How fiscal policies affect energy systems: the importance of an "Environmental Social Wage"

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Abstract

We employ a regional computable general equilibrium model to measure the impact on CO_2 emissions of a balanced-budget increase in public environmental expenditure. We identify conditions under which an economic stimulus accompanied by a reduction in emissions could occur. Our results suggest that this is conceivable if the population values the environmental amenity funded by the increase in public expenditure and if this is reflected in wage bargaining behaviour. Given increasing concerns over climate change, public spending on environmental improvement could attract support together with the establishment of an "environmental social wage", where workers accept a lower pay in return for that improvement.

Key words: energy policy; fiscal policy; income tax; energy demand; computable general equilibrium.

JEL: C68, D58, Q43, Q48

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Introduction

Cox et al. (2019) conduct a wide-ranging review of literatures concerning the impacts of 'non-energy policies'[1] on the energy system. The interdependence of the energy and economic systems is widely recognised. However, this interdependence has not featured prominently in impact assessments of non-energy economic policies, such as industrial and fiscal policy. Rather, the evaluation of such policies tends to focus on the attainment of their principal economic objectives (e.g. Cox et al., 2016; Royston et al., 2018). However, policies whose primary aim is to boost economic activity are likely to influence key elements of the energy system, the neglect of which may lead to inefficiencies in the design of appropriate energy and economic policies.

Cox et al. (2019, p183) note that the "literature mainly refers to specific energy taxes and does not explore the broader tax regime within which these sit. There appears to exist a significant gap in the literature on the impacts of income, property and other personal taxes on energy demand". Our first aim is therefore simply to identify how a straightforward debt-financed fiscal expansion will affect energy demand and CO_2 emissions. In the present extremely low interest rate regime this appears an increasingly attractive option for stimulating the economy.

However, environmental economists have also pointed to the now familiar "double-dividend" notion that the introduction of a carbon tax accompanied by a balanced-budget reduction in labour taxes can both reduce emissions and increase economic activity (e.g. Friere-Gonzalez, 2018). In the present paper we investigate whether a similar double dividend can exist where public sector spending is used to provide environmental amenities. That is to say, can funding such projects generate a balanced-budget fiscal expansion which itself increases economic activity, but would also further reduce carbon emissions?

It transpires that the response of wage bargainers to tax changes proves critical to the economic, energy and emissions impacts of balanced-budget fiscal expansions. The growing strength of the environmental movement might motivate support for greater public spending on environmental amenities financed through increased income tax payments, without producing pressure for higher pre-tax wages. This would imply an “Environmental Social Wage” effect. Here we analyse how the valuation of environmental benefits by local workers and migrants, generated through public consumption, affects the economic and indirect environmental impact of such expenditure.

We analyse these issues using a multi-sectoral computable general equilibrium (CGE) model for Scotland that captures the interdependence between the economy and central elements of the energy systems.[2] 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) outlines 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.

Scotland provides an interesting case study of the general trend towards increasing regional fiscal autonomy. It has recently been endowed with substantial powers over income tax rates (but not allowances) to complement its already extensive control over public spending (Scottish Government, 2016). This serves to emphasise the fact that the relevance of our

analysis is not confined solely to national economies; rather it is applicable to the far more numerous set of regional economies that have a degree of fiscal autonomy.[3]

Our model captures specific regional characteristics and is able to track the impact of key fiscal policy interventions on the major goals of both energy and economic policies, such as those outlined in Scotland's Energy and Economic strategies (Scottish Government 2015, 2017). The model thereby delivers a more 'holistic' perspective on the impacts of policy actions.[4]

We begin by comparing the energy consequences of tax and government expenditure changes separately. 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, building on the work of Emonts-Holley et al. (2016, 2019) to accommodate the notion of an environmental social wage.

Model

We investigate the likely nature and scale of the impacts associated with fiscal policy interventions through simulations using AMOSENVI[5], an energy-economy-environment computable general equilibrium (CGE) model of Scotland. We calibrate the model using information from the Scottish Social Accounting Matrix (SAM) for 2010.[6] Figus et al. (2017) and Lecca et al. (2014) provide detailed descriptions of the model whose primary characteristics are outlined below.

AMOSENVI is essentially a regional, multi-sectoral, dynamic, variant of the Layard, Nickell & Jackman (1991, 2005) model. It has three domestic transactor groups, namely, households, firms and government; and four major components of final demand: consumption, investment,

government expenditure and exports. The version adopted in the present paper has eighteen commodities/activities.

The regional nature of the model is reflected in four main ways. First, no exogenous balance of payments constraint is imposed. This is consistent with Scotland’s not possessing a full range of fiscal and monetary powers and receiving endogenous transfers from the central Government (see Lecca et al., 2014). Second, in the default version of the model the economy is open to inter-regional factor flows. It incorporates flow-equilibrium migration to accommodate the free movement of labour within the UK and unlimited finance is available at an interest rate fixed exogenously in national and international markets. Third, the SAM data on which the model is initially calibrated embodies the regional economy’s extreme openness to trade compared with that of a typical nation. Finally, we employ the small region assumption that extra-regional economic variables are exogenous and, in all the simulations employed here, remain unchanged. This applies specifically to the real wage and unemployment rate in the rest of the UK (RUK) and the price of commodities in the rest of the world (ROW) and RUK.

Current household consumption is modelled using a CES function with household expenditure determined by current income with a Keynesian savings function. Households consume goods produced both domestically and imported, where imports are combined with domestic goods under the Armington assumption of imperfect substitution (Armington, 1969).[7]

The production structure takes the form of the classical KLEM nested CES production function, where capital and labour generate value added, and energy and materials are combined as intermediate inputs. The combination of intermediate inputs and value added forms gross output. Again, domestic and imported intermediate inputs are combined under the Armington

assumption. The demand functions for capital and labour are obtained from the first order conditions of the CES production function.

In each time period and in every sector, the level of investment equals depreciation plus a proportion of the difference between the actual and desired capital stock. The depreciation rate is fixed exogenously. The desired capital stock is a function of the industry output and input prices, where the price of capital is determined by the cost of physical capital, the exogenous interest and depreciation rates, taxes and subsidies. In long-run equilibrium all capital stocks are optimally adjusted so that actual and desired capital stocks are equal. That is to say, in long-run equilibrium there is zero net investment so that gross investment just equals depreciation.

In each time period we assume that the labour force is fixed, though total employment can vary with changes in the unemployment rate. Labour is perfectly mobile across industries. We assume no natural population change but in the default model the size of the labour force adjusts between time periods through inter-regional migration of the Harris & Todaro (1970) type. This adjustment is determined using the econometrically parameterised regional net migration function reported in Layard et al. (1991, 2005), augmented to accommodate the amenity effects.[8] Here the level of net migration is positively related to the ratio between regional and national real tax-adjusted wages, and negatively related to the ratio between regional and national unemployment rates:

$$m = \varsigma - 0.08\left[\ln(u^S) - \ln(u^R)\right] + 0.06\left[\ln\left(\frac{w^S}{cpi^S}\right) - \beta\ln(1-\tau) - \ln\left(\frac{w^R}{cpi^R}\right)\right] \quad (1)$$

where m is net in-migration as a proportion of the regional population; u is the unemployment rate; β is the relative valuation of the public expenditure and associated environmental benefit; τ is the tax rate; the S and R superscripts stand for Scotland and the Rest of the World (including the Rest of the UK), respectively; and ς is a parameter calibrated to specify zero net migration in the base period.

Equation (1) gives the period-by-period labour force adjustment, but in long-run equilibrium the labour force must be optimally adjusted. This requires zero net migration (ZNM). It is therefore useful to set m = 0 in equation (1) and rearrange the terms to derive a ZNM function:

$$\ln\left(\frac{w^S}{cpi^S}\right) = \beta\ln(1-\tau) + \ln\left(\frac{w^R}{cpi^R}\right) + 1.33\left[\ln(u^S) - \ln(u^R)\right] - \frac{\varsigma}{0.06}$$

(2)

Equation (2) gives the combinations of the regional post-tax real wage and unemployment rate that generate no net migration. Note that the relationship between the real wage and the unemployment rate is positive; an increase in the regional unemployment rate must be accompanied by an increase in the real post-tax wage if zero net migration is to be retained.

Wage setting is determined by a regional wage curve, according to which the bargained real wage is inversely related to the unemployment rate (Blanchflower & Oswald, 2009). The formulation we use is the econometrically derived specification given in Layard et al., (1991, 2005), again augmented by amenity effects:

$$\ln\left(\frac{w^S}{cpi^S}\right) = c - 0.113\ln\left(u^S\right) + \alpha\beta\ln\left(1-\tau\right)$$

(3)

In equation (3) α represents the extent to which the environmental amenity effect is reflected in the wage bargain and c is a calibrated parameter. This formulation explicitly acknowledges imperfect competition and unemployment in the labour market.

The demand for Scottish exports is determined by export demand functions with a price elasticity of demand of 2.0.[9] Imports are modelled by an Armington (1969) link with trade substitution elasticities of 2.0 (Gibson, 1990). Essentially, the price of foreign goods are the model's numeraire.

There is flexibility in the determination of government expenditure and receipts. First, we do not typically require the public sector budget to balance, so that the default setting of the model would have tax rates and real government consumption set at their base year levels. However, these can be varied exogenously as the source of a shock and/or as an imposed balanced-budget closure.

Base-year industrial territorial CO_2 emissions are calculated through links 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 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 emission results.

Simulation strategy

The model is calibrated as being initially in long-run equilibrium. All the shocks are permanent step changes in exogenous fiscal disturbances and the analysis is long-run comparative static.

That is to say, we compare the new long-run equilibrium with the initial one.[10] The detailed simulation strategy is as follows.

We run two broad sets or groups of simulations. In the first, the fiscal stimulus is financed through borrowing and either takes the form of an increase in government consumption or a reduction in the rate of income tax. Both these exogenous shocks are calibrated so that they produce an identical 0.60% long-run increase in GDP. The model is the standard default version, with no budget constraint, a bargained real take-home wage and with the environmental amenity not entering either the migration or bargaining function.[11] Two alternative specifications of the model are run for each fiscal stimulus. One has no migration, which implies a fixed labour force; the second incorporates equilibrium flow migration which means that, as explained in the simulation results section, in the long run there is an infinitely elastic supply of labour to the region, via migration, at the initial take-home real wage.

The two treatments of migration reflect alternative extreme positions concerning the flexibility of the regional labour market. The notion that regional migration is unaffected by changes in the local level of economic activity is not supported by econometric evidence. On the other hand, the long-run reinstatement of the initial wage and unemployment rate seems overly restrictive: it implies that no policy intervention can affect a region’s real wage or unemployment rate unless it affects the bargaining or migration functions themselves. Moreover, as we shall see, the long-run equilibrium is only reached after an extended period of time when brought about through the interaction of the wage, migration and investment functions.

In the second group of simulations, a balanced-budget increase in government consumption is financed by a 5% increase in the income tax rate. The characteristics of the different

simulations that comprise this second group are shown in Table 1. These simulations investigate the sensitivity of the results to the form of the bargaining and migration functions adopted in the model.

Two alternative bargaining functions are employed. One is the standard variant where the bargain is over the post-tax take-home wage. The second is the Environmental Social Wage bargain where the worker fully takes into account the environmental amenity generated by the taxes paid on the wage. Essentially this implies that the bargain is over the pre-tax wage. Table 1 also shows the corresponding values of α and β, as used in equations (1) to (3) in the previous section. For the standard bargaining function $\alpha=0$; for the Social Wage bargain $\alpha,\beta=1$.

For the migration function three options are used. One is simply to switch off the migration function so that the labour force is fixed. If the model is run with migration on, there is a further choice between the standard case, where the real post-tax take-home wage is the driver of migration or the Social Wage variant, where the real pre-tax wage is the key variable. Again Table 1 also gives the relevant β values. For the standard bargaining function $\beta=0$; for the Environmental Social Wage bargain $\beta=1$.

In this second group of simulations, where the standard bargaining function is adopted, the models correspond to familiar existing approaches. Where neither local residents nor potential migrants place any value on an environment-enhancing amenity, or at least where this does not enter their bargaining or migration decisions corresponds to the Conventional Macro model; $\alpha,\beta=0$. Macro-modellers typically do not take into account amenity values when assessing the impact of fiscal policies.

In the Conventional Micro model potential migrants value the environmental amenity and factor that into their migration decision whilst wage bargainers do not. This approach is

motivated by models of fiscal federalism in the Tiebout (1956) tradition (Stiglitz, 1982). This corresponds to the assumption, $\alpha=0$, $\beta=1$. The standard argument is that the level of public goods is essentially independent of the wage bargains undertaken by individuals or small groups and is therefore irrelevant to the wage bargain, but the rate of income tax directly affects the worker’s trade-off between work and leisure. However, both the level of public goods and the tax rate are relevant for the migration decision. Rationally, decentralised bargaining should therefore focus on the post-tax real wage.

Where migration is switched off the Conventional Macro and Micro approaches converge to produce the same model.

In the Environmental Social Wage models, the environmental improvement associated with the increased public consumption is valued equally to the loss in private consumption by both workers and migrants. Since in this case workers/migrants feel no worse off after the public expenditure and tax changes – their lower take home pay is compensated by the increased supply of environment-enhancing goods – there is no upward pressure on wages. In this variant, $\alpha=\beta=1$.

These simulations are repeated but with migration removed so that labour force is fixed. This makes the Conventional Micro model redundant, so that only the Conventional Macro and the Environmental Social Wage apply in the no-migration case.

{Insert Table 1 around here}

The results are presented in Tables 2 and 3 which report the long-run impacts on endogenous economic, energy and emissions variables of the relevant permanent step changes in the local fiscal variables for the first and second group of simulations respectively. Recall that in the first group, either the level of current public consumption or the average income tax rate is adjusted in order to produce a 0.60% increase in GDP. The regional economy is much more flexible if migration is allowed; the exogenous fiscal shocks have therefore to be larger in the models without migration than in those where flow-equilibrium migration is imposed. In particular, the exogenous increase in government consumption is 1.36% where migration is activated and 4.86% where there is no migration: the permanent step reductions in the income tax rates are 0.96% with flow migration and 2.58% without.

The economy is initially taken to be in long-run equilibrium so that if the model were run forward in the absence of any disturbance, each period would simply replicate the base-year dataset. The results presented in Tables 2 and 3 are then typically percentage changes in the endogenous variables relative to this unchanging base. All the reported variations in economic 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. To observe the full evolution of all the economic variables simulations are run for 50 years. The primary focus is on the long-run period, over which migration is complete and all sectoral capital stocks are fully adjusted.

Simulation results: individual fiscal stimuli

In this section we discuss the results presented in Table 2. For simplicity we assume that changes in the individual fiscal stimuli are financed through government borrowing at

unchanged interest rates.[12] Recall that in all the cases we are discussing the long-run equilibrium responses to permanent step changes in exogenous fiscal disturbances.

Increased public consumption

We begin by considering the impact of an expansion in government expenditure with equilibrium flow migration. These results are given in the second data column in Table 2.

Three key model features drive the outcomes in this particular case. The first is an attribute which is typical of CGE models in general and applies to all the results given here: the model is calibrated to be in long-run equilibrium in the initial period. The second is a characteristic of one of the key closure rules that we adopt for our model. This is that in a regional economy there is an infinitely elastic supply of finance at a rate set exogenously in national or international markets. The third applies to all the models that simultaneously incorporate flow equilibrium migration and real wage bargaining. This is that in the long run, the real wage will return to its initial level through the interaction of the labour market and migration. Essentially real wages above, and unemployment rates below, their initial levels will generate in-migration which will gradually lead to the reinstatement of the initial equilibrium values.

This means that where there is an exogenous demand shock, such as an increase in government expenditure, there are no long-run changes in prices and the model operates as an extended linear Input-Output system (McGregor et al, 1996) as fully reflected in the results reported here. There are no changes in the real or nominal wage, the consumer price index (CPI) or the unemployment rate. The 0.60% expansion in GDP is accompanied by a 0.72% increase in employment and the labour force, and an increase in investment of 0.45%. Household income and consumption increase by 0.44% and 0.47% respectively. Note that

because there is no change in prices, there is no change in exports; the flexibility of the supply side in an open regional economy ensures that there is ultimately no induced “crowding out” of investment or exports.

As expected, the expansion in economic activity also stimulates energy demand, albeit very modestly in this case; increased production, consumption, investment and government expenditure all require greater energy inputs. Total energy use increases by 0.24%, reflecting the proportionate increase in 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. The rise 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.[13]

If we fix the labour force, the results are as given in the first data column of Table 2. The 0.60% increase in GDP is accompanied by an increase of 0.90% and 1.73% in employment and the real wage. This produces increases in household income and consumption of 1.45% and 1.56% respectively. However, the rise in the real wage leads to a corresponding increase in prices, reflected in a 0.73% rise in the CPI. This reduction in the region’s competitiveness is accompanied by a decline in exports of 1.23% as increases in private and public consumption crowd out exports.

Although the labour force is restricted, the supply of finance is not. The price of capital goods falls relative to the wage therefore the production of value added in each sector will become more capital intensive. However, in aggregate this is overwhelmed by the structural changes

that the government demand shock generates. Export-intensive industries decline whereas those sectors serving public and private consumption expand. In aggregate the increase in investment is only 0.10%, a much smaller percentage increase than the rise in employment. Note also the 1.93% increase in imports.

Where the expansion in public consumption occurs with a fixed labour force, total energy use falls by 0.05% and territorial CO_2 emissions by 0.43%. Given that GDP increases, energy productivity rises and emissions intensities fall. These changes are partly driven by the change in sectoral composition of output and partly by offshoring of energy use and emissions through increased imports.[14]

Reduced income tax rate

By design, the income tax cuts have the same, 0.60%, impact on GDP as the increases in public consumption discussed in the previous section. However, their effect on the composition of activity is quite different. Again, we begin by reporting the outcomes from the simulation that incorporates inter-regional migration. These results are shown in column four in Table 2 and are generated by a 0.96% reduction in the income tax rate.[15] This is an exogenous shock with supply-side implications, in that there will be a direct, continuing effect on prices. However, recall that in long-run equilibrium the initial real wage and unemployment rate will again be reinstated. Given public consumption is fixed, the major direct stimulus comes through the 0.35% increase in exports driven by the improvement in regional competitiveness.

The nominal pre-tax wage and the CPI fall by 0.69% and 0.21% respectively. The increase in GDP leads to a 0.62% rise in employment and a 0.46% increase in household consumption. Although the price of labour falls relative to the price of capital, so that production of value

added will become more labour intensive in all sectors, again the sectoral composition of the stimulus to the economy is such that relatively capital-intensive sectors grow more rapidly than labour-intensive ones.

Removing the possibility of inter-regional migration holds the labour force constant so that a greater income tax reduction is required, 2.58%, to produce the same, 0.60%, increase in GDP. In this case the post-tax real wage rises by 1.11% in response to the 0.59% increase in employment. Once migration is precluded, the fall in the CPI, and the subsequent stimulus to exports are a good deal lower, at 0.08% and 0.14%, respectively. The increase in economic activity is here driven by the 1.13% and 0.69% increases in household consumption and investment

For the reduction in income tax, where migration is incorporated in the model, there is an increase in energy use and CO_2 emissions of 0.40% and 0.46% respectively as the price of energy falls and economic activity increases. Where the labour force is fixed, the increase in energy use is even higher, at 0.48%, and the CO_2 marginally further increased at 0.47%. However, for both the models (with and without migration) energy productivity is increased and emissions intensity reduced, although these changes are less than for the public consumption simulations.

{Insert Table 2 around here}

The fiscal expansion, whether generated by expenditure increases or tax reductions, has the desired effect on the main goals of the policy: both GDP and employment rise. However, tax

and expenditure changes do have different effects on the composition of GDP and this matters, even for overall economic impacts. So in the case of expenditure increases the composition of value-added shifts in favour of public as against private spending, 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 where the expansion is driven by an increase in public expenditure, rather than a reduction in tax.

While the fiscal policies have the desired effect (though differentially) in stimulating economic activity, the impact on both energy use and emissions is more problematic. Because of their different impacts on the composition of economic activity, tax- and expenditure-induced expansions face different trade-offs between economic and environmental goals. With the reduction in taxation and the subsequent stimulus to export sectors, energy and emissions rise both with and without migration. However, government spending is less energy intensive, so expenditure-induced expansions generate significantly less emissions and with a fixed labour force energy use and emissions actually fall.

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 that might be generated by fiscal expansions. An idea of the scale of the change required is that the emissions in the electricity producing sector would need to fall by 0.56% so as to offset entirely the emissions directly attributable to the 1.36% fiscal expenditure expansion with migration.[16] 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.

Simulation results: balanced-budget fiscal expansion

In this section we consider the impact of a balanced-budget 5% rise in the income tax rate i.e. we introduce the increase in the income tax rate and then spend the additional revenue in public consumption. The outcomes are reported in Table 3.

Standard Bargaining

In the Conventional Macro model, both bargaining and the migration function operate with the post-tax real wage. These results are reported in the second data column of Table 3. Two countervailing forces are generated in this case. There is a beneficial stimulus to aggregate demand coming from the 0.57% increase in government expenditure. The characteristics of such an expansion are indicated in the results section on increased public consumption. However, there is a simultaneous adverse change in competitiveness, as bargaining and migration interact to reinstate the initial real wage. This generates outcomes which are the mirror image of those described in the results section for the case of the increased public consumption. The net impact depends on the relative sizes of these countervailing demand- and supply-side forces (Lecca et al., 2014; Emonts-Holley et al., 2016, 2019). In the present case, as indicated in Table 3, the result is a clear reduction in aggregate economic activity. GDP and employment fall by 2.78% and 2.86% respectively whilst the nominal (pre-tax) wage and CPI increase, by 3.66% and 1.05%. All elements of final demand, apart from government consumption, fall. This comprises exports (-1.79%), household consumption (-2.14%) and investment (-2.98%).

{Insert Table 3 around here}

The results from the Conventional Micro model are reported in data column three in Table 3. In this simulation migrants value the improvement in the environment equally to the reduction in the take-home wage imposed through the income tax increase. However, this valuation is not at all reflected in regional wage bargaining. Long-run equilibrium is established where the nominal wage increases significantly, but not sufficiently to restore fully the real wage. Employment falls by 2.64%, whilst the unemployment rate increases by 0.11 percentage points. Given that the long-run unemployment rate rises, the extent of the adverse supply shock is less than under the Conventional Macro case. As compared to the Conventional Macroeconomic outcomes, the nominal wage rises by less, so that employment and GDP effects are improved and induced net out-migration is reduced. Nevertheless, the adverse competitiveness effect still predominates, as reflected in the substantial 2.58% fall in GDP.

The results for the Conventional Macro/Micro model with a fixed labour force are given in the first data column in Table 3. For the model results reported in columns 2 and 3, extensive outmigration substantially stabilised the take-home real wage. Where the labour force is fixed, outmigration is precluded. The fall in labour demand leads to a 0.78 percentage point increase in the unemployment rate and an accompanying 1.39% reduction in the real after-tax take-home wage. This fall in the real wage cushions the negative competitiveness impact of the increase in income tax. But CPI still increases by 0.49%, leading to falls in exports, household consumption and investment. In this case the decline in GDP and employment are 0.97% and 0.83% respectively.

In all the simulations of the balanced-budget fiscal expansion using the standard wage bargaining function, a contraction in economic activity occurs; fiscal policy fails to have its

traditional positive effect on its primary goal. The news on energy goals appears better in that total energy use and emissions fall. However, this principally reflects reductions in economic activity and in the simulations with migration, energy productivity actually falls and emissions intensity increases. In the model with the fixed labour supply, there is a very slight improvement (0.01%) in energy efficiency and a 0.17% reduction in emissions intensity.

Where the standard bargaining function is used, an increase in public consumption providing an environmental improvement would actually lead to a fall in economic activity, simply through the means of financing that expenditure. For the region the size of this fall is positively linked to the degree of outmigration. The environmental implications of the fiscal expansion are heavily driven by the impact on economic activity although with low levels of migration emissions intensities would fall.

Social Wage

In simulations using the Environmental Social Wage, the improvement in the environment associated with higher public spending is valued equally to the loss in private consumption and this is reflected in the wage bargain. This implies that workers feel as well-off after the change as they did before and therefore at a given unemployment rate, do not push to restore their take-home wage following the policy change. This issue could be approached theoretically as a moral hazard problem.

Workers may wish in principle to vote for the tax-funded environmental amenity but suspect that the subsequent tax implications, together with standard bargaining, will have a depressing effect on the local economy. This view was verified in the analysis in the Conventional Micro simulations reported in the previous section. The problem is one of time inconsistency

(Kydland & Prescott, 1977). In suggesting an Environmental Social Wage, we are advancing the notion that the Government and unions could agree to limiting wage bargaining in return for the environmental amenity (see also Keating and Harvey, 2014). This could be seen as a form of commitment device.

When this is accompanied by a corresponding migration function, any long-run adverse competitiveness effect from a balanced-budget fiscal expansion are removed completely; neither the nominal pre-tax wage nor the CPI are impacted. The results for the balanced-budget Social Wage simulations are given in columns 4 and 5. Column four shows the results for a fixed labour supply; column five, the outcomes with flow migration.

We discuss the with-migration results first. Recall that in this case there are no changes in prices or the pre-tax nominal wage. The model works similarly to an extended linear IO system where the proportionate reduction in household consumption is matched by an increase in government expenditure. As there is no loss of competitiveness, the beneficial net demand stimulus associated with the fiscal expansion predominates. The 3.31% increase in government expenditure is accompanied by a 2.51% fall in the post-tax take-home real wage and a 1.02% reduction in household consumption. Exports are unchanged and there is a small (0.06%) increase in investment. GDP increases by 0.61%, and employment by 0.94% in a manner similar to that envisaged in the simple Keynesian balanced-budget multiplier.

Where the Social Wage operates together with the fixed labour force the 0.25% increase in employment generated by the positive demand shock reduces the unemployment rate by 0.23 percentage points, increasing the pre-tax real and nominal wages by 0.45% and 0.64% respectively. Therefore, in this case domestic commodity prices rise and there is a degree of

crowding out of exports and investment falling by 0.32% and 0.50% respectively. The overall impact is that, although employment is rising, GDP shows a very slight fall of 0.01%.

In both the Social Wage simulations, total energy use falls, together with improvements in energy productivity and a decline in emissions and emissions intensity. Clearly where bargaining is over the Social Wage, the provision of the environmental amenity will be associated with an increase in employment and, unless migration is extremely restricted, an increase in GDP. However, these positive changes in activity are also accompanied by additional reductions in energy use and emissions. While the aggregate environmental improvements are greatest in the model without migration, the improvements in energy efficiency and emissions intensity are higher where migration is included.

Summary and conclusion

A review of the literatures on the impacts of 'non-energy policies' on the energy system identified a significant gap (Cox et al., 2019). We seek to address this gap by exploring empirically the impacts of selected fiscal interventions on key elements of the energy system through using a multi-sectoral computable general equilibrium (CGE) model for Scotland. This captures the interdependence between the economy and central elements of the energy systems. 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. However, for the tax-induced expansion, there are unambiguous adverse impacts on total energy use and territorial emissions creating a clear trade-off between economic and environmental objectives. For the public expenditure stimulus the environmental impact is a little different. With migration energy use and

emissions rise as output expands However, where migration is restricted the rise in the real wage reduces regional competitiveness and exports. The resulting change in the composition of demand leads to the increase in economic activity being accompanied by a small fall in energy use and a rather more substantial reduction in territorial emissions.

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 aimed at improving the environment. Overall, the aggregate results of the standard Conventional Macro and Micro 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. Furthermore, emissions intensity rises with high levels of migration whilst energy efficiency falls if there is any migration at all.

The Environmental Social Wage model, in which workers and migrants value higher government spending on environmental improvements equally to their lost consumption expenditure and reflect this in wage bargaining, generates radically different outcomes from those exhibited by the Conventional models with standard bargaining. With flow equilibrium migration the Environmental Social Wage essentially eliminates any adverse long-run supply shock associated with the fiscal stimulus by preventing any upward pressure on the pre-tax nominal wage so that GDP expands in the long run. This, however, implies a willingness by workers to accept a substantial cut in their real take home pay. Nevertheless, in this case balanced-budget fiscal policy has the desired effect on its primary economic objectives as low import-intensity government consumption replaces household consumption. Furthermore,

this economic expansion is also accompanied by 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. This suggests that a ‘double dividend’ is possible as key economic and energy policy goals are simultaneously improved.

Where there is reduced migration, the expansionary impact of the balanced-budget fiscal expansion is more restricted and with no migration allowed at all, GDP shows a very small fall, though employment is still increased. However, again the fiscal policy has a positive impact on environmental goals.

Of course, the practical policy implications of these findings depend, to a degree, on the empirical relevance of the Environmental Social Wage case. Growing awareness of the significance of climate change and increasing dissatisfaction at the pace of the policy response (as reflected, for example, in the activities of groups such as Extinction Rebellion) perhaps suggests that the Environmental Social Wage case may appear more achievable. However, establishing the Environmental Social Wage would appear to require negotiation with unions, for example, to persuade them of the social value of increases in public spending generally, and of spending to improve the environment in particular.

The borrowing-financed and balanced-budget fiscal policies considered here have significant impacts on key elements of the energy system. Neglecting these creates a source of potential 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. Furthermore, while the importance of public attitudes in shifting to a low-carbon economy has,

of course, been widely recognised, the potentially valuable role of an Environmental Social Wage in facilitating a shift towards low-carbon growth has not.

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Table 1: Characteristics of the balanced-budget simulations

Bargaining	Model formulation	Value environmental amenity		α	β
		Worker	Migrant		
Standard	Conventional Macro	No	No	0	0
	Conventional Micro	No	Yes	0	1
	No migration	No	-	0	-
Social Wage	Social Wage with migration	Yes	Yes	1	1
	Social Wage without migration	Yes	-	1	-

Table 2: Long-run effects of a 1.36% (4.86% for fixed labour supply) increase in government spending, and a 0.96% (2.58%) 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	
	No migration	Migration	No migration	Migration
GDP	0.60	0.60	0.60	0.60
CPI	0.73	0	-0.08	-0.21
Unemployment rate (pp difference))	-0.85	0	-0.55	0
Total employment	0.90	0.72	0.59	0.62
Nominal wage	2.48	0	-0.27	-0.69
Nominal after tax	2.48	0	1.03	-0.21
Real wage	1.73	0	0.19	-0.48
Real wage after tax	1.73	0	1.11	0
Labour force	0	0.72	0	0.62
Investment	0.10	0.45	0.69	0.62
Households consumption	1.56	0.47	1.13	0.46
Households income	1.45	0.44	0.28	0.14
Labour income	3.40	0.72	0.32	-0.07
Capital income	0.83	0.41	0.54	0.35
Government consumption	4.86	1.36	0	0
Total imports	1.93	0.41	0.49	0.08
Total exports	-1.23	0	0.14	0.35
Total energy use	-0.05	0.24	0.48	0.40
- Electricity	0.38	0.35	0.66	0.46
- Gas	0.35	0.32	0.63	0.43
Energy use in production (total intermediate)	0.14	0.36	0.58	0.50
Energy consumption (total final demand)	-0.18	0.12	0.37	0.29
- Households	1.59	0.43	1.05	0.39
- Investment	-0.12	0.32	0.57	0.52

- Exports	-0.87	0	0.10	0.25
Energy output prices	0.44	0	-0.05	-0.13
Energy productivity (GDP/Total energy use)	0.65	0.36	0.12	0.20
Territorial CO_2 emissions	-0.43	0.20	0.47	0.46
Emission intensity (territorial CO_2/GDP)	-1.03	-0.39	-0.12	-0.13

Table 3: Long-run effects of a 5% increase in the income tax rate under a balanced budget. % changes from base year.

	Standard wage bargaining			Environmental Social Wage (ESW)	
	No migration	Standard Migration	Migration with ESW	No Migration	Migration with ESW
	Conventional Micro/Macro	Conventional Macro	Conventional Micro		
GDP	-0.97	-2.78	-2.58	-0.01	0.61
CPI	0.49	1.05	0.99	0.19	0
Unemployment rate (pp difference))	0.78	0	0.11	-0.23	0
Total employment	-0.83	-2.86	-2.64	0.25	0.94
Nominal wage	1.65	3.66	3.39	0.64	0
Nominal wage after tax	-0.90	1.05	0.79	-1.89	-2.51
Real wage	1.15	2.58	2.37	0.45	0
Real wage after tax	-1.39	0	-0.20	-2.07	-2.51
Labour force	0	-2.86	-2.53	0	0.94
Investment	-1.35	-2.98	-2.79	-0.50	0.06
Households consumption	-1.55	-2.14	-2.09	-1.23	-1.02
Households income	0.04	-0.48	-0.46	0.34	0.53
Labour income	0.80	0.72	0.66	0.89	0.95
Capital income	-0.72	-1.62	-1.54	-0.24	0.07
Government consumption	2.00	0.57	0.67	2.80	3.31
Total imports	-0.14	-0.21	-0.23	-0.08	-0.05
Total exports	-0.83	-1.79	-1.67	-0.32	0
Total energy use	-0.98	-1.93	-1.82	-0.47	-0.15
- Electricity	-1.15	-2.17	-2.06	-0.61	-0.26
- Gas	-1.11	-2.04	-1.93	-0.61	-0.29
Energy use in production (total intermediate)	-1.11	-2.36	-2.22	-0.44	-0.01
Energy consumption (total final demand)	-0.81	-1.42	-1.35	-0.49	-0.28
- Households	-1.37	-1.78	-1.76	-1.14	-0.99
- Investment	-1.20	-2.48	-2.33	-0.51	-0.08

- Exports	-0.58	-1.26	-1.17	-0.23	0
Energy output prices	0.30	0.64	0.60	0.12	0
Energy productivity (GDP/Total energy use)	0.01	-0.87	-0.78	0.47	0.76
Territorial CO_2 emissions	-1.14	-2.26	-2.13	-0.56	-0.18
Emission intensity (territorial CO_2/GDP)	-0.17	0.54	0.47	-0.55	-0.79

[1] Defined here as "policies which are not explicitly formulated with energy system consequences in mind” (Cox et al., 2019, p180).

[2] This paper is an extended and revised version of a preliminary analysis presented in Ross et al. (2019).

[3] Comparable analysis for the UK is given in Ross et al. (2020).

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

[5] AMOS is the acronym of A Micro-macro model Of Scotland. ENVI indicates a variant of the model explicitly incorporating economy/energy/environmental interaction.

[6] Emonts-Holley et al. (2014) describe the methods employed. The SAM is available at: https://doi.org/10.15129/bf6809d0-4849-4fd7-a283-916b5e765950

[7] This includes imports from the RUK and the ROW.

[8] In the literature there is extensive testing of the link between amenities and regional migration. See for example Rodriguez-Pose and Ketterer (2012).

[9] This is a relatively conservative value for the price elasticity of demand for exports. A higher value would increase the sensitivity of activity in export sectors in simulation where prices deviate from their base-year values.

[10] Whilst climate change is clearly a long-run phenomenon, it would be of interest to assess in more detail the evolution of the regional economy as it adjusts to the fiscal shocks in order to identify the temporal incidence of possible costs and benefits. Unfortunately, space restrictions preclude such an analysis here.

[11] In the formulation of equations (1) to (3), $\alpha,\beta=0$.

[12] The Scottish Government’s ability to engage in borrowing is currently limited. However, the simulations provide a very useful benchmark.

[13] 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.

[14] Information on the emissions embodied in trade are required to move from the production-oriented territorial emissions reported in the results Tables 2 and 3 and a consumption-oriented carbon footprint measure.

[15] Around 53% of total government expenditures are funded by taxes on households.

[16] Similarly, a 1.27% fall in emissions in the electricity sector would offset the increase arising from the 0.96% reduction in the income tax rate in the simulation with migration.