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

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December 2018.

Abstract

The energy system and the economy are inextricably intertwined. While this interdependence is, of course, widely recognised, it has not featured prominently in assessing the likely impact of economic policies. In principle, broad 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 spillover effects from fiscal policy instruments to energy policy goals. This is the focus of this paper. We employ a multi-sectoral computable general equilibrium (CGE) approach for the UK which allows us to track the impact of key fiscal policy interventions on key goals of economic and energy policies. Overall, our results suggest that a double dividend - a simultaneous stimulus to the economy and a reduction in emissions – induced by an increase in current public spending or a hike in the income tax rate seem unlikely in the UK context. Nonetheless, there are undoubted differential spillover effects on key components of the energy system from tax and public spending interventions that may prove capable of being exploited through the coordination of fiscal and energy policies. Even if it seems doubtful that fiscal policies would be formulated with a view to improved coordination with energy policies, policymakers should at least be aware of likely direction and scale of fiscal spillover effects to the energy system.

Acknowledgements: This research was undertaken by the Fraser of Allander Institute & the Centre for Energy Policy at the University of Strathclyde as part of the research programme of the UK Energy Research Centre, supported by the UK Research Councils under EPSRC award EP/L024756/1.

Key words: energy policy, fiscal policy, income tax

JEL: C68, D58, Q43, Q48

1. Introduction

The energy system and the economy are inextricably intertwined. The experience of the great recession, for example, provides dramatic evidence of this: total UK energy consumption fell by over 6% between 2008 and 2009 when the UK economy contracted by around 4% (BEIS, 2017). However, these spillovers are not necessarily negative, and "double dividends" (or even "multiple benefits") are possible, where policies simultaneously stimulate economic activity and reduce emissions (and potentially also contribute to other policy goals). While this interdependence is, of course, widely recognised, it has not featured prominently in assessing the likely impact of economic policies, notably industrial and fiscal policies: rather they have tended to focus on the primary *economic* objectives of these policies, including Gross Domestic Product (GDP) and employment.

In principle, fiscal policies are likely to have a significant influence on 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 spillover effects from fiscal policy instruments to energy policy goals. This is the focus of the present paper.

It has been suggested that the impacts of economic policies on the energy system have not been extensively researched. This perceived lack of systematic analysis is highlighted in a recent literature review by Cox et al. (2016). However, in the context of the energy-economy-environment modelling literature there has in fact been widespread recognition of the impact of the economy and economic policies on energy use, even if the primary emphasis has tended to be on the effects of energy and environmental policies. For example, there are studies suggesting that fiscal policies (primarily focused on government spending) are an important determinant of environmental pollution (see e.g. Halkos & Paizanos, 2013,2016; Gupta & Barman, 2009; and Lopez et al., 2011). Moreover, there is a considerable body of research assessing the (economy-wide) implications of taxation directed at fuel consumption (e.g. Zhang et al., 2016 for a recent review of research on carbon tax). A further example of the literature is on the Environmental Kuznets Curve, which posits that rising prosperity will ultimately be accompanied by falling pollution, following an earlier period in which growth is accompanied by increasing pollution (see, e.g. Grossman and Kreuger, 1994; Jaffe et al., 2003; Vollebergh et al., 2009 and Cui et al., 2017).

The multi-sectoral computable general equilibrium (CGE) approach which we employ here captures the interdependence of the economy and key elements of the energy systems and allows us to track the impact of key fiscal policy interventions on key goals of economic and energy policies. While there is a huge literature on energy-economy-environment CGE modelling (e.g. Bergman, 2005; McKibbin and Wilcoxen, 2013) and many example of CGE analyses of fiscal issues (e.g.Holmøy and Strøm, 2013), there are few examples combining these analyses. Our approach allows us ultimately to develop a more '*holistic*' perspective on the implications of policy actions. In particular, our intention is ultimately to create a framework that explicitly recognises, and seeks to quantify, the scale of spillovers from economic and energy policies to energy and economic policy goals respectively. Where these spillovers 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.

This paper continues recent work on the spillover effects between economic and key components of the energy systems using a CGE framework for the UK. Ross et al. (2018a,b,c) analyse the potential impacts of successful UK industrial, business and innovation policy on the UK economic and energy systems, as well as the corresponding energy policy goals. Ross et al. (2018a,b) analyse the system-wide effects of successful export strategies on economic and energy policy, and Ross et al. (2018c) consider the likely impacts of increased labour productivity on the economy, the energy system, and energy policy goals. In this paper we focus on the energy consequences of fiscal policy changes in the UK.

Our primary focus in this paper is on the impacts of fiscal policies on key elements of the energy system and their effects on energy policy goals such as energy use and carbon emissions, energy intensity and energy security. We start by considering the impacts on elements of the energy system of an increase in government spending in isolation, and then explore in more detail the impact of an increase in the average income tax rate. We then proceed by considering the implications of a balanced-budget rise in the income tax rate, where additional tax revenues are matched by a rise in government spending. Since we wish to focus on the direct linkages between fiscal policy instruments and the energy system we adopt a number of straightforward macroeconomic closures (which we shall relax in future work).

This paper is organised as follows. Section 2 outlines an ex-ante macroeconomic labour market analysis of increases in government expenditure and taxation, separately and in a balanced-budget context. Sections 3 and 4 outline the structure of our energy-economy-environment model of the UK economy, paying particular attention to the linkages between the economy and energy components of the model, and the simulation strategy. We present results in Section 5, and a summary of main conclusions in Section 6.

2. Ex-ante labour market analysis of the impacts of Government spending and taxation

In this section we provide some analytical insight into the factors underlying the impact of the various fiscal policies that we model. We focus on the labour market to highlight the implications of alternative perspectives on wage determination, which proves significant for outcomes for both the economy and key elements of the energy system. Whilst our underlying assumptions are UK specific, the labour market analysis is likely to have wider applicability. For simplicity, we assume that the change in fiscal policy is insufficient to generate a reaction from the Bank of England's Monetary Policy Committee, so that no financial 'crowding out' occurs.[1] Throughout we assume, again for simplicity, that government expenditure is current spending that has no immediate impact on the supply side of the economy.[2]

2.1 Increase in government expenditure

Consider first the case of an increase in government spending – and assume that the change is bong-financed. Figure 1 represents the long-run interactions of the general equilibrium labour demand and supply curves in the UK labour market. The analysis is comparative static in that it can be used to illustrate the impact on the real wage and employment, of the increase in government spending. Exports don't change where there are no changes in prices. In the long run, investment is replacement investment (covering depreciation only) and is therefore driven by absolute level of activity, sectoral composition, and sectoral capital intensities.

[1] In effect, it is 'as if' the UK is operating in a 'liquidity trap'.

[2] Clearly some expenditure classified as current would be expected to have supply side effects e.g. spending on education provision via its impact on human capital. We return to this in due course.

In Figure 1, the demand for labour is a general equilibrium relationship, which incorporates the entire system-wide consequences of a change in the real wage. There is a strong presumption that the curve has a negative slope in employment-real wage space, though this is not necessarily the case because as the real wage rises so too does labour income and demand. However, for the default parameter values of our CGE model (described in Section 3) the negative competitiveness effects of an increase in the real wage, which dampens exports and encourages imports, dominates the positive income effects.[3]

The initial equilibrium is represented in Figure 1 by the intersection of the labour demand curve, D_0, and wage setting/labour supply curves, at point *A*, generating the initial equilibrium employment and real wage levels rw_0, and E_0. The increase in government spending shifts the general equilibrium demand curve for labour to the right, indicating that more labour is demanded at each real wage. The labour demand curve shifts from D_o to D_{LR} in the long run.[4] Alternative visions of the effective supply of labour or wage setting mechanism are crucial to determining the impact of this stimulus on the economy. We show a number of alternative approaches in Figure 1. Their operation is outlined in greater detail in Section 3.3 and they are employed as alternative labour market closures in the simulations reported in Section 5.

Our default CGE model specification embodies a wage curve which is an inverse relationship between the rate of unemployment and the real wage. Wage curves are typically thought to reflect the outcome of a wage bargaining procedure, with the workers' bargaining power increasing as the level of unemployment falls.[5] As outlined in Ross et al. (2018a) in greater detail, there is substantial international evidence in support for such a model specification. Blanchflower and Oswald (2005), for example, provide a review of recent research on wage curves found across a range of countries. In the employment-real wage space of Figure 1, the wage curve, or bargained real wage function (BRW), is illustrated with an upward sloping curve, reflecting the negative relationship between the unemployment and employment rates.

Under our default assumption and benchmark BRW case, workers are able to bargain for higher wages as the labour market tightens. At the initial equilibrium, an excess demand for labour is created and the increased bargaining power of workers exerts upward pressure on the real wage. This leads to a degree of crowding out through the induced loss in competitiveness. The new long-run equilibrium is established at point *B*, where both and employment and the real wage increase to E_1 and rw_1 respectively. Since economic activity is stimulated so too, in general, is the demand for energy used in both production (intermediates) and final demand.[6]

While, as we have noted, there is compelling international evidence in favour of our default wage curve specification, we consider a number of different labour market closures, so as to reflect alternative visions of how the UK labour market operates. We do this for two main reasons. First, there exists genuine uncertainty about the way that the aggregate UK labour market currently operates and there has been considerable controversy surrounding the issue (e.g. Bell & Blanchflower, 2018). Secondly, we wish to check the extent to which spillovers from economic policies to elements of the energy system vary with alternative visions of UK labour market behaviour. This allows us, as far as is practical within

[3] This is what we would expect for a comparatively 'small' (as a proportion of total world trade), open economy like the UK.
[4] We focus here on the long run. In the short run, where sectoral capital stocks are fixed, the rightward shift is limited. However, this tends to push up capital rates, spurring sectors to invest in capital, and leads to increased capacity and a greater demand for labour in the long run.
[5] An efficiency wage explanation is also available.
[6] In the context of a multi-sectoral model the link is not inevitable given the importance of changes in the composition of economic activity as well as its level.

our CGE model, to check that our conclusions are robust with respect to the choice of any particular model of the UK labour market.

One alternative vision of the labour market is that it is characterised by excess capacity over a range, so that any changes in labour demand can be met by a corresponding change in the level of employment, but at a fixed real wage (FRW). Such a case could also be motivated in terms of the presence of 'real wage resistance': workers seek to maintain the real value of their take home pay (in this case we do not make a distinction between pre- and post-tax pay as taxes remain unchanged), regardless of the nature of any macroeconomic demand disturbance.[7] In this case, the effective labour supply curve is horizontal through point A (over the relevant range), and employment adjusts in response to labour demand through changes in the unemployment and participation rates.[8] Essentially, only quantities change since prices are invariant across long-run equilibria, with the new equilibrium at point *C* in Figure 1, and there is no crowding out of economic activity. The real wage is, of course, unchanged, but employment increases significantly to E_2.

We also consider the case where the nominal wage is fixed. Under present assumptions the fixed nominal wage (FNW) case generates the same results as the FRW case in the long run, since prices (and real and nominal wages) do not change across such equilibria. This corresponds to the simple Keynesian multiplier case, and the multi-sectoral results emulate the behaviour of an extended Input-Output system with entirely passive supply side in the long run[9]. Since the stimulus to economic activity is greater in this case than for BRW, we expect the use of energy to be greater too, both in production and in final demands.

A further alternative perspective on the labour market, often adopted in national CGE models, is of continuous full-employment with an exogenous labour supply (ELS) curve and fixed participation rate (see e.g. Partridge and Rickman (2010) for a brief discussion). In this closure, employment is effectively fixed and is represented by the vertical ELS curve through point A in Figure 1. Following the demand stimulus, a new long-run equilibrium is established where the real wage rises to rw_2: in effect, the real wage rises until it dampens the stimulus to demand entirely at point *D*. In this case there is complete crowding out in terms of employment, which remains fixed at E_0. In a multi-sectoral context, GDP may change as resources are reallocated across sectors in response to the demand stimulus and significant upward pressure on real wages, but the direction will depend on sectoral export, labour and intermediate intensities and key elasticities. However, if GDP increases, it is likely to be a much more modest change than is associated with either the BRW or FRW variant. Accordingly, we would expect any stimulus to energy use in production and final demands to be less than in the other cases.

In general, we would expect total energy use – in both production and final demand – to increase broadly with the level of economic activity, and so the energy impacts will be ranked similarly to the likely employment (and GDP) impacts. However, there is an important compositional effect here: UK public spending tends to be significantly less energy and emissions intensive than private expenditures such as consumption and investment. So in the presence of complete crowding out (under ELS), the increase in government expenditure will lead to an inevitable fall in emissions. In the absence of any

[7] Because with a simple increase in government expenditure the tax rate remains unchanged, there is no distinction between holding the real pre-tax and post-tax wage constant. In simulations where the rate of income tax changes, this distinction gains in salience.

[8] In general, net in-migration could generate such a response without incurring any capacity constraint.

[9] Input-Output is a general equilibrium system with fixed coefficient technologies, an absence of capacity constraints and an infinitely elastic supply of labour. McGregor et al. (1996) demonstrate that regional CGEs generate IO results in long-run equilibria given these assumptions.

crowding out (FRW) emissions must rise because government spending has increased and no element of private spending has fallen. In practice, whether total emissions rise or fall in response to an increase in government spending depends on its impact on private expenditures; certainly it is perfectly feasible for an expenditure-generated fiscal expansion to result in a decline in emissions and a simultaneous rise in economic activity.

2.2 Increase in income tax rate

Next, consider the case of an increase in the income tax rate, Figure 2 represents the long-run interactions of the general equilibrium labour demand and supply curves in the UK labour market of an increase in the income tax rate (embodying the same initial conditions as described for Figure 1). This corresponds to the actions of a government wishing to reduce the fiscal debt through increased taxation. This corresponds to the actions of a government wishing to reduce the fiscal debt through increased taxation.

The initial equilibrium is represented in Figure 2 by the intersection of the labour demand and supply curves, at point *A*, generating the initial equilibrium employment and real wage levels rw_0, and E_0. The increase in the income tax rate shifts the general equilibrium demand curve for labour to the left, indicating that less labour is demanded at each real wage. Here we see a contraction in aggregate demand since disposable incomes (and wealth) of households are reduced. The labour demand curve shifts from D_o to D_{LR} in the long run[10]. As previously, alternative visions of the effective supply of labour are crucial to determining the impacts.

The most straightforward case to consider here is that of the fixed pre-tax wage (Fixed Nominal Wage or Fixed Real (gross) Wage, which is equivalent here given no changes in prices or wages). In this case, the supply curve is effectively horizontal across long-run equilibria. The nominal and real wage remains fixed, so that there is no "adverse supply" impact arising from increased pressure on wages. However, employment falls, and the long-run equilibrium is at *C*. After-tax real wages do fall given the increase in tax and an unchanging gross real wage. The result is very like an extended Keynesian or Input-Output (fix-price) multiplier analysis with endogenous investment.

Under the BRW case, the impact is no longer a pure demand shock. As before, aggregate demand falls (as above, from D_o to D_{LR}). However, there is now an adverse supply shock since the BRW model assumes that workers bargain over the net-of-tax-wage (or take-home wage). The BRW curve thereby shifts upward from BRW_o to BRW_1 in the long run. The vertical upward shift, the distance *AE*, is exactly the rise in the gross real wage that is required to restore the post-tax real wage following the tax increase at the original level of employment. In general, we do not know the relative sizes of the demand and supply shifts, but Figure 2 assumes (in line with our simulation results) a predominant adverse supply shift so that the equilibrium level of the gross real wage rises to rw2. Of course, equilibrium employment falls, to E_2. In this case the contraction is greater than under FRW.

It is clear that in the regional bargaining case just analysed, workers fail to restore their post-tax real wage: rw_2 lies below rw_3. Suppose workers were to insist on the maintenance of their post-tax real wage: this post-tax variant of "real wage resistance" would imply a shift in the fixed real wage curve from FRW to FRWpt. The result would be a major fall in employment to E_3. In the ELS case the supply

[10] Again, we focus here solely on the long run.

curve remains unchanged but here even gross real wages fall, so that the long run equilibrium is at *B*, where employment is, of course, unchanged at E_0.

The adverse demand shock impacts directly on household disposable income and wealth, and hence consumption, and will have knock-on effects to investment and exports. The adverse supply shock (in the BRW case) induces a reduction in production which has further negative impacts on demand as wages and prices rise. As previously, we would expect total energy use – in both production and final demand – to fall with the level of economic activity, and so the energy impacts will be ranked similarly to the likely employment (and GDP) impacts. Notice that here we expect quite a close linkage between the change in economic activity generated by a tax rise and energy use and emissions. This contrasts markedly with the case of UK government spending given its comparatively low energy and emissions intensity.

While we have conducted the analysis for the case of an increase in the average income tax rate, it is easily extended to the (opposite) case of a tax fall. Here an induced expansion in the economy would operate through its stimulus to (energy and emissions intensive) private sector economic activity.

2.3 Balanced-budget fiscal expansion

Here we analyse the case of a balanced-budget fiscal expansion, where the income tax rate is raised, but, in contrast to the previous case, income tax revenues are recycled to stimulate current government expenditure. Since UK government spending is less import intensive than consumption, the substitution of the former for the latter results in a net expansion in demand, again in contrast to the analysis of a simple tax rise. However, there is also an adverse impact on the supply side if workers bargain for *post-tax* real wages. In general, we do not know a priori which pressure will dominate (when both are applicable), but Figure 3 is drawn on the assumption that, when present, adverse supply impacts dominate (with a resultant contraction in employment).

The supply side shifts are similar to those discussed in the context of Figure 2, but here D_{LR} shifts out and to the right of D_0. With a fixed *gross* real wage there is no adverse supply effect so that the expansionary demand effect results in a new equilibrium at point B, with employment increasing to E_1. We know that under regional bargaining, the BRW curve shifts up to BRW_1, which would restore the *post-tax* real wage at F. Given a predominant adverse supply effect, the new equilibrium is established at a point like E, with lower employment of E_3. Of course, at E the *pre-tax* real wage rises to rw_3, but is still associated with a fall in the *post-tax* real wage (rw_4). If workers manage to restore their post-tax real wage, the FRW curve shifts vertically up to FRWpt and passes through point F, ensuring a major contraction in employment. Under ELS the stimulus to demand ultimately raises the pre-tax real wage to the point where it chokes off the additional demand for labour at point D.

Here we include an additional labour market closure, the Social Wage case, which essentially reflects a situation where workers attribute the same value, at the margin, to the consumption of public and private goods (outlined in more detail in Section 4.3). The intuition is that workers may be willing to accept a cut in their post-tax wage given that there is an increase in government spending: their social wage is unaffected, so they do not press for higher wages to compensate for the tax rise. In this case bargaining is effectively over the pre-tax wage and the balanced budget fiscal contraction has no impact on BRW_0. Accordingly, this case is also associated with an expansion in employment to E_2, although this does allow workers to bargain for a higher (pre-tax) real wage (rw_1).

The potential impacts on the energy use and demands is the net-effect of the increase in government expenditure and the hike in the income tax rate. As previously, we would expect total energy use – in both production and final demand – to fall with the level of economic activity, and so the energy impacts will be ranked similarly to the likely employment (and GDP) impacts.

Figure 1: The (long run) system-wide labour market impact of an increase in government spending.

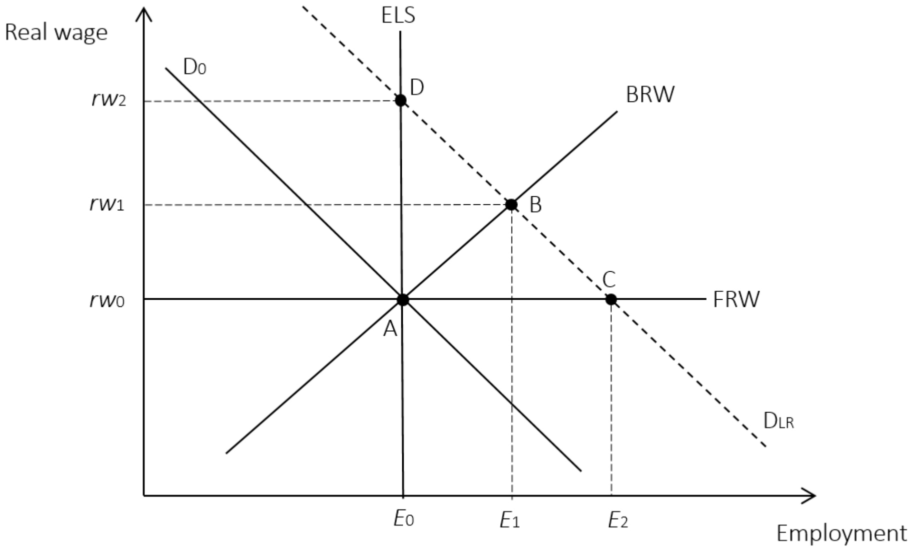


Figure 2: The (long run) system-wide labour market impact of an increase in the income tax rate.

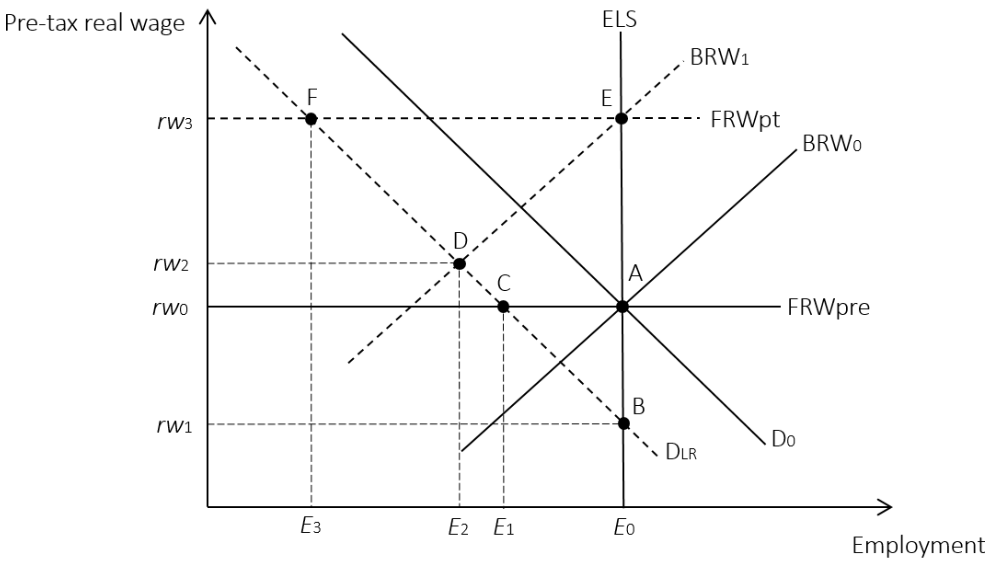
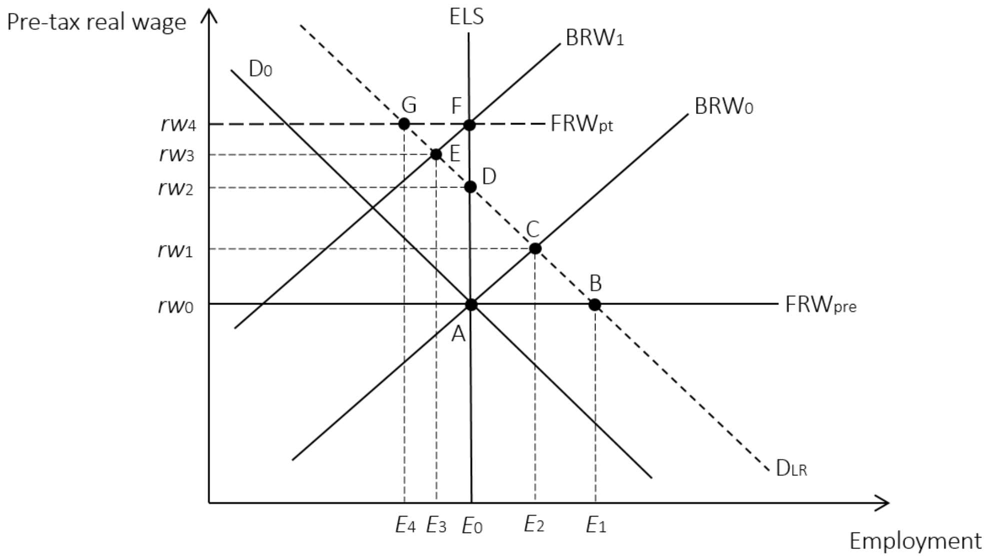


Figure 3: The (long run) system-wide labour market impact of a balanced budget increase in the income tax rate.



3. Model and data

We simulate the impacts of illustrative fiscal policies (see Section 5 for more details on the simulation strategy) using a computable general equilibrium (CGE) model of the UK, UK-ENVI. The UK-ENVI model was purpose built to capture the interdependence of the energy and non-energy sub-systems. Versions of this model have been employed, for example, to analyse the impacts of increased efficiency in the industrial use of energy (Allan et al., 2007), identify the impacts of energy efficiency programmes on households (Figus et al., 2017), and to identify total energy rebound effects of improvements in household energy efficiency (Lecca et al., 2014a). In the following sections we provide a brief description of the main characteristics of the model, with a particular emphasis on the linkages between the economic and energy sub-sectors.[11]

3.1 Consumption and trade

We model the consumption decision of five representative households *h* as follows:

$$C_h = YNG_h - SAV_h - HTAX_h - CTAX_h \tag{1}$$

where total consumption *C* is a function of income *YNG*, savings *SAV*, income taxes *HTAX*, and taxes on consumption *CTAX*.

Consumption is modelled to reflect the behaviour of a representative household that maximises its discounted intertemporal utility, subject to a lifetime wealth constraint. The solution of the household

[11] A full mathematical description of the model is given in Ross et al. (2018a).

optimisation problem gives the optimal time path for consumption of the bundle of goods C. To capture information about household energy consumption, consumption is allocated within each period and between energy goods and non-energy and transport goods and services (including fuel use in personal transportation) as indicated in the top level of the consumption structure shown in Figure 4. This choice is made in accordance with the following constant elasticity of substitution (CES) function:

$$C_h = \left[\delta_h^E \left(EC_h \right)^{\frac{\varepsilon_h - 1}{\varepsilon_h}} + \left(1 - \delta_h^E\right) TNEC_h^{\frac{\varepsilon_h - 1}{\varepsilon_h}} \right]^{-\frac{\varepsilon_h}{\varepsilon_h - 1}} \tag{2}$$

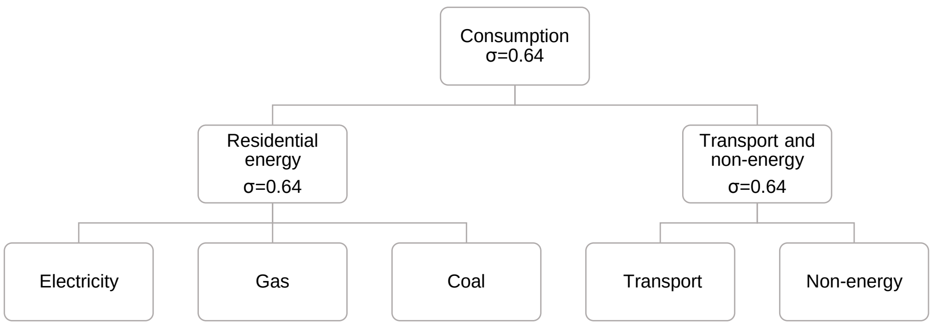
where ε is the elasticity of substitution in consumption, and measures the extent to which consumers substitute residential energy consumption, *EC*, for non-energy and transport consumption, *TNEC,* δ ϵ (0,1) is the share parameter. For simplicity (and in the absence of better information), in all households we impose a value, 0.61, for ε, which is the long-run elasticity of substitution between energy and non-energy estimated by Lecca et al. (2014a). The consumption of residential energy includes electricity, gas and coal, as shown in Figure 4, although coal represents less than 0.01% of total household energy consumption. Within the energy bundle, given that we do not focus on inter-fuel substitution in the analysis below, we impose a small but positive elasticity of 0.2.

Moreover, 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):

$$QH_i = \gamma_i^f \cdot \left[\delta_i^{hir} \cdot QHIR_i^{\rho_i^A} + \delta_i^{hm} \cdot QHM_i^{\rho_i^A} \right]^{\frac{1}{\rho_i^A}} \tag{3}$$

where *QH* is total household consumption by sectors, *QHIR* is consumption of locally produced goods, *QHM* is consumption of imported goods, and the *i* subscript represents the sector. With the price of imports being exogenous, substitution between imported and domestically produced goods depends on variations of national prices.

Figure 4: The structure of consumption



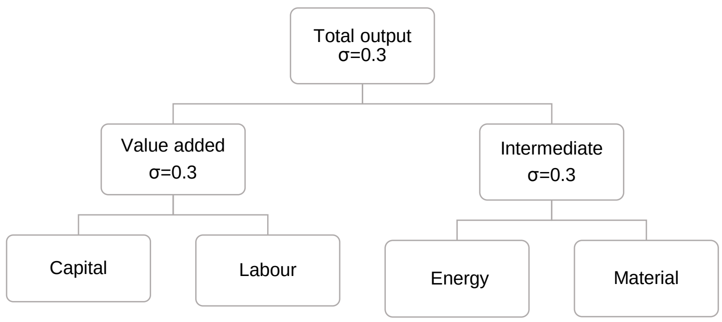
It must be noted that the Armington assumption has implications for the decisions of both producers and consumers. The choice over imported or domestic inputs for firms depends on their relative prices, as well as the Armington elasticity. Similarly, consumers choose over imported and domestic goods depending on relative prices and the Armington elasticity. Intermediate purchases in each industry are modelled as the demand for a composite commodity with fixed (Leontief) coefficients (as outlined in the following section in more detail). These are substitutable for imported commodities via an

Armington link, which is sensitive to relative prices. Given the importance of the Armington elasticities to trade we identify the implications of different values of these elasticities in our sensitivity analysis.

3.2 Production and investment

The production structure of each of the thirty production sectors is characterised by a capital, labour, energy and materials (KLEM) nested CES function. As we show in Figure 5, the combination of labour and capital forms value added, while energy and materials form intermediate inputs. In turn, the combination of intermediates and value added forms total output in each sector.

Figure 5: The structure of production



In the long run, investment is equal to depreciation, and there is no difference in the desired and actual capital stocks. The desired capital stock is a function of commodity output, the nominal wage and the user cost of capital. Desired capital stocks are driven by cost-minimisation criteria, and actual stocks reflect last period's stocks, adjusted for depreciation and gross investment.

3.3 The labour market

As already outlined in Section 2, we consider a number of alternative labour market closures. Our default model specification embodies a wage curve which is an inverse relation between the rate of unemployment and the real wage. Wages are thereby determined within the UK in an imperfectly competitive context, according to the following bargained real wage (BRW) specification:

$$\ln\left[\frac{wb}{cpi}\right] = \rho - \varepsilon \ln(u) \qquad \text{where } wb = \frac{w}{1+\overline{\tau}} \tag{4}$$

In equation 5, wb_t / cpi_t is the real take home wage, ρ is a parameter calibrated to the steady state, ε is the elasticity of wage related to the level of unemployment, u_t, and $\overline{\tau_t}$ is the income tax rate. So here the real consumption (after tax) wage is negatively related to the rate of unemployment (Blanchflower & Oswald, 2005), which is an indicator of workers' bargaining power.[12]

The working population is assumed to be fixed and exogenous. This model implies the presence of involuntary unemployment (with BRW lying above the competitive supply curve for labour).

[12] We also separately explore the consequences of a wage curve that has the pre-tax wage in the unemployment rate.

Next, we consider a case where workers reflect the amenity of value of public expenditure in the wage-bargaining process. This is implemented by augmenting equation 4 so that:

$$\ln\left[\frac{wb}{cpi}\right] = \rho - \varepsilon \ln(u) + \alpha\beta \ln(1-\tau) \tag{5}$$

where $\alpha \in (0,1)$ represents the extent to which public consumption is reflected in the wage determination; and $\beta \in (0,1)$ is relative valuation of public goods. When the two parameters equal 1, wage bargaining responds to the gross of tax wage. 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 (Lecca et al., 2014b). This is the social wage case (SOC)[13].

Conventional CGEs of national economies often make the simplifying assumption of an entirely exogenous labour supply (with both population and the participation rate invariant): that is labour supply exhibits a zero elasticity with respect to the real wage. This exogenous labour supply (ELS) specification of the labour market implies that employment is fixed.

$$Ls = \overline{Ls} \tag{6}$$

Of course, this vision of the labour market implies that the UK operates under a very tight supply constraint. Aggregate GDP can only vary in response to disturbances that alter the allocation of activity across sectors. Furthermore, employment is effectively fixed even in the longer-term, and is, of course, invariant to any change in demand, although capital stocks can adjust in response to changes in rental rates.[14]

Some take the view that workers in the UK bargain to maintain their real wage - 'real wage resistance' - that results in a fixed real wage (FRW) pre / post-tax model. This model implies:

$$FRWpt = \frac{wb_t}{cpi_t} = \frac{wb_{t=0}}{cpi_{t=0}} \tag{7}$$

$$FRWpre = \frac{w_t}{cpi_t} = \frac{w_{t=0}}{cpi_{t=0}} \tag{8}$$

This case effectively implies an infinitely elastic supply of labour over the relevant range. In stark contrast to the ELS case, here the real wage is fixed and any demand disturbances will be reflected only in employment changes (over a range).

The ELS and FRW cases represent limiting cases of the responsiveness of the effective supply of labour to the real consumption wage, with elasticities of zero and infinity respectively. The BRW case represents an intermediate case in which the effective (bargaining-determined) level of employment varies positively with the real consumption wage.

In the absence of changes in foreign prices, equation 8 can also be interpreted as a case of nominal wage inflexibility. This may be particularly important as recent experience casts some doubt on the

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[13] See Lecca et al. (2014) for more details.

[14] In the longer-term population and labour supply can, of course, increase through natural population growth. For simplicity we abstract from that here. Migration flows could also alter labour supply, but we assume that net migration is zero here. However, the fixed real wage model, discussed below, emulates many of the features of a system with endogenous (flow) migration.

current relevance of the BRW or FRW hypotheses, since real wages have been falling despite a fall in the unemployment rate. We illustrate the likely implications of this by exploring the limiting case of a fixed nominal wage (FNW).

3.4 Government

The Government in UK-ENVI collects taxes and spends the revenue on a range of economic activities. The Government operates according to the following budget constraint where the government budget is given by government income minus expenditure:

$$GOVBAL_T = GY_T - GEXP_T \quad \text{where } GY_t = d_g KY_t + IBT_t + \overline{\tau}_t \cdot LY_t + \overline{FE}_t \tag{9}$$

where *GOVBAL* is the government budget which is equal to the difference between government income *GY,* and government spending *GEXP.* GY is given by the share d_g of capital income *KY* that is transferred to the Government, Indirect business taxes, *IBT,* revenues from labour income *LY* at the rate τ [15], and foreign remittance FE.

In our simulations we make two alternative assumptions in which either GOVBAL or GEXP are fixed, denoted as FIXBAL and FIXGOV, respectively, and there is no change in the composition of government expenditure, so that:

$$GOVBAL_T = GY_T - \overline{GEXP}_T \tag{10}$$

or

$$\overline{GOVBAL}_T = GY_T - GEXP_T \tag{11}$$

3.5 Dataset

To calibrate the model, we follow a common procedure for dynamic CGE models which is to assume that the economy is initially in steady state equilibrium (Adams & Higgs, 1990). We calibrate the model using information from the UK Social Accounting Matrix (SAM) for 2010.[16]

The UK-ENVI model has 30 separate production sectors, including 6 main energy supply industries that encompass the supply of coal, refined oil, gas and electricity.[17] We also identify the transactions of UK households (by income quintile), the UK Government, imports, exports and transfers to and from the rest of the World (ROW).

The SAM constitutes the core dataset of the UK-ENVI model. However other parameter values are required to inform the model. These often specify technical or behavioural relationships, such as production and consumption function substitution and share parameters. Such parameters are either exogenously imposed, based on econometric estimation where available, or determined through the calibration process.

[15] Note that the income tax rate τ is fixed by default.

[16] Emonts-Holley et al. (2014) give a detailed description of the methods employed to construct these data. The SAM is produced by the Fraser of Allander Institute and available for download at: http://www.strath.ac.uk/business/economics/fraserofallanderinstitute/research/economicmodelling/

[17] See Appendix A for the full list of sectors in the aggregate 30 sector 2010 UK SAM.

Base year industrial territorial CO_2 emissions are calculated, and linked to the CGE sectoral primary fuel use according to Allan et al., (2018). This essentially converts ONS (2018a) data on sectoral physical use of energy to CO_2 using UK emissions factors (UK Government, 2010). From this, a proportioned emission factor for each of the 3 primary fuels (coal, oil and gas) is calculated for each sector to obtain sectoral base year emissions[18]. To determine the emissions resulting from changes in the economy, simulations are run using the CGE model, which give the sectoral changes in the use of each of the primary fuels. With these changes, the new emissions are calculated.

4. Simulation strategy

The simulations extend the ex-ante analysis of the previous section. In order to identify the likely impact of fiscal policies on the economy and the nature and scale of spillovers to energy policy goals, we proceed by exploring some simple simulations.

First, we investigate the impact of a 5% increase in real Government expenditure alone, so as to focus on the effects of expenditure *per se* on the economy and key elements of the energy system. This simply constitutes a stimulus to demand. We assume that the change is bond-financed, but recall we assume that the interest rate is fixed (by monetary policy action or a liquidity trap). We use this simulation as a way of isolating the impacts of changes in public spending on energy demands and supplies.

Next, we explore the impact of a 5% increase in the average rate of income tax rate in isolation. This corresponds to the actions of a government wishing to reduce the fiscal debt through increased taxation. This is associated with a negative demand shock (as take home pay and consumption are adversely affected) and, where bargaining is over a post-tax wage, an adverse supply shock (as workers seek to restore their post-tax wage). Again, the primary motivation is to identify the spillover effects to key elements of the energy system, although of course these depend critically on the economic impact of the tax rise.

Finally, we analyse the consequences of an increase in the average income tax rate (of 5 percent) as in the previous case, but here we impose a balanced budget; the increment to income tax revenues is used to fund an increase in current government expenditure. We know that in this final case there is a combination of a positive demand and a negative supply side shock. With the balanced budget simulation we also undertake sensitivity analysis to identify the extent to which the results vary with some key demand elasticities.

5. Simulation results

In the following sections we outline the simulation results for the increase in government spending, the increase in the income tax rate, and where the income tax rate is increased under a balanced budget assumption.

The economy is taken to be in long-run equilibrium prior to the shock (i.e. the increase in government spending / hike in the income tax rate), so that when the model is run forward in the absence of any disturbance it simply replicates the base year dataset (the 2010 SAM) in each period. The results

[18] This figure compares well with data on UK territorial and resident based CO_2 emissions from the ONS (2018b)

presented here are typically percentage changes in the endogenous variables relative to this unchanging equilibrium (unless otherwise specified). All of the effects reported are therefore directly attributable to the exogenous shocks. Given that the CGE model uses annual data, we take each period in the adjustment process to be one year.

To observe the adjustment of all the economic variables through time, simulations are run for 50 periods (years). Results for a range of economic and energy use are reported. The focus is primarily on the long run, over which capital stocks are fully adjusted.

5.1 Government spending

Table 1 reports the results of the stimulus to government expenditure. The aggregate results are significantly impacted by the assumed behaviour of wages, in line with our discussion of Figure 1 in Section 2; the qualitative results confirm the ex-ante analysis with the employment effects ranked FNW/FRW > BRW > ELS, with the ranking reversed for real wage changes.

So, under fixed wage closures, there is no crowding out from the supply side in the long-run: there are no changes in (real or nominal) wages or prices. This implies that there are no changes in exports. This model closure behaves like a traditional Keynesian demand-driven model, in which fix-price multipliers operate. In fact, inputs within each sector adjust equi-proportional and the system operates as if it were an extended input-output system (McGregor et al, 1996). This means that together with the direct expansion in production from the increase in government expenditure there is accompanying indirect and induced activity generated by additional consumption, investment and intermediate demand.

Accordingly, between all the labour market closures, the expansion in GDP and employment is greatest in this case. The increase in GDP (1.76%) is nearly three times the scale of that under regional bargaining (BRW), and employment increases by 2.01%. Although exports are unchanged (reflecting unchanged competitiveness), imports are stimulated by the increase in economic activity. Household consumption increases by 1.32% and investment by 1.36%.

Energy use and CO2 emissions rise due to the big increase in economic activity. This is particularly marked in energy use in production which increases by 1.32% as opposed to energy use in final demands (0.79%). However, energy and emissions intensities both fall; the stimulus to activity exceeds that to energy use. This is because UK government expenditure itself is not very energy intensive (see Appendix A for a sector breakdown of energy intensities) so that economic activity is stimulated without increasing energy use significantly.

Under BRW, the stimulus to demand also increases GDP and employment but by significantly less than under the fixed wage closures, in line with our ex-ante analysis. This reflects the fact that to induce further labour input firms need to bid up the real wage, which results in a rise in wages and prices, a loss of competitiveness and a fall in exports (of 1.40%). Consumption rises by only 1.02% and investment by 0.26%. This crowding out effect ensures a smaller expansion than under FNW/FRW.

The crowding out of some private sector expenditures and exports is reflected in a much smaller rise in total energy use in this case as compared to the fix-wage case (0.32% as compared to 1.14% under FRW) , but total emissions actually fall slightly (by 0.7%) in response to a change in sectoral mix and type of fuel use[19]. Energy and emissions intensities both fall. As expected, Under ELS the real wage rises, by 1.54%, in response to the stimulus to demand to re-equilibrate demand for labour with the fixed supply. GDP actually falls in this case; the private sector activity that is crowded out here is more value-added intensive than the public sector.

There is, depending on the model closure, some crowding out of exports. However, imports rise across all models, so that emissions are shifted abroad (and these emissions are not accounted for in our industrial territorial emissions).

Total energy use falls: government expenditure, which is has low energy intensity, displaces private expenditure (which has high energy intensity). While household consumption and energy use increases, total final demand use increases only very slightly (due to a fall in investment, and displacement from the proportionately large displacement of exports), and this is more than offset by the reduction in energy use in production. Changes in energy investment reflect the capital intensity of the composition of output.

Overall, Government expenditure is intrinsically low-energy using, so the overall impact on total energy use becomes critically dependent on the scale of any stimulus to/ contraction in private sector activity that is induced by the increase in public spending. Accordingly, where there is complete crowding out (under ELS), energy use falls; where there is no crowding out (FNW/FRW) energy use rises (since no part of the private sector is adversely impacted and the public sector expands). In intermediate cases it depends on the strength of the supply side constraint: here with BRW, overall there is an increase in energy use, but emissions actually fall due to the composition of energy use. The fall in CO2 emissions is, however, at least in part due to shifting emissions abroad.

5.2 Government taxation

Table 2 summarises the long-run impact of a 5% rise in the average tax rate that goes towards reducing the Government's debt. The qualitative results vary significantly across different labour market closures, and confirm the discussion of Figure 2 given in Section 2. In this case, both demand and (where applicable) supply-side pressures are contractionary, always generating a non-positive change in employment and economic activity. In particular, employment changes are ranked: ELS > FNW/FRWpre > BRW > FRWpt, where the latter closure assumes that it is the *post-tax* real wage that is fixed (and FRW fixes the *pre-tax* real wage).

Considering first the impacts under models in which the *pre-tax* real wage is fixed. Here, there is simply a contractionary demand effect, which operates through the impact of tax on disposable household incomes and wealth. For, while gross wages are unaffected, after tax wages fall significantly, reducing households' labour income and wealth, inducing a reduction in consumption demand. There is no adverse supply impact in this case, and neither the wage rate, nor the CPI, nor competitiveness (and therefore exports) are adversely impacted.

The big fall in household consumption (of 2.67%), reduces intermediate demand and investment too (by 1.53%). Neither government spending nor exports are impacted. This results in a 1.39% reduction

[19] Whilst total energy use and individual fuel use rise, there is a shift in the fuel-mix consumed at individual secretors. This shift entails a fall in emissions from oil (and coal) to fall, whilst these from gas rise. The fall in oil emissions is sufficient here to counter the rise in gas emissions for total industrial territorial CO2 emissions to fall.

in GDP and a 1.30% fall in employment. This decline in economic activity and final demands reduces energy use in both production and final demands, with an accompanying fall in emissions and the energy and emissions intensities.

The BRW case has a much greater negative impact than the FRWpre (fixed pre-tax real wage). This reflects the fact that workers seek to restore their post-tax real wage, and this puts upward pressure on real and nominal post tax wages and prices, despite the contraction in demand. In this case the CPI actually increases, inducing a loss of competitiveness and a reduction in exports, which reinforces the downward pressures on consumption and especially investment demands. So here GDP and employment fall by significantly more than under fixed wage cases – by 2.48% and 2.43% respectively. Not surprisingly therefore, energy use in production and final demand contract significantly, as do emissions; but while emissions intensity falls, energy intensity actually increases (as GDP falls by more than total energy use).

Notice that under the BRW closure the post-tax real wage actually falls by 2.2%; while labour seeks to restore its real wage, the downward pressure on wages from the reduction in demand prevents it from doing so. However, if workers were in a position to ensure the restoration of their real *post-tax* wage, the results reported in the first column of Table 2 would be generated. Of course, here the contractionary impact on the economy is greatest, as we would expect from our ex-ante analysis in Section 2. There is a greater loss of competitiveness and of export demand and the contraction in GDP and employment is significantly greater.

Under the ELS closure, the reduction in demand has no impact on employment: the real wage falls to re-equate labour demand with the exogenous supply of labour. So here even the pre-tax real wage falls (by 0.96%), and the post-tax wage falls by much more (4.0%). Of course, this moderates the scale of the contraction and prevents any fall in employment; ultimately the induced reduction in the CPI and the gain in competitiveness and exports compensates for the fall in consumption and investment. GDP falls by significantly less than under the other closures. Accordingly, energy use in production and final demand fall by less too, as do territorial emissions.

As such, a rise in taxation always adversely impacts household consumption demands by reducing disposable income and wealth. Under the FNW/ FRWpre closure this is the only effect, since there is no adverse supply effect in this case arising through labour's attempt to restore its real post-tax wage. In this fixed wage case there is a contraction in consumption, which does induce a further contraction in investment, but exports are not impacted. GDP falls as do energy use and emissions.

Matters are more complex when the supply-side becomes relevant. First, if bargaining is over the post-tax wage, as under BRW, there is an adverse supply-side impact accompanying the contraction in labour demand, as workers put upward pressure on wages in an attempt to restore their after-tax wage. If they were completely successful in doing this, the result is the maximum contraction in GDP and employment and in energy use and emissions.

Second, if labour market pressures impact wages – as they must under ELS so as to maintain the same equilibrium level of employment – wages tend to fall, and this moderates the scale of any contraction so as to prevent any reduction in employment. In our particular case GDP and energy use fall slightly, but this reflects sectoral compositional changes.

Of course, if we were to reverse the tax changes all the signs would change and there would be increases in GDP, employment, energy and emissions use and intensities, which would be greatest if workers retain their real post-tax wage. So when tax is used to stimulate the economy, the impact on the environment is adverse – which contrasts somewhat with the impact when government spending is used. We next explore this differential energy impact of public spending and taxation when viewed as alternative policy instruments for achieving the same economic goal.

5.3 The comparative impact of tax and public spending

It is clear from the simulations that taxation and public spending have differential impacts on both economic and energy policy goals. This is highlighted if we compare the energy implications of achieving a given GDP target through a reduction in income tax as against an expansion in public spending. Table 3 summarises the results for a 0.6% rise in GDP. The results of achieving this through an expansion in government spending are shown for the BRW closure (although the qualitative results are broadly similar across other closures). This requires an increase in 5.08% for government expenditure (similar in scale to the stimulus used to generate the results reported in Table 1) or a much smaller (1.34%) reduction in income tax. Total energy use is increased by 0.32% as a consequence of increased public spending, but by 0.57% if the expansion is achieved through lower taxation. With reduced taxation there is a relatively greater stimulus to private, as compared to UK public, spending and the former is more energy and emissions intensive. The link between economic activity and total energy use and emissions is much stronger in response to tax reductions than to expenditure increases. Indeed emissions actually fall slightly in the public-spending-induced expansion. It would appear that for any given fiscal stimulus, any adverse energy and emissions impacts would be limited by stimulating government spending rather than reducing taxation.

5.4 Government taxation: balanced budget

Here we consider the impact of a balanced-budget fiscal expansion – a rise in taxation matched by a rise in government spending. In all cases there is a stimulus to demand since government expenditure is increasing and substituting for private consumption, and the former has a lower propensity to import. The general equilibrium labour demand curve will exhibit a net outward shift, with an increase in labour demand at initial pre-tax real wage. The employment (and GDP) impacts of the results are ranked across the various labour market closures exactly as the discussion of Figure 3 suggests: FRW/FNWpre > SOCW > ELS > BRW > FRWpt.

Consider first the results under the simple Keynesian model with a fixed nominal (or pre-tax real) wage that are reported in column 1 of Table 4. Here the 5% increase in the income tax rate ultimately generates a 5.25% increase in government spending, so the results closely approximate simultaneous implementation of the government expenditure and taxation changes reported in Tables 1 and 2 respectively. In this case, there is a net stimulus to demand together with no adverse supply side impact, so that GDP and employment increasing by 0.43% and 0.78% respectively, where the order of magnitude is as expected given the results of Tables 1 and 2.

We know that under FRWpre the increase in public spending when applied alone increases economic activity and emissions, the latter reflecting the induced expansion in consumption and investment. On the other hand, the increase in the tax rate alone reduces activity and emissions. However, the relative reduction in economic activity from the tax increase is less than the increase though public spending, whilst the reduction in emissions is more. There is therefore a net increase in GDP and fall in emissions. Under a balanced budget FRWpre, consumption still falls as the post-tax wage rate falls but this is partly offset by the net contribution to the household budget brought about by the increase in employment. Household consumption falls by 1.3% with the balanced budget expansion therefore, as compared to 2.7 % with the tax increase alone. Investment also falls, although again by much less than in Table 2. Total energy use actually falls (by 0.34%), as do emissions (by 0.39%), despite the overall expansion in economic activity. This reflects the low energy (and emissions) intensity of government spending relative to that of private spending which is adversely impacted by the rise in income tax. Both energy and emissions intensities fall.

Note that, in these circumstances, a balanced budget fiscal expansion simultaneously improves the economy while reducing energy use and emissions (and intensities). There is an apparent *"double dividend"* as key government economic and energy policy goals are simultaneously improved.

Under BRW, however, there is an adverse supply effect which here dominates the net stimulus to demand, so that there is a significant contraction in GDP of 2.2% and employment of 2%. The wage rise leads to larger falls in wealth and consumption because of the contraction in employment. In this case there is also an even greater proportionate fall in investment than in the fix-wage cases. There are big reductions in energy use (2.1%) and emissions (2.4%), but not in intensity. Under these circumstances the balanced budget fiscal expansion therefore has a contractionary impact on the economy, which moderates energy use and emissions. Under BRW there seems no prospect of a double dividend, and indeed even the primary objective of the fiscal expansion is not achieved.

Matters are, of course, even worse if workers succeed in defending their post-tax real wage in the face of the fiscal changes. Here there is an even greater contraction in economic activity and reduction in energy use and emissions.

What if workers were to value the increased spending at the margin as much as their loss of after tax income and this was fully reflected in their bargaining behaviour? Under this "Social Wage" (SOCW) case workers would accept a fall in their post-tax wage because they value the increase in government expenditure and feel no worse off after the change (e.g. Lecca et al., (2014b). Accordingly, bargaining would effectively focus on the *pre-tax* real wage.

The impact of the balanced budget fiscal expansion in this case are summarised in the second column of Table 3. In this case, as expected given our ex-ante analysis, employment actually increases: the adverse supply impact of the fiscal expansion is nullified and only the demand stimulus is present. However, the stimulus to activity puts upward pressure on the pre-tax real wage, and the expansion is significantly less than under the fix-wage closures. Indeed, in this case GDP actually falls slightly, reflecting the change in the balance of economic activity between the private and public sectors. Total energy use and emissions, and their intensities, fall. So in the Social Wage case there is a double dividend in terms of employment and emissions, both of which simultaneously move favourably; however the dividend does not here extend to GDP.

Under ELS even pre-tax wages would have to rise to ensure that labour demand again equals the fixed labour supply, although post-tax wage rates fall. Here again GDP actually declines, though by much less than under BRW. Again, there is a compositional effect that lowers GDP, although employment, of course, is unchanging. Total energy use and emissions fall by more than under fix-wage cases. Of course, there is no double dividend in this case since economic activity (excepting employment) falls as do emissions.

Overall, the results across the different labour market models illustrate a number of potential trade-offs. First, there are two labour market models, FNW and FRWpre, where an increase in economic activity and employment can be observed along with a fall in total energy use and emissions. This would suggest that a double dividend is possible in a situation where workers are willing to accept cuts in their post-tax wage. Second, in the case where workers value public spending, SOC, a fall in economic activity can be observed along with a fall in total energy use and emissions. Here, however, employment increases. Third, there are three labour market models, ELS, BRW, and FRWpt, where economic activity falls along with total energy use and emissions.

Table 1: Long-run effects of a 5% increase in government spending. % changes from base year.

	FNW/FRW	BRW	ELS
GDP	1.76	0.59	-0.18
CPI	0.00	0.80	1.34
Unemployment rate (pp difference)	-1.89	-0.75	0.00
Total employment	2.01	0.80	0.00
Nominal gross wage	0.00	1.73	2.90
Real gross wage	0.00	0.92	1.54
Households wealth	1.30	0.99	0.80
Households consumption	1.32	1.02	0.82
Labour income	2.01	2.54	2.90
Capital income	1.36	1.01	0.78
Government budget	10.26	15.28	18.63
Government consumption	5.00	5.00	5.00
Investment	1.36	0.26	-0.47
Total energy use (intermediate+final)	1.14	0.32	-0.22
- Electricity	1.40	0.60	0.08
- Gas	1.34	0.70	0.28
Energy use in production (total intermediate)	1.32	0.34	-0.30
Energy consumption (total final demand)	0.79	0.32	0.02
- Households	1.30	1.17	1.10
- Investment	1.30	0.26	-0.43
- Government	5.00	5.00	5.00
- Exports	0.00	-0.91	-1.51
Energy output prices	0.00	0.54	0.89
Energy intensity (Total energy use/GDP)	-0.61	-0.27	-0.04
Territorial CO2 emissions	1.04	-0.07	-0.79
Emission intensity (territorial CO2/GDP)	-0.71	-0.65	-0.62
Total imports	1.49	2.21	2.70
Total exports	0.00	-1.40	-2.31

Note: Capital stocks are fixed in the short run at industry level. In the long run capital stocks fully adjust, across all sectors, to the shock, and are again equal to their desired levels. The short-run applies to a period of a year; the adjustment period to the long-run varies but is typically complete within 7-15 years. See Appendix B for short-run results.

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

	Long-run			
	FRWpt	BRW	FNW/ FRWpre	ELS
GDP	-5.17	-2.48	-1.39	-0.13
CPI	2.69	0.76	0.00	-0.86
Unemployment rate (pp difference)	4.90	2.28	1.23	0.00
Total employment	-5.21	-2.43	-1.30	0.00
Nominal wage	5.94	1.64	0.00	-1.82
Nominal wage after tax	2.69	-1.48	-3.07	-4.83
Real wage	3.17	0.88	0.00	-0.96
Real wage after tax	0.00	-2.22	-3.07	-4.00
Households wealth	-1.89	-1.20	-0.92	-0.57
Households consumption	-3.62	-2.95	-2.67	-2.33
Labour income	0.43	-0.82	-1.30	-1.82
Capital income	-2.71	-1.87	-1.53	-1.14
Government budget	5.64	-6.04	-10.56	-15.83
Government consumption	0.00	0.00	0.00	0.00
Investment	-5.09	-2.56	-1.53	-0.34
Total energy use (intermediate+final)	-4.15	-2.27	-1.51	-0.61
- Electricity	-4.29	-2.48	-1.74	-0.88
- Gas	-3.88	-2.41	-1.82	-1.11
Energy use in production (total intermediate)	-4.66	-2.42	-1.51	-0.45
Energy consumption (total final demand)	-2.94	-1.88	-1.44	-0.92
- Households	-2.88	-2.62	-2.50	-2.35
- Investment	-4.97	-2.58	-1.61	-0.47
- Government	0.00	0.00	0.00	0.00
- Exports	-2.98	-0.86	0.00	1.01
Energy output prices	1.78	0.50	0.00	-0.58
Energy output	-4.70	-2.41	-1.47	-0.38
Non energy output	-4.75	-2.35	-1.38	-0.25
Energy intensity (Total energy use/GDP)	1.07	0.21	-0.11	-0.48
Territorial CO_2 emissions	-5.02	-2.49	-1.45	-0.24
Emission intensity (territorial CO_2/GDP)	0.15	-0.01	-0.06	-0.11
Total imports	0.67	-1.02	-1.67	-2.40
Total exports	-4.55	-1.32	0.00	1.54

Note: See Appendix C for short-run results.

Table 3: Long-run effects of a 5.08% increase in government spending, and a 1.34% reduction in the income tax rate, BRW closure. % changes from base year.

	Increase in government expenditure	Reduction in income tax
GDP (calibrated)	0.60	0.60
CPI	0.81	-0.15
Unemployment rate (pp difference)	-0.76	-0.55
Total employment	0.81	0.58
Nominal wage	1.75	-0.32
Nominal wage after tax	1.75	0.50
Real wage	0.93	-0.17
Real wage after tax	0.93	0.65
Households wealth	1.01	0.31
Households consumption	1.04	0.79
Labour income	2.58	0.26
Capital income	1.03	0.49
Government budget	15.54	1.97
Government consumption	5.08	0.00
Income tax rate	0.00	-1.34
Investment	0.26	0.63
Total energy use (intermediate+final)	0.32	0.57
- Electricity	0.61	0.63
- Gas	0.71	0.62
Energy use in production (total intermediate)	0.34	0.60
Energy consumption (total final demand)	0.33	0.48
- Households	1.19	0.71
- Investment	0.26	0.64
- Government	5.08	0.00
- Exports	-0.93	0.17
Energy output prices	0.54	-0.10
Energy output	0.08	0.59
Non energy output	0.68	0.57
Energy intensity (Total energy use/GDP)	-0.27	-0.03
Territorial CO_2 emissions	-0.07	0.61
Emission intensity (territorial CO_2/GDP)	-0.67	0.01
Total imports	2.25	0.33
Total exports	-1.42	0.26

Table 4: Long-run effects of a 5% increase in the income tax rate under a balanced budget (FIXBAL). % changes from base year.

	Long-run				
	FNW/ FRWpre	SOCW	ELS	BRW	FRWpt
GDP	0.43	-0.09	-0.29	-2.20	-6.09
CPI	0.00	0.21	0.29	1.06	2.69
Unemployment rate (pp difference)	-0.73	-0.21	0.00	1.93	5.88
Total employment	0.78	0.22	0.00	-2.06	-6.26
Nominal wage	0.00	0.45	0.62	2.29	5.94
Nominal wage after tax	-3.07	-2.64	-2.47	-0.85	2.69
Real wage	0.00	0.24	0.33	1.22	3.17
Real wage after tax	-3.07	-2.84	-2.75	-1.89	0.00
Households wealth	0.42	0.18	0.09	-0.79	-2.59
Households consumption	-1.34	-1.57	-1.67	-2.54	-4.31
Labour income	0.78	0.67	0.62	0.19	-0.69
Capital income	-0.14	-0.39	-0.49	-1.45	-3.43
Government budget	0.00	0.00	0.00	0.00	0.00
Government consumption	5.25	4.62	4.38	2.05	-2.70
Investment	-0.14	-0.59	-0.76	-2.42	-5.80
Total energy use (intermediate+final)	-0.34	-0.69	-0.83	-2.12	-4.75
- Electricity	-0.32	-0.69	-0.84	-2.21	-5.02
- Gas	-0.44	-0.77	-0.90	-2.11	-4.58
Energy use in production (total intermediate)	-0.16	-0.58	-0.74	-2.25	-5.35
Energy consumption (total final demand)	-0.64	-0.85	-0.94	-1.73	-3.35
- Households	-1.19	-1.38	-1.45	-2.15	-3.56
- Investment	-0.27	-0.70	-0.87	-2.44	-5.65
- Government	5.25	4.62	4.38	2.05	-2.70
- Exports	0.00	-0.24	-0.33	-1.20	-2.98
Energy output prices	0.00	0.14	0.19	0.70	1.78
Energy output	-0.36	-0.75	-0.90	-2.34	-5.26
Non energy output	0.39	-0.09	-0.28	-2.04	-5.65
Energy intensity (Total energy use/GDP)	-0.76	-0.60	-0.53	0.08	1.42
Territorial CO2 emissions	-0.39	-0.80	-0.96	-2.48	-5.56
Emission intensity (territorial CO2/GDP)	-0.82	-0.71	-0.67	-0.29	0.55
Total imports	-0.14	-0.14	-0.14	-0.15	-0.16
Total exports	0.00	-0.36	-0.51	-1.83	-4.55

Note: See Appendix D for short-run results.

5.5. Sensitivity analysis

We explore the impact of increasing openness of the economy to trade by increasing Armington trade elasticities. This increases the sensitivity of the UK economy to changes in competitiveness. Results are summarised in Table 5 detailing the long-run results for Armington trade elasticities of 1.00, 1.50, 2.00, 2.50, and 3.00, where 2.00 is the central estimate used in the UK-ENVI model and in the simulations reported earlier. This analysis re-runs the balanced-budget fiscal expansion under alternative values of the Armington trade elasticities. As the degree of substitutability is increased from 1.00 to 3.00 the system becomes more sensitive to competitiveness changes. The higher the elasticity, the greater the responsiveness to the adverse competitiveness effects due to the increase in prices arising from the increase in the income tax rate. The scale of the adverse effects increases along with increases in the Armington trade elasticity. That is, domestic goods become more competitive both in home and foreign markets, the higher the elasticity. In this case there is less demand for domestic goods there is a smaller stimulus to output, and stimulated demand for labour, the higher the Armington elasticity. Overall, there is a smaller stimulus seen from an increase in the income tax rate when the Armington trade elasticity is increased. These results emphasise that the degree of openness of the UK economy to trade flows is significantly important in influencing the overall results.

Table 5: Armington sensitivity analysis. Long-run effects of a 5% increase in the income tax rate under a balanced budget (FIXBAL), BRW closure. % changes from base year.

	σv = 1.00	σv = 1.50	σv = 2.00	σv = 2.50	σv = 3.00
GDP	-1.92	-2.07	-2.20	-2.31	-2.41
CPI	1.23	1.14	1.06	0.99	0.93
Total employment	-1.81	-1.94	-2.06	-2.16	-2.25
Nominal wage	2.68	2.47	2.29	2.13	2.01
Nominal wage after tax	-0.47	-0.68	-0.85	-1.00	-1.13
Real wage	1.43	1.31	1.22	1.14	1.07
Real wage after tax	-1.69	-1.80	-1.89	-1.97	-2.04
Government consumption	2.30	2.17	2.05	1.95	1.85
Investment	-2.09	-2.27	-2.42	-2.55	-2.67
Total energy use (intermediate+final)	-1.78	-1.96	-2.12	-2.25	-2.37
Energy output prices	0.82	0.76	0.70	0.66	0.62
Energy intensity (Total energy use/GDP)	0.14	0.11	0.08	0.06	0.04
Territorial CO2 emissions	-2.17	-2.33	-2.48	-2.60	-2.71
Emission intensity (territorial CO2/GDP)	-0.26	-0.27	-0.29	-0.30	-0.31
Total imports	0.52	0.16	-0.15	-0.42	-0.65
Total exports	-1.07	-1.48	-1.83	-2.14	-2.41

Note: See Appendix E for a full set of simulation results.

6. Summary and conclusions

The energy system and the economy are inextricably intertwined. While this interdependence is widely recognised, it has not featured prominently in assessing the likely impact of economic policies, notably industrial and fiscal policies: rather these assessments have tended to focus on the primary economic objectives of these policies, often the impact on Gross Domestic Product (GDP) and employment.

In principle, fiscal policies are likely to have a significant influence on 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 spillover effects from fiscal policy instruments to the achievement of energy policy goals. This is the focus of the present paper.

The multi-sectoral computable general equilibrium (CGE) approach which we employ captures the interdependence of the economy and key elements of the energy systems and allows us to track the impact of key fiscal policy interventions on key goals of economic and energy policies.

Our primary focus in this paper is on the impacts of fiscal policies on elements of the energy system and their effects on energy policy goals such as energy use and carbon emissions, and energy intensity. We start by considering the impacts of on key elements of the energy system of an increase in government spending in isolation, and then explore the impact of an increase in the average income tax rate. We then proceed by considering the implications of a balanced-budget rise in the income tax rate, where additional tax revenues are matched by a rise in government spending.

Perhaps the most striking, but not surprising, result of our analysis is the crucial importance of the wage determination process in governing the impact of fiscal policy changes on both the economy and energy use and emissions. Given the widespread international evidence in favour of the "wage curve" we have generally adopted this as the default specification in our models. Since this implies that workers bargain over *post-tax* wages, any changes in income tax rates have supply-side impacts.

In general, (money-financed) increases in government spending stimulate the economy. Overall, UK Government expenditure is intrinsically not very energy intensive, so the impact on total energy use becomes critically dependent on the scale of any stimulus to/contraction in private sector activity that is induced by the increase in public spending. Accordingly, where there is complete crowding out, energy use falls; where there is no crowding out (fix-wage cases), energy use rises, since no part of the private sector is adversely impacted and the public sector expands. In intermediate cases it depends on the strength of the supply-side constraint. In the presence of a bargained real wage function/ wage curve, overall there is an increase in energy use, but emissions actually fall slightly, offering some prospect of a "double dividend" of an increase in economic activity with a reduction in emissions. However, this result is the net outcome of countervailing effects on emissions and so is not guaranteed.

While (money financed) income tax reductions also stimulate the economy, the outcomes results again depend on the precise nature of wage determination. However, typically there is a stimulus to the economy and a broadly similar increase in both total energy use and in emissions. The link between movements in economic activity and energy use and emissions is noticeably stronger for tax cuts than for public spending increases. This reflects the fact that tax cuts operate through the expansion of disposable income and wealth, stimulating consumption and other private sector spending, which tends to be energy and emissions intensive relative to current public spending.

In the context of general balanced budget expansions there are countervailing demand and supply side influences. Aggregate demand is stimulated since government expenditure is less import intensive than private spending. However, the increase in taxation puts upward pressure on wages IF workers seek to restore their post-tax wage. In the default version of our model the latter adverse supply effect dominates and economic activity declines. This is associated with a reduction in energy use (though an increase in energy intensity) and in emissions (whose intensity falls). The adverse economic impact is associated with a beneficial impact on emissions. Similarly, a balanced budget fiscal contraction would be associated with a simultaneous expansion of economic activity and energy use and emissions; again there would appear to be a trade-off between economic and emissions objectives.

Is the trade-off inevitable? It does depend, inter alia, on whether workers value public spending and their willingness to accept cuts in their post-tax wage. Under a Social Wage arrangement, workers would effectively bargain for a pre-tax wage in return for some augmentation of public services. In these circumstances the adverse supply effect of an increase in taxes is mitigated, and our results suggest it is then possible to obtain a simultaneous stimulus to economic activity and reduction in emissions, though again this result is not inevitable. If the recent past experience of the comparative constancy of pre-tax real wages were to continue, the supply side impact of the tax rise would be nullified, and economic expansion would result, with the possibility of an accompanying reduction in emissions.

Overall, our results suggest that a double dividend - a simultaneous stimulus to the economy and a reduction in emissions – induced by an increase in current public spending or a hike in the income tax rate seem unlikely in the UK context. However, if workers accept the shift from both emission and import intensive consumption to public sector output, economic activity can rise, emissions fall and imports fall too. Nonetheless, there are undoubted differential spillover effects on key elements of the energy system from tax and public spending policies that may prove capable of being exploited through the coordination of fiscal and energy policies. Even if it seems unlikely that fiscal policies would be adjusted with a view to improved coordination with energy policies, the latter should at least be aware of likely direction and scale of fiscal spillover effects to the energy system.

Future research will relax the rather restrictive assumptions about macroeconomic closure employed here, notably the assumption that interest rates are fixed, and the absence of deficit and balance of payments constraints. However, these simplifications serve the important purpose in the current paper of allowing a clear focus on the direct spillovers from key fiscal policy instruments to key elements of the energy system. Future research will also: relax the assumption that current government consumption has no supply side impact effects (e.g. through human capital investment); analyse the spillover effects arising from a wider range of taxes, and explore the possibility of the social wage case being linked to the composition of government spending.

Appendices

Appendix A: Sector characteristics by income and expenditure components, 2010 UK Social Accounting Matrix

		% share of costs (expenditures)						% share of incomes (receipts)					
		Activities	Energy (2,3,4,9,16 and 17)	Labour	OVA	Taxes on expenditures	ROW imports	Activities	Households	Government	Capital formation	Stock	ROW exports
1.AGR	Agriculture, forestry & fishing	47	3	17	31	-9	14	54	32	0	4	0	10
2. MIN	Mining & quarrying	47	17	28	7	5	13	97	30	0	0	-36	8
3. CRU	Crude Petroleum + Natural Gas & Metal Ores + coal	26	12	7	61	1	5	46	4	0	1	-1	49
4. OMI	Other Mining & mining services	33	9	17	36	2	11	54	7	1	1	0	37
5. FOO	Food (+ Tobacco)	57	3	23	5	1	15	50	35	1	0	0	14
6. DRI	Drink	57	4	17	15	2	8	50	22	0	0	1	27
7. TEX	Textile, Leather & Wood	35	2	28	10	1	26	55	13	1	4	0	28
8. PAP	Paper & Printing	37	5	28	11	2	23	70	15	1	3	0	10
9. COK	Coke & refined petroleum products	21	15	10	3	5	62	34	25	0	0	0	41
10. CHE	Chemicals & Pharmaceuticals	34	3	17	17	1	30	28	3	0	1	0	68
11. RUB	Rubber, Cement, + Glass	37	6	28	7	2	26	73	2	0	1	1	24
12. IRO	Iron, steel + metal	37	3	27	6	2	29	64	2	0	5	3	26
13. ELM	Electrical Manufacturing	40	2	30	10	1	20	36	4	0	11	1	48
14. MOT	Manufacture of Motor Vehicles, Trailers & Semi-Trailers	53	1	18	5	1	23	24	13	0	2	1	60
15. TRA	Transport equipment + other Manufacturing (incl Repair)	47	2	27	7	1	18	40	8	1	9	0	43
16. ELE	Electricity, transmission & distribution	67	53	6	11	2	14	67	30	1	1	0	2
17. GAS	Gas; distribution of gaseous fuels through mains; steam & air conditioning	57	45	10	12	3	18	56	44	0	0	0	0
18. WTR	Natural water treatment & supply services; sewerage services	29	4	20	43	5	2	31	69	0	0	0	0
19.WAM	Water Management & remediation	50	1	21	16	6	7	38	13	25	2	0	22
20. CON	Construction - Buildings	49	1	22	19	3	7	47	1	0	52	-1	1
21.WHO	Wholesale & Retail Trade	39	2	35	15	4	7	24	57	1	3	0	16
22. TRL	Land Transport	43	3	35	12	2	8	53	40	1	1	0	4
23. TRO	Other transport	46	2	23	9	3	19	12	53	0	0	0	34
24. TRS	Transport support	52	1	33	7	3	5	86	4	1	0	0	9
25. ACC	Accommodation & Food Service Activities	35	1	32	12	8	13	13	72	1	2	0	12
26. COM	Communication	32	1	35	20	2	12	50	25	2	11	0	12
27. SER	Services	35	1	23	33	2	6	45	37	0	3	0	16
28. EDU	Education health & defence	29	1	49	6	5	11	16	14	68	1	0	1
29. REC	Recreational	35	1	28	24	5	8	28	50	5	4	0	14
30. OTR	Other private services	22	1	47	21	4	6	37	43	4	8	0	8

Appendix B: Short- and long-run effects of a 5% increase in government spending. In % changes from base year.

	Long-run			Short-run			
	FNW/FRW	BRW	ELS	FNW	FRW	BRW	ELS
GDP	1.76	0.59	-0.18	0.98	0.77	0.46	-0.01
CPI	0.00	0.80	1.34	0.58	0.69	0.96	1.28
Unemployment rate (pp difference)	-1.89	-0.75	0.00	-1.52	-1.18	-0.71	0.00
Total employment	2.01	0.80	0.00	1.61	1.26	0.76	0.00
Nominal gross wage	0.00	1.73	2.90	0.00	0.69	1.84	3.48
Real gross wage	0.00	0.92	1.54	-0.58	0.00	0.87	2.17
Households wealth	1.30	0.99	0.80	0.84	0.89	0.99	1.13
Households consumption	1.32	1.02	0.82	0.84	0.74	0.88	0.86
Labour income	2.01	2.54	2.90	1.61	1.96	2.62	3.48
Capital income	1.36	1.01	0.78	2.71	2.18	1.57	0.53
Government budget	10.26	15.28	18.63	16.56	17.39	18.77	20.72
Government consumption	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Investment	1.36	0.26	-0.47	2.19	1.65	0.71	-0.55
Total energy use (intermediate+final)	1.14	0.32	-0.22	0.75	0.59	0.44	0.14
- Electricity	1.40	0.60	0.08	1.13	0.92	0.73	0.35
- Gas	1.34	0.70	0.28	0.80	0.69	0.66	0.51
Energy use in production (total intermediate)	1.32	0.34	-0.30	0.65	0.50	0.34	0.05
Energy consumption (total final demand)	0.79	0.32	0.02	0.42	0.37	0.45	0.45
- Households	1.30	1.17	1.10	0.91	0.86	1.09	1.19
- Investment	1.30	0.26	-0.43	1.69	1.26	0.73	-0.14
- Government	5.00	5.00	5.00	5.00	5.00	5.00	5.00
- Exports	0.00	-0.91	-1.51	-0.39	-0.41	-0.52	-0.61
Energy output prices	0.00	0.54	0.89	0.29	0.33	0.45	0.59
Energy intensity (Total energy use/GDP)	-0.61	-0.27	-0.04	-0.23	-0.18	-0.02	0.15
Territorial CO2 emissions	1.04	-0.07	-0.79	0.29	0.16	0.03	-0.22
Emission intensity (territorial CO2/GDP)	-0.71	-0.65	-0.62	-0.69	-0.60	-0.43	-0.22
Total imports	1.49	2.21	2.70	2.20	2.20	2.46	2.65
Total exports	0.00	-1.40	-2.31	-0.83	-1.00	-1.41	-1.90

Appendix C: Short- and long-run effects of a 5% increase in the income tax rate (FIXGOV). In % changes from base year.

	Long-run				Short-run				
	FRWpt	BRW	FNW /FRWpre	ELS	FRWpt	BRW	FNW	FRWpre	ELS
GDP	-5.17	-2.48	-1.39	-0.13	-1.32	-0.85	-0.46	-0.19	0.00
CPI	2.69	0.76	0.00	-0.86	0.12	-0.40	-0.71	-0.84	-1.05
Unemployment rate (pp difference)	4.90	2.28	1.23	0.00	2.00	1.29	0.70	0.30	0.00
Total employment	-5.21	-2.43	-1.30	0.00	-2.12	-1.37	-0.75	-0.31	0.00
Nominal wage	5.94	1.64	0.00	-1.82	3.29	1.40	0.00	-0.84	-1.59
Nominal wage after tax	2.69	-1.48	-3.07	-4.83	0.12	-1.72	-3.07	-3.89	-4.61
Real wage	3.17	0.88	0.00	-0.96	3.17	1.80	0.71	0.00	-0.55
Real wage after tax	0.00	-2.22	-3.07	-4.00	0.00	-1.32	-2.38	-3.07	-3.60
Households wealth	-1.89	-1.20	-0.92	-0.57	0.03	-0.14	-0.25	-0.31	-0.37
Households consumption	-3.62	-2.95	-2.67	-2.33	-1.57	-2.02	-2.10	-1.99	-2.18
Labour income	0.43	-0.82	-1.30	-1.82	1.10	0.00	-0.75	-1.15	-1.59
Capital income	-2.71	-1.87	-1.53	-1.14	-4.12	-3.36	-2.56	-1.92	-1.59
Government budget	5.64	-6.04	-10.56	-15.83	-11.53	-13.59	-15.08	-16.01	-16.86
Government consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment	-5.09	-2.56	-1.53	-0.34	-4.98	-3.39	-2.24	-1.57	-0.84
Total energy use (intermediate+final)	-4.15	-2.27	-1.51	-0.61	-1.39	-1.23	-1.01	-0.80	-0.74
- Electricity	-4.29	-2.48	-1.74	-0.88	-1.87	-1.65	-1.37	-1.11	-1.02
- Gas	-3.88	-2.41	-1.82	-1.11	-1.10	-1.18	-1.11	-0.97	-1.00
Energy use in production (total intermediate)	-4.66	-2.42	-1.51	-0.45	-1.07	-0.86	-0.64	-0.45	-0.37
Energy consumption (total final demand)	-2.94	-1.88	-1.44	-0.92	-0.67	-0.91	-0.96	-0.90	-1.01
- Households	-2.88	-2.62	-2.50	-2.35	-1.22	-1.83	-2.02	-1.97	-2.23
- Investment	-4.97	-2.58	-1.61	-0.47	-3.66	-2.90	-2.19	-1.65	-1.33
- Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- Exports	-2.98	-0.86	0.00	1.01	0.20	0.43	0.54	0.57	0.66
Energy output prices	1.78	0.50	0.00	-0.58	-0.01	-0.25	-0.38	-0.44	-0.54
Energy output	-4.70	-2.41	-1.47	-0.38	-0.80	-0.68	-0.53	-0.40	-0.35
Non energy output	-4.75	-2.35	-1.38	-0.25	-1.36	-0.94	-0.58	-0.32	-0.15
Energy intensity (Total energy use/GDP)	1.07	0.21	-0.11	-0.48	-0.07	-0.38	-0.55	-0.61	-0.74
Territorial CO2 emissions	-5.02	-2.49	-1.45	-0.24	-0.84	-0.67	-0.48	-0.32	-0.25
Emission intensity (territorial CO2/GDP)	0.15	-0.01	-0.06	-0.11	0.48	0.18	-0.02	-0.13	-0.25
Total imports	0.67	-1.02	-1.67	-2.40	-1.54	-2.14	-2.37	-2.37	-2.60
Total exports	-4.55	-1.32	0.00	1.54	-0.21	0.59	1.07	1.29	1.62

Appendix D: Short- and long-run effects of a 5% increase in the income tax rate (FIXBAL). In % changes from base year.

	Long-run					Short-run					
	FNW/ FRWpre	SOCW	ELS	BRW	FRWpt	FRWpre	FNW	SOCW	ELS	BRW	FRWpt
GDP	0.43	-0.09	-0.29	-2.20	-6.09	0.54	0.49	0.30	-0.01	-0.50	-0.92
CPI	0.00	0.21	0.29	1.06	2.69	-0.15	-0.13	-0.08	0.03	0.12	0.07
Unemployment rate (pp difference)	-0.73	-0.21	0.00	1.93	5.88	-0.84	-0.75	-0.46	0.00	0.75	1.37
Total employment	0.78	0.22	0.00	-2.06	-6.26	0.89	0.80	0.49	0.00	-0.80	-1.46
Nominal wage	0.00	0.45	0.62	2.29	5.94	-0.15	0.00	0.47	1.29	2.46	3.24
Nominal wage after tax	-3.07	-2.64	-2.47	-0.85	2.69	-3.22	-3.07	-2.62	-1.82	-0.68	0.07
Real wage	0.00	0.24	0.33	1.22	3.17	0.00	0.13	0.55	1.26	2.34	3.17
Real wage after tax	-3.07	-2.84	-2.75	-1.89	0.00	-3.07	-2.94	-2.54	-1.85	-0.80	0.00
Households wealth	0.42	0.18	0.09	-0.79	-2.59	0.54	0.55	0.55	0.56	0.53	0.45
Households consumption	-1.34	-1.57	-1.67	-2.54	-4.31	-1.22	-1.23	-1.34	-1.46	-1.79	-2.24
Labour income	0.78	0.67	0.62	0.19	-0.69	0.74	0.80	0.96	1.29	1.64	1.73
Capital income	-0.14	-0.39	-0.49	-1.45	-3.43	0.19	0.06	-0.44	-1.17	-2.54	-3.89
Government budget	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Government consumption	5.25	4.62	4.38	2.05	-2.70	4.71	4.65	4.49	4.21	3.77	3.44
Investment	-0.14	-0.59	-0.76	-2.42	-5.80	0.14	0.02	-0.60	-1.32	-3.13	-5.23
Total energy use (intermediate+final)	-0.34	-0.69	-0.83	-2.12	-4.75	-0.21	-0.25	-0.40	-0.62	-1.07	-1.56
- Electricity	-0.32	-0.69	-0.84	-2.21	-5.02	-0.18	-0.23	-0.44	-0.72	-1.34	-2.04
- Gas	-0.44	-0.77	-0.90	-2.11	-4.58	-0.28	-0.31	-0.42	-0.58	-0.90	-1.26
Energy use in production (total intermediate)	-0.16	-0.58	-0.74	-2.25	-5.35	0.04	0.00	-0.13	-0.33	-0.69	-1.02
Energy consumption (total final demand)	-0.64	-0.85	-0.94	-1.73	-3.35	-0.52	-0.53	-0.58	-0.63	-0.78	-0.99
- Households	-1.19	-1.38	-1.45	-2.15	-3.56	-1.08	-1.09	-1.16	-1.23	-1.48	-1.87
- Investment	-0.27	-0.70	-0.87	-2.44	-5.65	-0.34	-0.44	-0.88	-1.45	-2.71	-4.18
- Government	5.25	4.62	4.38	2.05	-2.70	4.71	4.65	4.49	4.21	3.77	3.44
- Exports	0.00	-0.24	-0.33	-1.20	-2.98	0.15	0.15	0.15	0.14	0.17	0.28
Energy output prices	0.00	0.14	0.19	0.70	1.78	-0.10	-0.10	-0.08	-0.04	-0.02	-0.06
Energy output	-0.36	-0.75	-0.90	-2.34	-5.26	-0.13	-0.16	-0.25	-0.39	-0.64	-0.87
Non energy output	0.39	-0.09	-0.28	-2.04	-5.65	0.50	0.45	0.27	-0.03	-0.53	-0.97
Energy intensity (Total energy use/GDP)	-0.76	-0.60	-0.53	0.08	1.42	-0.75	-0.73	-0.70	-0.62	-0.57	-0.64
Territorial CO2 emissions	-0.39	-0.80	-0.96	-2.48	-5.56	-0.15	-0.18	-0.28	-0.44	-0.71	-0.94
Emission intensity (territorial CO2/GDP)	-0.82	-0.71	-0.67	-0.29	0.55	-0.70	-0.67	-0.58	-0.44	-0.21	-0.02
Total imports	-0.14	-0.14	-0.14	-0.15	-0.16	-0.21	-0.22	-0.34	-0.42	-0.85	-1.55
Total exports	0.00	-0.36	-0.51	-1.83	-4.55	0.26	0.23	0.15	-0.03	-0.18	-0.10

Appendix E: Armington sensitivity analysis for a 5% increase in the income tax rate (FIXBAL). In % changes from base year.

	Long-run					Short-run				
	σv = 1.00	σv = 1.50	σv = 2.00	σv = 2.50	σv = 3.00	σv = 1.00	σv = 1.50	σv = 2.00	σv = 2.50	σv = 3.00
GDP	-1.92	-2.07	-2.20	-2.31	-2.41	-0.47	-0.49	-0.50	-0.52	-0.53
CPI	1.23	1.14	1.06	0.99	0.93	0.29	0.19	0.12	0.06	0.01
Unemployment rate (pp difference)	1.70	1.83	1.93	2.03	2.12	0.70	0.73	0.75	0.77	0.79
Total employment	-1.81	-1.94	-2.06	-2.16	-2.25	-0.74	-0.78	-0.80	-0.82	-0.84
Nominal wage	2.68	2.47	2.29	2.13	2.01	2.70	2.56	2.46	2.38	2.31
Nominal wage after tax	-0.47	-0.68	-0.85	-1.00	-1.13	-0.46	-0.59	-0.68	-0.76	-0.83
Real wage	1.43	1.31	1.22	1.14	1.07	2.40	2.37	2.34	2.32	2.30
Real wage after tax	-1.69	-1.80	-1.89	-1.97	-2.04	-0.75	-0.78	-0.80	-0.82	-0.84
Households wealth	-0.50	-0.66	-0.79	-0.91	-1.02	0.62	0.57	0.53	0.50	0.47
Households consumption	-2.23	-2.40	-2.54	-2.66	-2.77	-1.48	-1.64	-1.79	-1.92	-2.04
Labour income	0.82	0.48	0.19	-0.07	-0.29	1.93	1.77	1.64	1.54	1.45
Capital income	-0.96	-1.22	-1.45	-1.65	-1.82	-2.18	-2.39	-2.54	-2.66	-2.75
Government consumption	2.30	2.17	2.05	1.95	1.85	3.75	3.76	3.77	3.78	3.78
Investment	-2.09	-2.27	-2.42	-2.55	-2.67	-2.70	-2.93	-3.13	-3.29	-3.43
Total energy use (intermediate+final)	-1.78	-1.96	-2.12	-2.25	-2.37	-0.90	-0.99	-1.07	-1.13	-1.19
- Electricity	-1.90	-2.07	-2.21	-2.33	-2.45	-1.10	-1.23	-1.34	-1.44	-1.53
- Gas	-1.79	-1.96	-2.11	-2.24	-2.36	-0.70	-0.81	-0.90	-0.98	-1.06
Energy use in production (total intermediate)	-1.95	-2.11	-2.25	-2.38	-2.49	-0.57	-0.64	-0.69	-0.73	-0.77
Energy consumption (total final demand)	-1.33	-1.55	-1.73	-1.89	-2.04	-0.63	-0.71	-0.78	-0.84	-0.89
- Households	-1.81	-1.99	-2.15	-2.29	-2.41	-1.14	-1.32	-1.48	-1.62	-1.75
- Investment	-2.16	-2.31	-2.44	-2.55	-2.66	-2.35	-2.54	-2.71	-2.87	-3.01
- Government	2.30	2.17	2.05	1.95	1.85	3.75	3.76	3.77	3.78	3.78
- Exports	-0.70	-0.97	-1.20	-1.40	-1.58	0.05	0.11	0.17	0.24	0.30
Energy output prices	0.82	0.76	0.70	0.66	0.62	0.07	0.02	-0.02	-0.04	-0.07
Energy output	-2.04	-2.20	-2.34	-2.46	-2.57	-0.56	-0.60	-0.64	-0.67	-0.70
Non energy output	-1.73	-1.90	-2.04	-2.17	-2.29	-0.45	-0.50	-0.53	-0.56	-0.58
Energy intensity (Total energy use/GDP)	0.14	0.11	0.08	0.06	0.04	-0.44	-0.51	-0.57	-0.62	-0.67
Territorial CO2 emissions	-2.17	-2.33	-2.48	-2.60	-2.71	-0.65	-0.68	-0.71	-0.73	-0.76
Emission intensity (territorial CO2/GDP)	-0.26	-0.27	-0.29	-0.30	-0.31	-0.18	-0.20	-0.21	-0.22	-0.23
Total imports	0.52	0.16	-0.15	-0.42	-0.65	-0.33	-0.62	-0.85	-1.03	-1.18
Total exports	-1.07	-1.48	-1.83	-2.14	-2.41	-0.24	-0.23	-0.18	-0.10	0.00

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