Figus et al., (2017, 2018) and Lecca et al., (2014) provide detailed descriptions of the main characteristics of the model. We calibrate the model using information from the Scottish Social Accounting Matrix (SAM) for 2010.[4]

The economy is initially taken to be in long-run equilibrium so that if the model is run forward in the absence of any disturbance, in each period it simply replicates the base year dataset, the 2010 SAM. The results presented in Section 3 are then typically percentage changes in the endogenous variables relative to this unchanging base. All the reported variations in economic

[2] The comparable analysis for the UK is provided in Ross et al, (2018d).
[3] For simplicity we assume that this expenditure has no direct supply-side effects.
[4] Emonts-Holley et al. (2014) give a detailed description of the methods employed to construct these data. The SAM is available at: https://doi.org/10.15129/bf6809d0-4849-4fd7-a283-916b5e765950

activity and energy use are therefore directly attributable to the exogenous fiscal changes. Given that the CGE is calibrated on annual data, we take each period in the adjustment process to be one year.

Base year industrial territorial CO_2 emissions are calculated by linking them to sectoral primary fuel use, as outlined in Allan et al. (2018). This essentially converts data on sectoral physical use of energy to CO_2 emissions using UK technology assumptions; a proportioned emission factor for each of the three primary fuels (coal, oil and gas) is calculated for each sector to obtain sectoral base year emissions. CGE simulations generate sector-specific changes in the use of each of the primary fuels. Thereby generating a new set of emissions.

To observe the full evolution of all the economic variables simulations are run for 50 years. Results for the more important economic and energy use impacts are reported with the primary focus being the long run, over which migration is complete and all sectoral capital stocks are fully adjusted.

3. Simulation results

We proceed in Section 3.1 by comparing the effects of an increase in government expenditure with those following a reduction in the average income tax rate. Section 3.2 reports the impacts of an increase in the income tax rate under the imposition of a balanced budget.

3.1. Expenditure and tax policy impacts compared in the Conventional Macroeconomic model

To facilitate the analysis the sizes of the increase in government expenditure and the reduction in average income tax rate are chosen so as to generate the same (0.6%) long-run expansion in GDP. Table 1 shows that this requires a 1.36% increase in government expenditure or a 0.96% reduction in the average income tax rate. Results are in percentage change from base year and in nominal terms unless indicated otherwise.[5] For simplicity we assume that it is feasible to finance these changes through government borrowing at unchanged interest rates.[6]

[5] Around 53% of total government expenditures are funded by taxes on households.
[6] Under the current system the Scottish Government's ability to engage in borrowing is limited. However, the simulations allow us to identify key distinguishing characteristics of tax and expenditure changes.

In the Conventional Macroeconomic Scottish model, a 1.36% increase in public consumption is enough to generate the 0.60% rise in long-run GDP. A key factor here is the role of migration. Initially, real wages rise and the unemployment rate falls in response to increased demand, but this attracts inter-regional in-migration which ultimately restores the real wage and unemployment rates to their initial levels, as is apparent from Table 1. Similarly, domestic profits initially rise and this leads to higher investment and subsequently increased capital stocks, again eventually returning profit rates to their base-year equilibrium values. Ultimately, all prices return to their original levels so that there is no long-run impact on competitiveness Because of the flexibility of the supply side in an open regional economy, there is ultimately no induced "crowding out" of investment or exports. [7]

As expected, the expansion in economic activity also stimulates energy demand, albeit very modestly in this case; increased production, consumption, investment and government expenditure requires greater energy inputs. Total energy use increases by 0.24%, reflecting the increased use in production (0.36%) and in final demands (0.12%). There is apparently a trade-off here between economic and energy policy goals in that greater economic activity has been secured, but with industrial territorial emissions increasing (by 0.2%). However, the "energy productivity" (GDP/total energy use) indicator, as targeted by the Scottish Government (2017) in its Energy Strategy, increases because GDP is stimulated more than energy use. The increase in "energy productivity" reflects the relatively low emissions intensity of public consumption, which increases by 1.36% as compared to the 0.60% increase in GDP.[8]

By design, the 0.96% cut in the average income tax rate generates the same 0.6% stimulus to GDP. However, its impact on the composition of activity is quite different. The stimulus to demand here comes entirely through increased consumption, investment and exports with government spending unaffected. Given that wages are here taken to be bargained net of tax (as in the Conventional Macro/Micro models discussed below), the reduction in income taxes puts downward pressure on the real pre-tax wage rate. This falls by 0.48%, the CPI declining by 0.21% and nominal pre-tax wages by 0.69%. The increased competitiveness that this produces stimulates exports, which rise by 0.35%. Although in both cases the change in GDP is the same,

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[7] With no access to migration a similar percentage expansion in UK GDP would require well over three times the percentage increase in Government expenditure as required in the Scottish model.

[8] Although this is referred to as energy productivity it is actually here a change in energy intensity. There is no change in productivity as economists usually use the term.

the increase in employment is slightly less than with the stimulus to government expenditure, reflecting the lower labour intensity of private sector activity.

The different composition of value-added in the two cases is also reflected in different impacts on energy use. The tax-induced expansion is associated with a significantly greater increase in total energy use (0.40% as compared to 0.24%). Energy use is higher in both production (0.50% compared to 0.36%) and in consumption (0.29% as compared to 0.12%) under the tax-, as opposed to the expenditure-, induced fiscal expansion. Furthermore, the increase in industrial territorial emissions is much higher in the tax-induced expansion. This result reflects the greater energy and emissions intensity of exports against public spending.

What are the implications for policy? The first point to note is that the fiscal expansion, whether this is generated by expenditure increases or tax reductions, here has the desired effect on the main goals of economic policy: both GDP and employment rise. However, tax and expenditure policies do have different effects on the composition of GDP and this matters even for economic impacts. So the composition of value-added shifts in favour of public relative to private spending in the case of expenditure increases, but the shift is reversed in the case of tax reductions. Since the public sector is, on average, more labour intensive than the private sector, the stimulus to employment is greater under an expenditure-induced expansion than under a tax-induced expansion.

While the fiscal policies have the desired effect (though differentially) on their primary objective of stimulating economic activity, both energy use and emissions rise. There therefore appears to be a trade-off between the main economic and energy policy goals. However, because of their different impacts on the composition of economic activity, tax- and expenditure-induced expansions face different trade-offs. Government spending is less energy and emissions intensive than private spending, so expenditure-induced expansions generate significantly less emissions than tax-induced expansions; the trade-off between the key GDP and emissions objectives is much less severe for expenditure-induced expansions.

What of the other goals of energy policy? The GDP change is, by design, the same, so the differences in energy use imply that the energy productivity indicator increases more in the expenditure-induced expansion (by 0.36% as compared to 0.20%). Note, however, that energy efficiency is unchanged in both simulations: the energy productivity indicator simply reflects the change in the composition of economic activity. It would appear that in order to meet its energy productivity targets it would seem preferable for the Scottish Government to pursue expenditure-, rather than tax-, induced fiscal expansions.

When operated in isolation of each other and of other policies, including energy policies, tax and expenditure increases do involve trade-offs between economic and environmental objectives, which are quantitatively more important for taxation. Of course, in practice, energy policies directed at decarbonisation are in place, and it is instructive to consider how these might be adjusted to counter any adverse effects on emissions generated by fiscal expansions. An idea of the scale of the change required is to consider by how much the emissions in the electricity producing sector would need to fall so as to offset entirely the emissions directly attributable to the fiscal expansion. A fall of 0.56% in emissions in the electricity sector would offset the increase in emissions arising here from the 1.36% increase in government spending.[9] Given that emissions in the electricity production sector have fallen by around 80% in the Scotland over the past 20 years, it is not unreasonable to suggest that these emissions could be offset. This said, other things being equal some adjustment in energy policy at the margin would be required to offset the additional emissions associated with a fiscal expansion.

3.2. Impacts of a balanced budget fiscal expansion

In practice, tax and expenditure changes are often operated in tandem. In general two countervailing forces are generated by the balanced-budget rise in income tax. First, there is a beneficial stimulus to aggregate demand as government expenditure is less import intensive than private consumption. Second, there is an adverse change in aggregate supply as workers and migrants push up wages and reduce competitiveness in an attempt to restore their net of tax real consumption wage. If the beneficial demand effect dominates the adverse supply effect, the economy expands. However, if the supply-side effect is the greater, the balanced budget increase in public expenditure actually induces a contraction in economic activity. The net effect of these countervailing demand and supply forces depends crucially on migration and wage bargaining behaviour (e.g. Lecca et al., 2014; Emonts-Holley et al., 2016, 2019). In the balanced budget case both government expenditure and the tax rate rise, which generates conflicting impacts on energy use and emissions as well as on economic activity. Net, emissions will tend

[9] Similarly, a fall of 1.27% in emissions in the electricity sector would offset the increase in emissions arising here from the0.96% reduction in the income tax rate.

to rise if economic activity rises and fall in the presence of predominant negative supply-side impact.

In our simulations we consider three alternative treatments of regional wage bargaining and migration behaviour which prove to be important for fiscal policy impacts on economic and energy systems. In the first, *Conventional Macro*, case neither local residents nor potential migrants place any value on the increase in public consumption, so that migrants and workers care only about the fall in their take home wage and behave accordingly. Here the adverse supply effect is at its most powerful. In the second, *Conventional Micro*, labour market closure potential migrants value the increase in public services and factor that into their migration decision, which mitigates the strength of the adverse supply shock. This is motivated by models of fiscal federalism (e.g. Tiebout, 1956). In the final, *Social Wage*, case the increase in public consumption is valued equally to the loss in private consumption by both workers and migrants. Since workers feel no worse off after the public expenditure and tax changes in this case – their lower take home pay is compensated by the increased supply of public goods – there is no upward pressure on wages. Here there is no adverse supply effect of a balanced budget expansion: only the beneficial demand effect is present and the impact is expansionary.

Table 2 summarises the long-run impacts of a 5% increase in the income tax rate under a balanced budget - a rise in taxation matched by a rise in government spending - for the three models. We proceed by summarising the impacts on economic activity and key energy policy goals.

Consider first the Conventional Macro simulations, reported in the first column of Table 1. In this case the post-tax real consumption wages govern both migration and bargaining decisions. This implies that in both the bargaining and zero net migration functions, at any given employment rate the nominal wage will have to rise by the amount required to offset the increase in the tax rate and any induced increase in the CPI. Workers seek to restore their real take home pay (their post-tax real wage) and they succeed in doing so in the long run. As such, there is upward pressure on wages and prices and this creates adverse competitiveness effects. It is clear from the simulation results that in this case the adverse competitiveness effect dominates the beneficial demand effect and there is a significant contraction in economic activity, in line with the results reported in e.g. Emonts-Holley et al (2019).

Migration here responds to post-tax real wage and unemployment differentials. The predominant adverse competitiveness effect means that real post-tax wages initially fall, unemployment rises and net outmigration occurs. This process continues until reductions in the population, restore the unemployment rate and the real post-tax wage to their initial levels. The 0.57% increase in public expenditure is therefore accompanied by a fall in population and employment of 2.86% and a reduction in GDP of 2.78%. Total exports fall by 1.79% in response to the loss of competitiveness driven by the 3.66% rise in the nominal pre-tax wage and the 1.05% increase in CPI, as workers successfully restore the initial value of their real take home pay.

Here the intended expansionary fiscal policy actually induces a contraction; the policy therefore fails in its primary objective of increasing economic activity. What is the impact on energy policy goals? The fall in economic activity in this case reduces total energy use by 1.93%, reflecting the 2.36% and 1.42% reductions in production and final demand uses respectively. The adverse impact on the economy is, perhaps not surprisingly, associated with lower energy use and emissions, although “energy productivity” actually declines. While energy prices rise, they do so by less than the CPI, so in that sense energy affordability improves, but household incomes fall. The impact on energy policy goals is therefore somewhat ambiguous. However, in so far as the reduction in total emissions is the Scottish Government’s primary environmental energy concern, under a model driven by the Conventional Macroeconomic assumptions, there is clearly a conflict between meeting economic and energy goals using this policy.

In the Conventional Micro case reported in column two of Table 1, potential migrants value the increase in public services and factor that into their migration decision. Migrants are motivated by their ‘social wage’, which we take to be unaffected by the balanced-budget fiscal expansion: migrants value the increased public spending equally to the reduced take-home wage resulting from the income tax increase. However, this valuation is not reflected in regional wage bargaining.[10] Long-run equilibrium is established where the nominal wage increases significantly, but not sufficiently to fully restore the real wage. Employment falls by 2.64%, whilst the unemployment rate increases by 0.11% points. While the long-run unemployment rate rises, the extent of the adverse supply shock is less than under the Conventional Macro case. As

[10] The conventional argument is that the level of public goods is essentially independent of the wage bargains undertaken by small groups of workers and is therefore irrelevant to the bargain. However, the income tax rate directly effects the workers trade-off between work and leisure for the worker. However, both the level of public goods and the tax rate are relevant for the migration decision.

compared to the Conventional Macroeconomic outcomes, the nominal wages rise by less, so that employment and GDP effects are improved and any induced net out-migration is reduced. Nevertheless, the adverse competitiveness effect still predominates, as reflected in the substantial 2.58% fall in GDP.

Again, in this case a balanced budget fiscal expansion actually leads to a contraction in economic activity; fiscal policy does not have its traditional positive effect on its primary goal. The news on energy goals appears better in that total energy use and emissions fall, although by less than in the Conventional Macro model (-1.82% as compared to -1.93%; and -2.13% against -2.26%). However, it is highly unlikely that government would wish to reduce emissions by reducing economic activity. The "energy productivity" indicator here falls, but by less than in the Conventional Macro case, and again this is likely to be weighted less heavily than the fall in energy use and emissions. Affordability is impacted similarly to the Conventional Macro case.

In the Social Wage case, the increase in public consumption is valued equally to the loss in private consumption. This implies that in the long run, the nominal pre-tax wage and employment rate are unchanged from their base-year values. This reflects the fact that workers feel as well-off after the change as they did before and do not push to restore their take-home wage following the policy change. This eliminates the adverse competitiveness effect completely; neither wages nor prices are impacted. In this case, therefore, the beneficial net demand stimulus associated with the fiscal expansion must predominate, and output and employment expand. GDP increases by 0.61%, and employment by 0.94% in a manner similar to that envisaged in the simple Keynesian balanced budget multiplier. However, the whole of the increase in tax is reflected in a significant reduction in the post-tax real wage of 2.51%.

Overall, the aggregate results of the Conventional Micro/Macro models are very similar, reflecting the predominance of adverse competitiveness effects in both cases. However, the impact on real wage and unemployment rates shows some differences, indicating the underlying migration assumptions of the models. The trade-off between economic activity and emissions is apparent in these models, although it simply reflects the fact that emissions fall in line with the fall in economic activity. However, the Social Wage model differs from both Conventional models in that it eliminates any adverse supply shock associated with the fiscal stimulus by preventing any upward pressure on the nominal wage. Furthermore, there are compositional effects as public expenditures replace private expenditures and these have differential implicit (and actual) energy contents. Overall, total emissions actually fall, despite the increase in economic activity and, of course, the emission intensity of GDP also falls. In the Social Wage case, there is a "double dividend" as key economic and energy policy goals are simultaneously improved. This is can be seen from the results reported in Figure 1; GDP and energy productivity rises by 0.61% and 0.76% respectively whilst total energy use and emissions fall by 0.15%, and 0.18% in the Social Wage case.

The impact on affordability is ambiguous in the two Conventional Micro/Macro models because although energy prices rise by less than the CPI, real household incomes fall. In the Social Wage case, all prices remain unchanged in the long run but there is a fall in real after tax incomes.

The effect on both the economy and key elements of the energy-system (and corresponding policy goals) clearly depend on workers' and migrants valuation of the amenity associated with the greater public expenditure, and especially to the extent to which this is reflected in their wage bargaining behaviour. The analysis presented here suggests that there are significant spill-overs from fiscal policy actions to key elements of the energy-system. Neglecting these spill-over effects is likely to create a source of inefficiency in the conduct of policy. Knowledge of their likely scale could be used to develop a more 'holistic', coordinated approach to policy formation and implementation.

Of course, in practice energy policies aimed at limiting emissions operate simultaneously with fiscal policies. However, we have sought here to isolate the impact of fiscal policies on the energy system, so that an assessment can be made of the extent to which they act to worsen or alleviate trade-offs between economic and environmental objectives at the margin. Under the Conventional Micro/Macro models, a balanced budget fiscal expansion generates a contraction in economic activity. Although the achievement of emissions targets is then made easier, this is only because fiscal policies fail to have the desired impact on their primary objectives. Clearly reducing economic activity is an undesirable method of reducing emissions, and conflicts with a major economic policy objective. However, in the presence of a Social Wage there is potential for a double dividend with economic activity increasing while emissions (and energy use) fall and energy productivity increases.

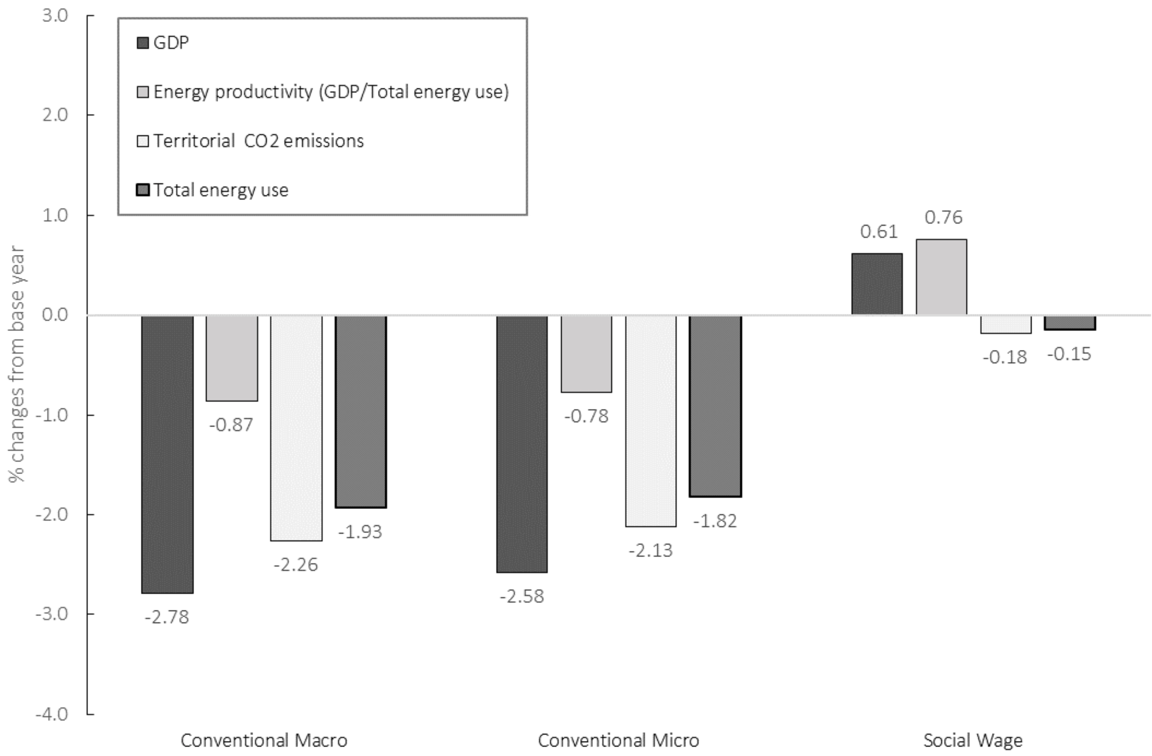
Table 1 Long-run effects of a 1.36% increase in government spending, and a 0.96% reduction in the income tax rate, calibrated to increase GDP by 0.6%, Bargained Real Wage closure (% changes from `base year).

	Increase in government expenditure	Reduction in income tax
GDP	0.60	0.60
CPI	0.00	-0.21
Unemployment rate (percentage points difference)	0.00	0.00
Total employment	0.72	0.62
Nominal wage	0.00	-0.69
Nominal after tax	0.00	-0.21
Real wage	0.00	-0.48
Real wage after tax	0.00	0.00
Labour force	0.72	0.62
Investment	0.45	0.62
Households consumption	0.47	0.46
Households income (real)	0.44	0.14
Labour income	0.72	-0.07
Capital income	0.41	0.35
Government budget	1151.10	70.02
Government consumption	1.36	0.00
Total imports	0.41	0.08
Total exports	0.00	0.35
Total energy use	0.24	0.40
- Electricity	0.35	0.46
- Gas	0.32	0.43
Energy use in production (total intermediate)	0.36	0.50
Energy consumption (total final demand)	0.12	0.29
- Households	0.43	0.39
- Investment	0.32	0.52
- Exports	0.00	0.25
Energy output prices	0.00	-0.13
Energy productivity (GDP/Total energy use)	0.36	0.20
Industrial territorial CO_2 emissions	0.20	0.46
Emission intensity (industrial territorial CO_2/GDP)	-0.39	-0.13

Table 2 Long-run effects of a 5% increase in the income tax rate under a balanced budget (% changes from base year).

	Conventional Macro	Conventional Micro	Social Wage
GDP	-2.78	-2.58	0.61
CPI	1.05	0.99	0.00
Unemployment rate (percentage points difference)	0.00	0.11	0.00
Total employment	-2.86	-2.64	0.94
Nominal wage	3.66	3.39	0.00
Nominal wage after tax	1.05	0.79	-2.51
Real wage	2.58	2.37	0.00
Real wage after tax	0.00	-0.20	-2.51
Labour force	-2.86	-2.53	0.94
Investment	-2.98	-2.79	0.06
Households consumption	-2.14	-2.09	-1.02
Households income (real)	-0.48	-0.46	0.53
Labour income	0.72	0.66	0.95
Capital income	-1.62	-1.54	0.07
Government budget	0.00	0.00	0.00
Government consumption	0.57	0.67	3.31
Total imports	-0.21	-0.23	-0.05
Total exports	-1.79	-1.67	0.00
Total energy use	-1.93	-1.82	-0.15
- Electricity	-2.17	-2.06	-0.26
- Gas	-2.04	-1.93	-0.29
Energy use in production (total intermediate)	-2.36	-2.22	-0.01
Energy consumption (total final demand)	-1.42	-1.35	-0.28
- Households	-1.78	-1.76	-0.99
- Investment	-2.48	-2.33	-0.08
- Exports	-1.26	-1.17	0.00
Energy output prices	0.64	0.60	0.00
Energy productivity (GDP/Total energy use)	-0.87	-0.78	0.76
Industrial territorial CO_2 emissions	-2.26	-2.13	-0.18
Emission intensity (industrial territorial CO_2/GDP)	0.54	0.47	-0.79

Figure 1: Long-run effects on GDP, emissions, and energy use/productivity of a 5% increase in the income tax rate under a balanced budget. % changes from base year.



4. Summary and conclusion

The energy and economic systems are inextricably intertwined. In principle, fiscal policies are likely to have a significant influence on key components of the energy system, the neglect of which may lead to inefficiencies in the design of appropriate energy and economic policies. The importance of this in practice depends on the strength of the spill-over effects from fiscal policy instruments to energy policy goals. We explore this issue using a multi-sectoral computable general equilibrium (CGE) model for Scotland. This model allows us to track the impact of fiscal policy interventions on key goals of both economic and energy policies, such as these outlined in Scotland's Energy & Economic Strategies (Scottish Government 2015, 2017).

Tax-reduction and public-expenditure-expansion policies, financed by borrowing at an unchanged interest rate, both have beneficial impacts on their primary economic objectives of increasing GDP and employment, but also have an adverse impact on attempts to reduce total energy use and CO_2 emissions. Moreover, the trade-off between economic and environmental objectives is more restrictive for tax-induced expansions since these result in an increase in private relative to public expenditure (and corresponding price effects) and the former is more emissions-intensive than the latter. While energy productivity rises (and by more for expenditure-induced expansions), energy policymakers are more likely to be concerned about the adverse impact on emissions. While the extent to which emissions increase in response to expansionary fiscal policy is very modest compared to the historical reductions in emissions, some further adjustment of energy policies would be required to ensure these are offset.

In our analysis of balanced-budget increases in public expenditure we consider alternative wage bargaining regimes, reflecting different valuations by workers and migrants of increases in public expenditure. Overall, the aggregate results of the Conventional Micro/Macro models are very similar, with GDP falling in both cases in the long run indicating the predominance of adverse competitiveness effects. In these circumstances fiscal expansions have perverse effects on their primary economic objectives. While emissions also fall, policy makers would not typically wish to secure emissions reductions through this means. Energy productivity also falls.

The Social Wage model, in which workers and migrants value higher government spending equally to their lost consumption expenditure and reflect this in wage bargaining, differs from the Conventional models. This model essentially eliminates any adverse supply shock associated with the fiscal stimulus, by preventing any upward pressure on the nominal wage and therefore GDP increases in the long run. This, however, implies a willingness by workers to accept a substantial cut in their real take home pay. Nonetheless, in this case balanced budget fiscal policy has the desired effect on its primary economic objectives. Furthermore, it also has a positive, if small, impact on the objectives of energy policy: the shift away from private to lower emissions-intensive public spending leads to a reduction in emissions (and energy use) and an improvement in the "energy productivity" indicator.

In general, there are significant spill-over effects from the borrowing-financed and balanced-budget fiscal policies considered here on key elements of the energy system. Neglecting these spill-overs creates a source of inefficiency in the conduct of policy, and a knowledge of their likely scale should be used to develop a more 'holistic', coordinated approach to policy formation and implementation. However, in the Social Wage case, a "double dividend" is possible as key economic and energy policy goals are simultaneously improved, where GDP, employment and energy productivity increase whilst energy use and emissions fall. Where fiscal expansions do increase emissions, the scale is typically modest relative to the decarbonisation that has occurred in Scotland over the past 20 years, since carbon emissions targets were first adopted. Nonetheless, in these circumstances fiscal expansion does add to the challenge that energy policy faces in meeting emissions targets.

Our intention is ultimately to create a framework that explicitly recognises, and seeks to quantify, the scale of spill-overs from economic and energy policies to both energy and economic policy goals. Where these spill-overs prove to be significant, accounting for them through better coordination of economic policies with energy policies would create the potential to deliver improved outcomes for both.

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