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THE IMPACT OF FUEL DUTY ON THE MACRO-ECONOMY

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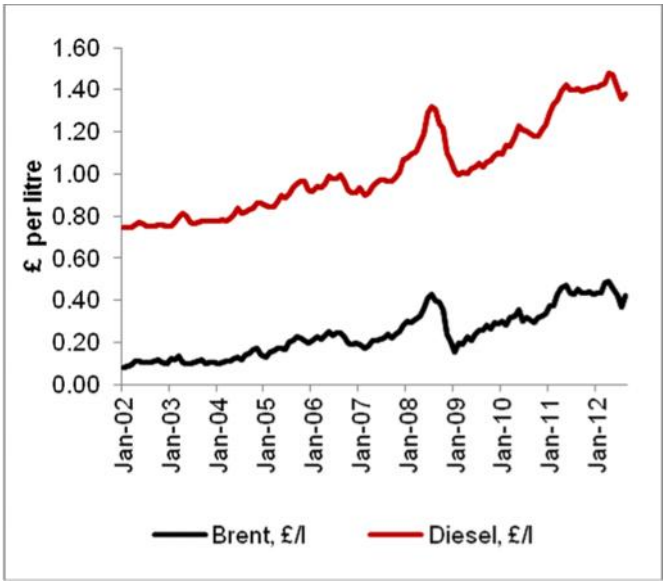
Introduction

In this short study, we assess the macro-economic impact of government plans to increase the rate of fuel duty from 1st January 2013. The assessment is carried using the National Institute's Global Econometric Model, NiGEM. We use the methodology developed by Bagaria, Holland and Van Reenen (2012) to allow for the current depressed state of the UK economy, which will amplify and prolong the effects of any fiscal tightening measures introduced in the near term. We also consider some alternative policy options in relation to fuel duty.

Fuel duty in the UK in context

High crude oil prices are often held responsible for high pump prices, especially following events such as political tensions in the Middle East, supply and demand imbalances and changes in OPEC policies and views. Figure 1 plots together the price of Brent crude oil on the open market and diesel pump prices in the UK since 2002. The similarity in the behaviour of the two time series is striking, with pump prices strongly correlated with crude oil prices. Yet, Delannoy (2012) shows that variations in crude oil prices explain only about half of historical diesel price movements at the pumps.

Figure 1. Brent spot (free on board) and UK diesel pump prices



Source: Datastream

Note: Monthly averages. One barrel of Brent = 159 litres. Dollar Brent prices converted using Bank of England GBP to USD exchange rate.

Whilst considering other factors to explain the variations in pump prices, the analysis shows that the various costs and margins involved in the production and distribution chain of road fuels have a relatively small impact on pump prices. Table 1 describes the decomposition of UK pump prices in 2011, highlighting the shares of each element into the final price. High pump prices in the UK, as in the rest of Europe, primarily reflect taxes imposed by the governments involved, *i.e.* the government in the oil producing country and the one in the fuel consuming country. The UK is both a major producer and consumer of oil, allowing the government to raise revenues from both the production and consumption of many petroleum products domestically consumed. Overall, in 2011, the UK government collected on average almost three-quarters of diesel pump prices in tax revenues, most of which was collected at the consumption stage of the market.

Table 1. Breakdown of the UK diesel pump price in 2011

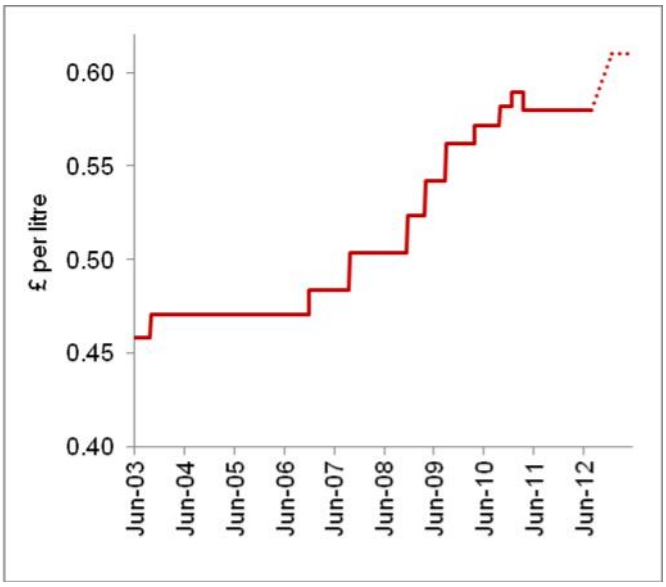
Pence per litre of diesel		**2011**	**%**
Consumption:	Pump price	138.2	
	VAT	23.0	16.7
	Fuel duty	58.2	42.1
M&D:	Marketing & Distribution	5.8	4.2
Refining:	Refining operating costs	1.1	0.8
	Refining profit margin	6.1	4.4
Transportation:	Freight	0.4	0.3
Production:	Production costs	20.1	14.5
	Petroleum revenue tax	11.8	8.5
	Ring-fenced corporate tax	3.5	2.6
	Supplementary charge	3.8	2.7
	Producers' profit margin	4.5	3.2

Source: Delannoy (2012)

The UK taxation on fuel consumption is composed of two elements: a fuel duty, *i.e*. a fixed excise tax per litre of fuel consumed, and the standard value-added tax (VAT) rate. The fuel duty rose steadily from 45.8 pence per litre in 2001 to 58.9 pence in January 2011 (see figure 2). In his Budget statement in March 2011, Chancellor George Osborne announced a temporary 1 penny cut in the main rate of road fuel duty, and a suspension of the previous Government's duty escalator, while raising the supplementary charge paid by North Sea oil and gas producers from 20 to 32 per cent. A 3.02 pence rise in duty (5.2 per cent) was scheduled to come into force in January 2012, raising the duty to 60.97 pence per litre of fuel, followed by an inflation-only rise in August 2012 (Seely, 2012). Yet, in a move to support the economy, the government revised this decision and announced in its Autumn Statement of 2011 that the 3.02 pence rise would be deferred from January 2012 to August 2012, while

the inflation-related increase was scrapped altogether[1]. As the economy continued to weaken, the government subsequently decided to further delay the 3.02 pence rise in fuel duty by 5 months, which is now expected to come into force from January 2013[2].

Figure 2. Fuel duty on diesel and unleaded petrol



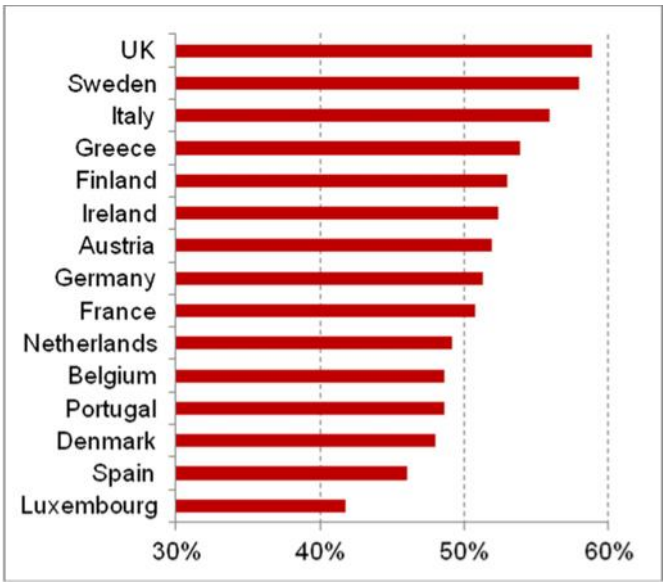
Source: DECC (2012a)

Note: The dotted line represents the 3.02 pence planned rise from January 2013

Focussing on diesel fuels, which represent the majority of the UK road fuel demand in volume, British taxes on diesel fuel consumption averaged 59 per cent of pump prices in June 2012 (Figure 3). It has fallen significantly in percentage terms since 2003, when the tax share on diesel prices reached 74 per cent. This reflects the significant rise in crude oil prices over the period. Concerning unleaded petrol, the tax-share reached 61 per cent in June 2012, slightly higher than for diesel fuels, as unleaded pre-tax prices are cheaper than diesel pre-tax prices, while the fuel duty on both is the same. In both cases, the UK has the highest tax share in Europe (EU-27), as shown in Figure 3. More strikingly, despite being amongst the cheapest countries in Europe when it comes to diesel pre-tax prices, over the last decade British drivers have consistently paid the highest pump prices after accounting for the fuel duty and VAT (Figure 4).

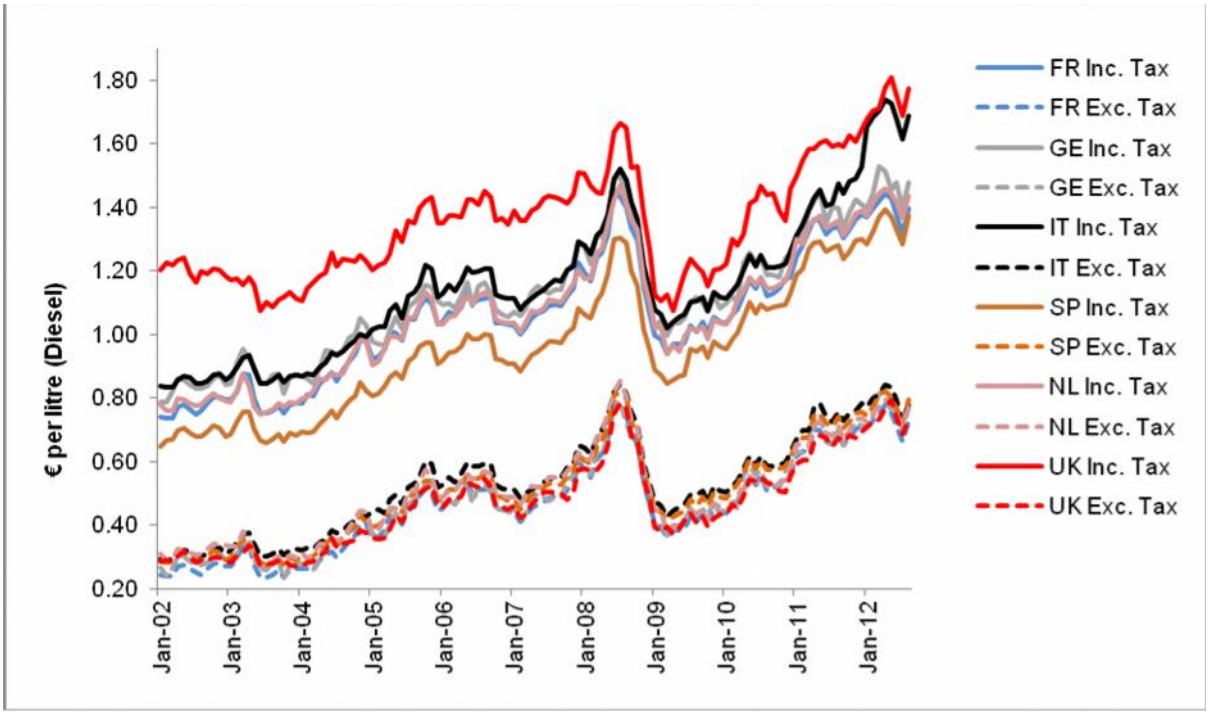
[1] http://www.hmrc.gov.uk/budget2012/ootlar-rates.pdf
[2] http://www.hmrc.gov.uk/tiin/new-clause-fuel-duty.pdf

Figure 3. Consumption tax share in diesel pump prices (Jun-12, EU-15)



Source: DECC (2012b), table 5.2.1.

Figure 4. Historical diesel prices excluding and including fuel consumption taxes in France, Germany, Italy, Spain, the Netherlands and the UK



Source: Datastream

Due to the nature of the fuel duty, which is applied on pre-tax pump prices, prior to VAT, a 3.02 pence hike in the duty simultaneously adds 0.604 pence (20 per cent) per litre of fuel consumed in VAT receipts, resulting in a total increase of 3.62 pence per litre of fuel at the pump, effective from the 1st January 2013. This will further strain households, especially

those with the lowest income, as their fuel expenditure represents about 7½ per cent of their total expenditure 2010 estimate (DECC, 2012c). The rise in fuel duty may also be further exacerbated if pre-tax pump prices rise simultaneously, notably following a rise in crude oil prices on the international markets. Naturally, consumers cannot expect much support from the oil producers and refiners in order to relieve the inflationary pressures caused by fuel prices, as their pricing strategy reflects market conditions and profit maximisation. The government is the only agent who may have an incentive and the capacity to mitigate any increases in pump prices in a significant manner. Yet, the solution is not that simple, as oil prices and fuel consumption are also key elements in wider issues such as government revenues for policy-making, as well as energy and environmental issues. Last year, the fuel duty alone contributed 1.8 per cent of GDP, and was the fifth biggest contributor to the government tax revenues after income taxes, national insurance contributions, VAT receipts and corporation tax receipts (OBR, 2012).

Model-based simulations

In this section we analyse the expected macro-economic impact of the planned rise in fuel duty that is scheduled to come into force in January 2013. We then go on to look at alternative policy options for fuel duty, which could be used to stimulate the economy in the short-term. The analysis is carried out using the National Institute's Global Econometric Model, NiGEM. A description of the core features of the model are reported in the Appendix, as well as the specific details underlying the modelling assumptions behind the four scenarios that we present below.

Impact of a 3 pence rise in fuel duty from 1 January 2013

Like all fiscal tightening measures, a rise in fuel duty will have a negative impact on output and employment in the short-term. Bagaria, Holland and Van Reenen (2012) demonstrate that the negative impacts of any fiscal tightening measures introduced at the current juncture, when output remains 4½ per cent below its pre-recession peak of 2008 and the unemployment rate is high, are likely to be significantly greater than they would be were the policy delayed until the economy has recovered from the current downturn. Their estimates suggest that the negative impacts on output and employment of introducing the rise in fuel duty in January 2013 may be more than double the effects that would be expected if the policy were delayed. The increase in the amplitude of the effects of fiscal policy innovations on output and employment comes through three channels: interest rates are currently close to zero, and there can be little monetary stimulus to offset the fiscal tightening; due to the ailing banking sector and weak economic prospects both within the UK and in our major EU trading partners, a high number of households and firms find themselves 'liquidity

constrained', or unable to borrow funds to smooth their consumption and investment spending; long spells of depressed output and high unemployment can lead to 'hysteresis', or a decline in the probability of becoming re-employed after an extended period of unemployment. In the three scenarios we report below, we take account of all three of these factors. The interest rate channel is somewhat different in relation to a fiscal tightening enacted through an indirect tax rate rise than through other fiscal channels, as the associated rise in the price level tends to override the negative impact on output when the Central Bank follows a policy rule that includes an inflation target. Fiscal tightening through an indirect tax rate tends to put upward pressure on interest rates, whereas other fiscal instruments tend to induce a monetary loosening.

The channel of transmission of a rise in fuel duty to the macro-economy is as follows. Any increase in fuel duty raises prices, and therefore causes a fall in households' real spending power and reduces consumer spending. The demand for fuel itself is relatively inelastic to price changes in the short-term, so much of the decline in consumer spending will fall on other goods and services within the consumption basket. Lower consumer spending means that firms sell less, leading to bankruptcy and job losses, and putting further pressure on household income. Firms will curtail investment in response to the decline in demand until economic conditions improve. The fiscal position in the economy will improve in response to a rise in fuel duty, as fuel duty receipts rise. But this is partly offset by government revenue losses elsewhere, as the decline in consumer spending and employment income reduces VAT and income tax revenues. Over time, the economy will start to recover, as firms cut prices in response to the drop in demand, stimulating both domestic and external demand for their goods, and the rise in unemployment puts downward pressure on wages, encouraging firms to take on more employees. As Bagaria, Holland and Van Reenen (2012) demonstrate, this process of recovery can be expected to more prolonged than usual if the policy tightening is introduced when the economy is already exceptionally weak.

If consumers anticipate a rise in duty in the future, they can be expected to bring forward some consumption, in order to avoid the additional tax (see Barrell and Weale, 2009). This shifts some of the output from 2013 into 2012. While the scope for stockpiling of fuel is limited, it is not negligible, and we would expect some forward shift in expenditure from 2013 to 2012 as a result of the planned rise in fuel duty.

Table 2 illustrates the expected impact of a 3 pence rise in fuel duty in January 2013 on GDP, consumer spending, employment, inflation and the government budget position. Our estimates suggest that GDP growth will be 0.1 percentage point lower next year if this policy plan goes ahead than it would be if the rise in fuel duty were postponed (a loss of output equivalent to about £1 billion in 2009 prices), costing 35,000 jobs. The fiscal balance would

be expected to improve by about £880 million, or less than 0.1 per cent of GDP. Over the longer term these effects can be expected to dissipate, but the negative impact on growth is expected to persist into 2015, with a full recovery not anticipated for 6 years. These effects are prolonged due to the current depressed state of the economy.

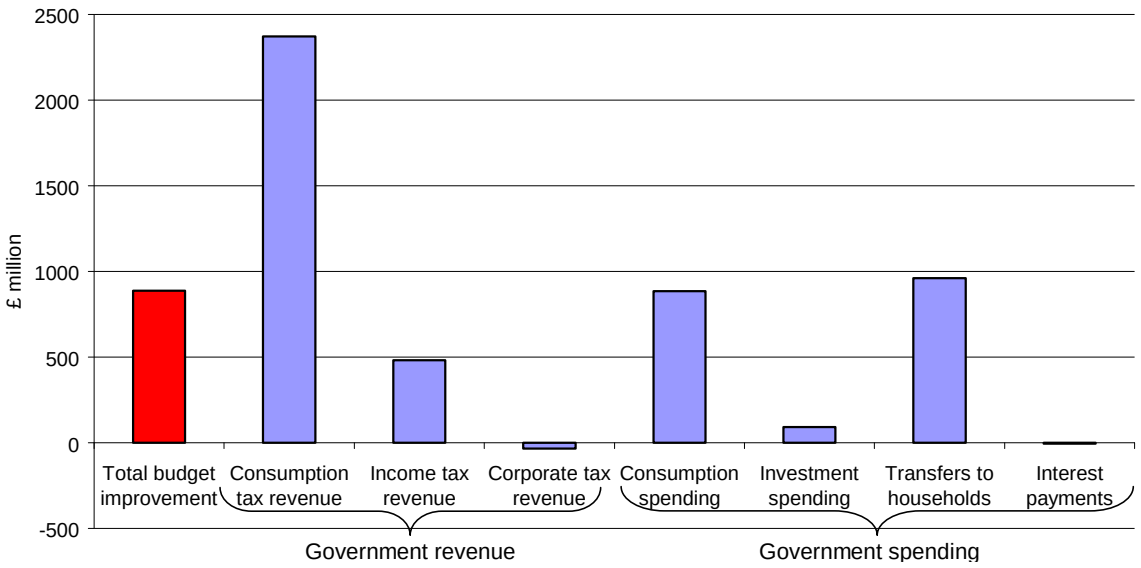
Table 2. Impact of 3 pence rise in fuel duty

	GDP, % diff. from base	Consumption, % diff. from base	Employment, abs diff. from base (1000s)	Inflation, abs diff. from base	Fiscal balance, per cent of GDP diff. from base	Budget balance, £Mn diff. from base
2012Q4	0.00	0.02	-10.98	0.00	-0.01	-40.34
2013Q1	-0.03	-0.03	-23.23	0.22	0.09	292.89
2013Q2	-0.07	-0.09	-28.82	0.27	0.08	220.53
2013Q3	-0.09	-0.11	-32.63	0.31	0.07	192.85
2013Q4	-0.11	-0.12	-35.93	0.32	0.07	180.71

Source: NiGEM simulations. See Appendix for detailed assumptions.

Figure 5 details the sources of the expected improvement in the government fiscal position. Consumption tax revenue would be expected to increase by more than £2 billion next year. This reflects both the rise in fuel duty revenue itself and the rise in the price level overall, which attracts additional VAT revenue on all goods, despite the decline in the volume of consumer spending overall.

Figure 5. Impact of 3 pence rise in fuel duty on government revenue and spending, 2013



Source: NiGEM simulations. See Appendix for detailed assumptions.

The impacts on other sources of government revenue are small. The slight rise in income tax revenue reflects the pass-through of higher inflation to wages, which offsets the job losses. However, the rise in unemployment and rise in the price level increase government spending on benefits as well as both consumption and investment spending, as the prices for most goods and services are set by the market rather than the government. The rise in spending offsets part of the rise in consumption tax revenue, so that total budget would be expected to improve by just £880 million.

The results reported in Table 2 are based on an underlying assumption that the Bank of England does not respond to the rise in inflationary pressures introduced by the rise in fuel duty by raising interest rates. However, the Bank may come under increasing pressure to tighten monetary policy as inflation rises. We expect the rise in fuel duty to raise headline inflation by about 0.3 percentage point next year. Last year's rise in the rate of VAT, combined with a sharp rise in the oil price, pushed inflation close to 5 per cent, which led to increasing calls for a response from the Bank of England[3]. If the added inflationary pressure were to lead to a monetary tightening, the negative impact of the rise in fuel duty on output and employment would be exacerbated. In table 3 we report the estimated impact on our key indicators, when the Bank of England follows a monetary policy rule that reacts to the rise in inflation. In this case, the effects of the rise in fuel duty are nearly doubled. The level of GDP would be expected to reach 0.2 per cent below base by the end of 2013 (a loss of output equivalent to more than £2 billion in 2009 prices), and more than 50,000 jobs would be lost.

Table 3. Impact of 3 pence rise in fuel duty with interest rate response

	GDP, % diff. from base	Consumption, % diff. from base	Employment, abs diff. from base (1000s)	Inflation, abs diff. from base	Fiscal balance, per cent of GDP diff. from base	Budget balance, £Mn diff. from base
2012Q4	-0.03	-0.02	-9.72	-0.03	-0.04	-167.79
2013Q1	-0.09	-0.10	-27.39	0.19	0.04	105.76
2013Q2	-0.15	-0.17	-40.89	0.25	0.01	-19.15
2013Q3	-0.17	-0.20	-50.62	0.30	-0.01	-77.04
2013Q4	-0.19	-0.22	-56.58	0.35	-0.01	-94.36

Source: NiGEM simulations. See appendix for detailed assumptions.

The government budget balance would be expected to worsen in 2013 rather than improve under this scenario, as the losses of revenue associated with weaker consumption and employment would outweigh the gains from higher fuel duty revenue. The impact on

[3] While there was increased pressure on the Bank of England to act, the Monetary Policy Committee takea more forward-looking view, and do not tend to respond to temporary inflationary factors.

inflation itself is negligible, as the speed of monetary policy feed-through to inflation is close to two years, with little impact in the first year.

Impact of a 3 pence cut in fuel duty from 1 January 2013

Contrary to the UK policy, some other countries are discussing policy measures aimed at reducing fuel costs for consumers, in an effort to stimulate the economy. The new French government is considering a temporary decline in fuel duty, while in the US policy makers are discussing options to release some strategic reserves in order to put downward pressure on the oil price itself. In this section we consider an alternative policy option, which would involve reversing the planned policy action, announcing that as of 1st January 2013, UK fuel duty will be cut by 3 pence rather than raised by 3 pence.

The expected impacts on key macro indicators of a 3 pence cut in fuel duty are reported in Table 4. The effects of a planned rise and planned cut in fuel duty are broadly symmetrical. In order to calculate the potential effects on the economy of changing policy plans from a 3 pence rise in fuel duty to a 3 pence cut in fuel duty, we would need to sum the effects reported in tables 2 and 4, as this effectively equate to a 6 pence cut in the expected rate of fuel duty, as the planned rise scheduled for January 2013 would not happen. Our estimates suggest that GDP growth next year will be 0.2 percentage points higher if fuel duty were cut by 3 pence, rather than raised by 3 pence (a rise of output equivalent to about £2 billion in 2009 prices), creating 70,000 jobs. The fiscal balance would be expected to worsen by about £1.8 billion, or less than 0.2 per cent of GDP.

Table 4. Impact of 3 pence cut in fuel duty

	GDP, % diff. from base	Consumption, % diff. from base	Employment, abs diff. from base (1000s)	Inflation, abs diff. from base	Fiscal balance, per cent of GDP diff. from base	Budget balance, £Mn diff. from base
2012Q4	0.00	-0.02	10.86	0.00	0.01	38.11
2013Q1	0.03	0.03	22.93	-0.21	-0.10	-300.17
2013Q2	0.07	0.09	28.58	-0.27	-0.08	-228.57
2013Q3	0.09	0.11	32.63	-0.30	-0.07	-201.18
2013Q4	0.11	0.12	36.23	-0.32	-0.07	-186.83

Source: NiGEM simulations. See appendix for detailed assumptions.

Impact of a temporary 10p cut in fuel duty, 1 January 2013-31 December 2013

The final scenario that we consider is a larger temporary stimulus measure, where we consider the impact of cutting fuel duty by 10 pence for one year. The expected impacts on key macroeconomic indicators of a 10 pence cut in fuel duty are reported in table 5. In order to calculate the potential effects on the economy of changing policy plans from a 3 pence rise in fuel duty to a temporary 10 pence cut in fuel duty, we would need to sum the effects reported in tables 2 and 5, as this effectively equates to a 13 pence cut in the expected rate of fuel duty next year, as the planned rise scheduled for January 2013 would not happen. Our estimates suggest that GDP growth next year would be 0.2 percentage point higher if fuel duty were cut by 10 pence, rather than raised by 3 pence (a rise of output equivalent to £2.3 billion in 2009 prices), temporarily creating 100,000 jobs. The fiscal balance would be expected to worsen by about £4.5 billion, or 0.4 per cent of GDP, but this effect would decline markedly when the temporary cut is lifted at the end of 2013. The effects are only slightly greater than in the previous scenario, when fuel duty was only cut by 3 pence. This is due to the temporary nature of the policy, and savings behaviour is adjusted in advance of the rise in inflation anticipated at the end of 2013. The permanent policy also changes the competitiveness of UK exports, as the exchange rate would be expected to depreciate in response to a permanent tax adjustment, stimulating exports in the short-term. We would not anticipate a similar reaction in the exchange rate in response to a temporary policy adjustment.

Table 5. Impact of 10 pence temporary cut in fuel duty

	GDP, % diff. from base	Consumption, % diff. from base	Employment, abs diff. from base (1000s)	Inflation, abs diff. from base	Fiscal balance, per cent of GDP diff. from base	Budget balance, £Mn diff. from base
2012Q4	-0.03	-0.06	39.15	-0.06	0.04	160.45
2013Q1	0.00	0.07	72.72	-0.77	-0.33	-1000.20
2013Q2	0.07	0.25	78.86	-0.97	-0.30	-828.55
2013Q3	0.11	0.29	76.77	-1.09	-0.30	-816.25
2013Q4	0.16	0.37	41.31	-1.06	-0.34	-994.71

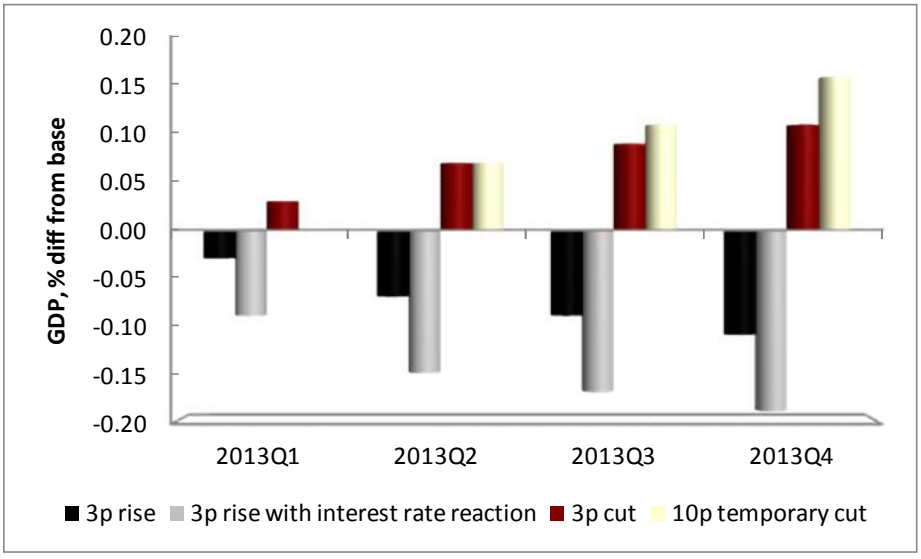
Source: NiGEM simulations. See appendix for detailed assumptions.

Summary of results

The figures below illustrate the expected effects of the four scenarios graphically. The planned rise in fuel duty that is scheduled to come into force in January 2013 is not expected to lead to a dramatic improvement in government finances, but should improve the fiscal deficit by about 0.1 per cent of GDP in 2013, or £880 million. Households will find their finances strained, and consumer spending will be about 0.1 per cent lower next year than we would expect if the fuel duty were left at its current rate. This is the dominant factor behind the expected loss of GDP, which is estimated to amount to about £1 billion (in 2009 prices) in 2013. However, if the rise in inflation were to induce the Bank of England to raise interest rates earlier than currently anticipated, the negative impact on consumers and GDP overall would be expected to be approximately doubled, and the policy could lead to job losses in excess of 50,000. The policy could even prove self-defeating as a budgetary consolidation measure under these conditions.

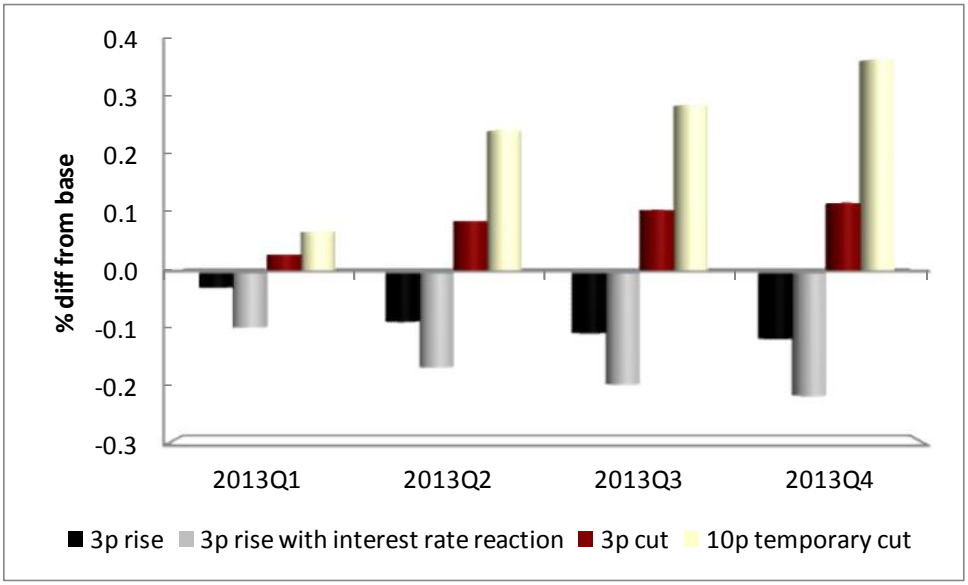
If instead of raising fuel duty the government were to introduce a temporary or permanent cut in fuel duty – in line with policies under discussion in France and the US – instead of exacerbating the economic downturn the policy could provide a small stimulus to the economy. Introducing a cut rather than a rise in fuel duty next year would be expected to raise growth by 0.2 percentage point in 2013 relative to current projections, or £2-£2.3 billion (in 2009 prices). The benefits of the stimulus would accrue predominantly to household, and could create 70,000 jobs. A large temporary stimulus would create additional jobs in the short-term, and we would expect consumer spending to rise by ½ per cent next year in response to a 10 pence temporary cut in fuel duty.

Figure 6. Impact on GDP



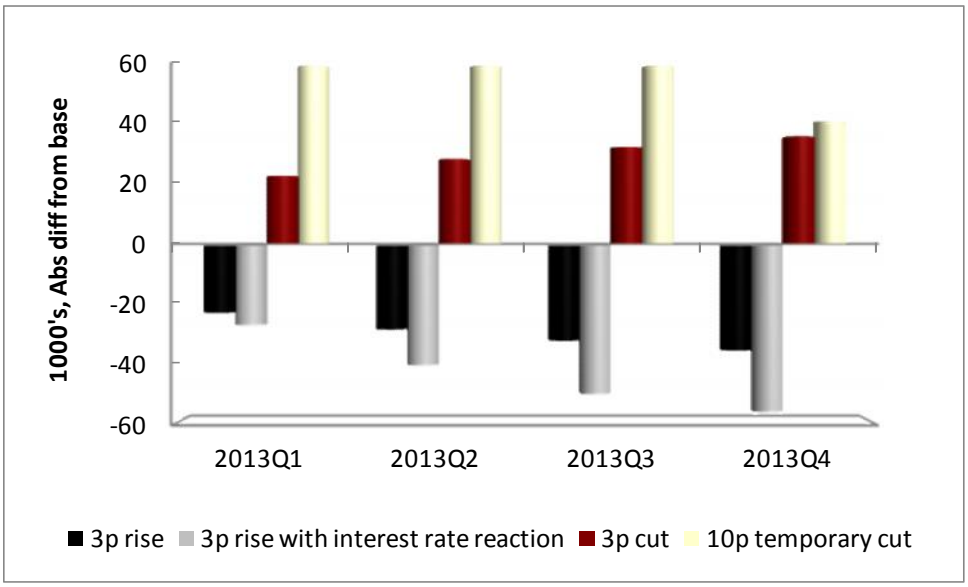
Source: NiGEM simulations. See appendix for detailed assumptions.

Figure 7. Impact on consumption



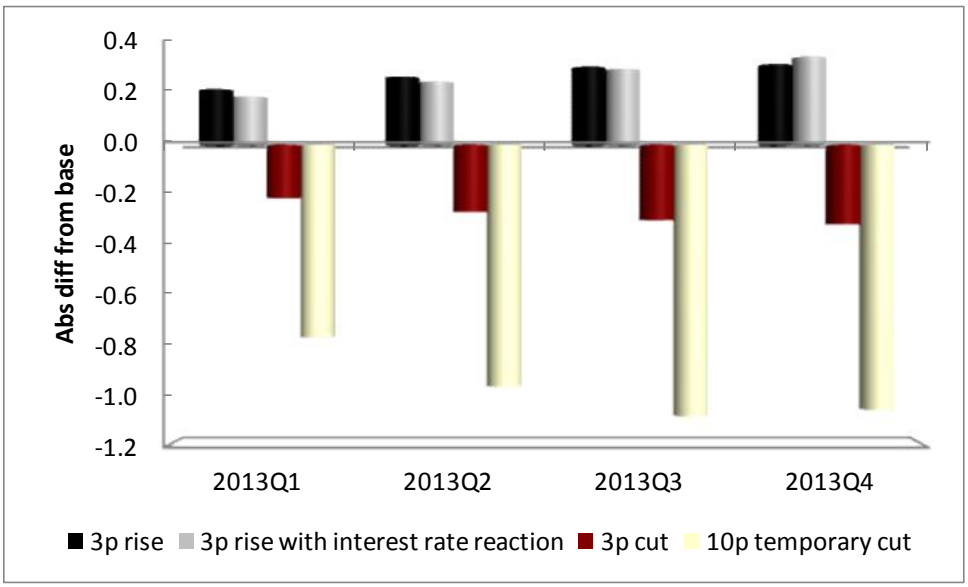
Source: NiGEM simulations. See appendix for detailed assumptions.

Figure 8. Impact on employment



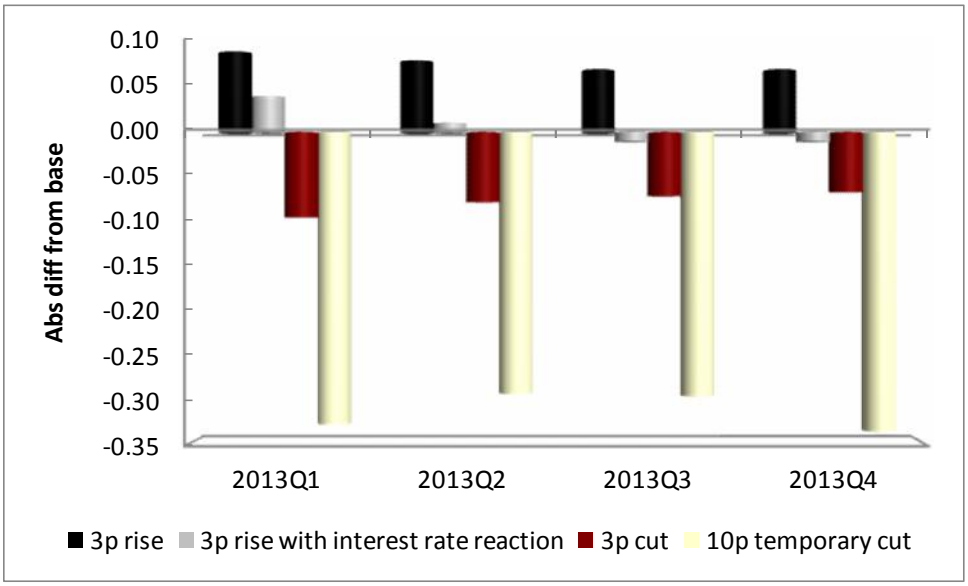
Source: NiGEM simulations. See appendix for detailed assumptions.

Figure 9. Impact on inflation



Source: NiGEM simulations. See appendix for detailed assumptions.

Figure 10. Impact on budget balance (% GDP)



Source: NiGEM simulations. See appendix for detailed assumptions.

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Appendix

The scenarios reported in the study were undertaken using the National Institute's Global Econometric Model, NiGEM. The NiGEM model has been in use at the National Institute for forecasting and policy analysis since 1987, and is also used by a group of about 40 model subscribers, mainly in the policy community, including the Bank of England, the FSA, the ECB, the OECD, the IMF and the central banks of France, Germany, Italy, Netherlands, Spain, Portugal, the Czech Republic, Hungary and Sweden. Below we review the core structure of the model, followed by a description of the detailed assumptions underlying each of the four scenarios presented in the paper.

NiGEM

The NiGEM model is essentially New-Keynesian in its approach, in that agents are presumed to be forward-looking, at least in some markets, but nominal rigidities slow the process of adjustment to external events. It has complete demand and supply sides, and there is an extensive monetary and financial sector. GDP (*Y*) is determined in the long run by supply factors, and the economy is open and has perfect capital mobility. The production function has a constant elasticity of substitution between factor inputs, where output depends on capital (*K*) and on labour services (*L*), which is a combination of the number of person in work and the average hours of those persons. Technical progress (*tech*) is assumed to be labour augmenting and independent of the policy innovations considered here.

$$Y = ¥(¢(K)^{-°} + (1-¢)(Le^{ª_L tech})^{-°})^{-1/°} \qquad (1)$$

We normally assume forward looking behaviour in production and because of 'time to build' issues investment depends on expected trend output four years ahead and the forward looking user cost of capital. However, the capital stock does not adjust instantly, as there are costs involved in doing so that are represented by estimated speeds of adjustment. The equilibrium level of unemployment is the outcome of the bargaining process in the labour market, as discussed in Barrell and Dury (2003), and the speed of adjustment depends on (rational) expectations of future inflation unless we use backward oriented learning. Financial markets normally follow arbitrage conditions and they are forward looking. The exchange rate, the long rate and the equity price will all 'jump' in response to news about future events. Fiscal policy involves gradually adjusting direct taxes to maintain the deficit on target, but we assume that taxes have no direct effect on the labour supply decision. Monetary policy involves targeting inflation with an integral control from the price level, as discussed in Barrell, Hall and Hurst (2006) and inflation settles at its target in all our simulations after a

period of adjustment. Some of the key features of the model that determine the outturns of the simulation studies are detailed further below.

Consumer behaviour

As Barrell and Davis (2007) show, both the level of total asset based wealth (ln(*TAW*) or ln(*NW*+*HW*)) and changes in financial (*d*ln(*NW*)) and especially housing wealth (*d*ln(*HW*)) will affect consumption (*C*)[4]. Their estimates suggest the impact of changes in housing wealth have five times the impact of changes in financial wealth in the short run, although long run effects are the same. Barrell and Davis (2007) also show that adjustment to the long run equilibrium shows some inertia as well. We may write our equation for *d*ln(*C*) as

$$\begin{aligned} d\ln(C_t) = {} & \alpha\{\ln(C_{t-1}) - [a + b_0 \ln(TAW_{t-1}) + (1-b_0)\ln(RPDI_{t-1})]\} \\ & + b_1 d\ln(RPDI_t) + b_2 d\ln(NW_t) + b_3 d\ln(HW_t) \end{aligned} \qquad (2)$$

where the long-run relationship between ln(*C*) and ln(*RPDI*) and ln(*TAW*) determine the equilibrium savings rate, and this relationship forms the long run attractor in an equilibrium correction relationship. The logarithmic approximation is explained in Barrell and Davis (2007).

In the presence of perfect capital markets and forward-looking consumers with perfect foresight, households will smooth their consumption path over time, and consumer spending will be largely invariant to the state of the economy or temporary fiscal innovations. However, some fraction of the population at any given time is liquidity constrained with little or no access to borrowing, so that their current consumption is largely restrained by their current income. Al Eyd and Barrell (2005) discuss borrowing constraints, and investigate the role of changes in the number of borrowing constrained households. The share of the population that is liquidity constrained will affect the short-term income elasticity of consumption, given by parameter b_1 from equation (2) above:

Cross-country differences in the average short-term income elasticity of consumption have a strong correlation with the tax multipliers, as highlighted by Barrell, Holland and Hurst (2012). However, access to credit is dependent both on credit history and on current income, and so is necessarily sensitive to the state of the economy. As unemployment rises, a greater share of the population will be unable to access credit at reasonable rates of interest – at precisely the moment when they are in need of borrowing to smooth their consumption path. This means that consumption is likely to be cyclical, and that b_1 is likely to be time varying and dependent on the position in the cycle. Following a banking crisis the effects can be

[4] Throughout *d* is the change operator and ln is the natural logarithm.

expected to be particularly acute, as banks tighten lending criteria, as discussed by Barrell, Fic and Liadze (2009). This also suggests that fiscal multipliers are dependent on the state of the economy – especially tax innovation multipliers – and this is consistent with recent studies such as Delong and Summers (2012) and Auerbach and Gorodnichenko (2012).

Following the approach in Bagaria, Holland and Van Reenen (2012), we modify the parameter b_1 in our analysis to allow for the heightened liquidity constraints currently present in the UK economy.

Prices

Consumer prices (CED) are modelled as a dynamic weighted average of unit costs of production and import prices, adjusted by the indirect tax rate, which includes fuel duty. A policy shift that involves changing the indirect tax rate, therefore, has a direct impact on the price level. Unit costs of production (*UTC*) are derived from the cost minimization problem around the underlying production function, given by:

$$\text{Minimize } C = WL + rK \tag{3}$$

$$\text{s.t. } Y = ¥(¢(K)^{-°} + (1-¢)(Le^{ª_L tech})^{-°})^{-1/°} \tag{4}$$

where the factors of production L and K are associated with factor prices W (wages) and r (user cost of capital).

The first order conditions of the cost minimization problem give the optimal input ratio, which can be substituted into the production function to derive the cost minimizing levels of factor inputs to produce a given level of output. We use the assumption that firms operate on their factor demand curves, at least in the long-run, which leads to the following expression for marginal costs:

$$\ln(MC) = ¯_1 + \ln(W) - (1+°)\ln\left(\frac{Y}{L}\right) + °ª_L tech \tag{5}$$

$$\text{where } ¯_1 = °\ln(¥) - \ln(1-¢) \tag{6}$$

We treat marginal cost as a shadow price, whereas observed basic prices (*P*) incorporate an endogenous mark-up, which we model as a function of the output gap.

Government sector

In order to evaluate multipliers we need a reasonably disaggregated description of both spending and tax receipts. We model corporate (*CTAX*) and personal (*TAX*) direct taxes and

indirect taxes (*MTAX*) on spending, along with government spending on investment (*GI*) and on current consumption (*GC*), and separately identify transfers (*TRAN*) and government interest payments (*GIP*). Each source of taxes has an equation applying a tax rate to a tax base (profits, personal incomes or consumption). As a default, we have government spending on investment and consumption rising in line with trend output in the long run, with delayed adjustment to changes in the trend. They are re-valued in line with the consumers' expenditure deflator (*CED*). Government interest payments are driven by a perpetual inventory of accumulated debts. Transfers to individual are composed of three elements, with those for the inactive of working age and the retired depending upon observed replacement rates. Spending less receipts is the budget deficit (*BUD*), which flows onto the debt stock.

$$BUD = CED*(GC+GI)+TRAN+GIP-TAX-CTAX-MTAX \quad (7)$$

We have to consider how the government deficit (*BUD*) is financed. We allow either money (*M*) or bond finance (*DEBT*).

$$BUD = d(M) + d(DEBT) \quad (8)$$

rearranging gives:

$$DEBT = DEBT_{t-1} + BUD - d(M) \quad (9)$$

In all policy analyses we use a tax rule to ensure that Governments remain solvent in the long run. The default rule is applied to the personal direct tax rate, which is adjusted endogenously to bring the government deficit into line with a specified target. This ensures that the deficit and debt stock return to sustainable levels after any shock. A debt stock target can also be implemented and we do that exercise below. The income tax rate (*TAXR*) equation is of the form:

$$TAXR = \text{f(target debt or deficit ratio - actual debt or deficit ratio)} \quad (10)$$

If the government budget deficit is greater than the target, (e.g. 3 per cent of GDP and the target is 1 per cent of GDP) then the income tax rate is increased.

Monetary policy

Interest rates are set by the monetary authority in relation to a targeting regime, where policy interest rates are set in relation to a rule that is normally forward looking. We distinguish two types of rules, those that target only inflation and those that target a nominal aggregate such as the price level or a nominal variable such as GDP or the money stock. During the Great

Moderation central bankers and many economists became convinced that they had changed the world they lived in by adopting simple feedback rules for monetary policy in combination with rules for fiscal policy that kept debt in bounds. The simple feedback rule was based on the Taylor Principal (TR) that when inflation increases the central bank should increase the interest rate more than in proportion to the rise in inflation, and hence the real interest rate would rise and help choke off demand. In a forward looking world it is possible to improve on this principal. If agents see the central bank as fully credible, then the announcement of a price level target (PLT), rather than just an inflation target, will stabilise fluctuations in output and in inflation. A price level targeting central bank will loosen policy more rapidly as it has to get the price level back to target. The converse will be true in a boom. We may encompass these two feedback rules in equation (11) below, with *int* being the intervention rate, *ssr* being the steady state (endogenous) real interest rate, *og* being the output gap, *inf* and *inft* being the inflation rate and the target, and *P* and *PT* being the price level and the target.

$$int_t = a_0 + a_1 ssr_t + a_2 og_t + a_3\left(inf_{t+1} - inft\right) + a_4\left(P_t - PT_t\right) \qquad (11)$$

In a Taylor rule a_0 is zero, a_1 is 1.0, a_2 is 0.5, a_3 is 1.5 and a_4 is zero, whilst in a PLT regime $a_{(1)}$ is zero, $a_{(2)}$ is also zero, and we set $a_{(3)}$ to 0.7 and $a_{(4)}$ to 0.4. The PLT rule has the advantage of working only on observables. The same is true of a Two Pillar strategy as discussed by the ECB. The bank responds to deviations of inflation from target and also deviations of a nominal aggregate (*NOM*) – the money stock for instance – as described in equation:

$$int_t = b_0 + b_1\left(inf_{t+1} - inft\right) + b_2\left(NOM_t - NOMT_t\right) \qquad (12)$$

Forward looking financial markets

A deflationary shock such as a fiscal tightening will have a weaker interest rate response under a Taylor Rule than under price level targeting, and both may be weaker than a Two Pillar rule. If actors know the rule is in place then they will form expectations of the future path of short rates, and this will cause the current long rate to change, along with the exchange rate and the equity price. Forward looking long rates (*LR*) should be related to expected future short term rates

$$\left(1 + LR_t\right) = \prod_{j=1}^{T}\left(1 + int_{t+j}\right)^{1/T} \qquad (13)$$

Forward looking equity prices (*EQP*) are related to future profits (*PR*) in a forward recursion where *eprem* is the equity premium

$$EQP_t = PR_t + \frac{EQP_{t+1}}{(1+int_t)(1+eprem_t)} \quad (14)$$

The exchange rate depends on the expected future path of interest rates and exchange rate risk premia, solving an uncovered interest parity condition, so that the expected change in the exchange rate is given by the difference in the interest earned on assets held in local and foreign currencies.

$$e_t = e_{t+1}\left(\frac{1+\text{int}^*_t}{1+\text{int}_t}\right)(1+rp_t) \quad (15)$$

where e_t is the bilateral exchange rate at time t (defined as domestic currency per unit of foreign currency), int_t is the short-term nominal interest rate at home set in line with a policy rule, int_t* is the interest rate abroad and rp_t is the exchange rate risk premium.

Further details on the NiGEM model are available on:
http://nimodel.niesr.ac.uk/logon/introduction.php

Core assumptions underlying simulations

We present four scenarios in this study. In each case a 'shock' is applied to the indirect tax rate (ITR), which includes both VAT and fuel duty. In order to calibrate the appropriate size of the shock to ITR, we use the following base data for the financial year 2010-11, updated with the most recent tax rates:

$$\frac{VAT^{non-fuel} + VAT^{fuel} + DUTY^{fuel}}{TaxableConsumption} \quad (16)$$

Where we split total VAT receipts as reported by the OBR, into VAT on fuel and non-fuel, based on DECC's information on total fuel consumption, the average pre-tax price of fuel and the average fuel duty paid per litre.

Table A1. Decomposition of VAT receipts, financial year 2010-11

Total VAT receipt (OBR)	**86.30**	**bn £**
Ave. Fuel Duty (DECC) - A	0.5786	£/litre
Fuel Consumption (DECC) - B	44.6997	bn litres
Ave VAT Rate (DECC) - C	18.08%	
VAT on fuel duty (A*B*C)	4.68	bn £
Average pre-tax price (derived from DECC) - D	0.4740	£/litre
VAT on pre-tax fuel prices (D*B*C)	3.83	bn £
VAT on fuel total	**8.51**	**bn £**
VAT on non-fuel consumption	**77.79**	**bn £**

Total taxable consumption is then derived as non-fuel consumption (VAT on non-fuel consumption divided by the VAT rate) and fuel consumption (total consumption in litres adjusted by the average pre-tax price per litre). The ratios were then updated to reflect current VAT and fuel duty rates. Shocks were calibrated by upgrading the specified rise in duty by the 20% VAT rate, adjusting by the total litres of fuel consumption, and adding this to the numerator of the ratio specified as equation (16). These calibrations lead to the following magnitude of shocks:

Table A2. Magnitude of shocks [a]

Scenario 1 and 2	3 pence rise in duty	ITR increased 0.36 percentage point
Scenario 3	3 pence cut in duty	ITR decreased 0.36 percentage point
Scenario 4	10 pence temporary cut in duty	ITR decreased by 1.19 percentage points for 4 quarters

a In all cases, the scenarios are run in relation to a baseline that assumes a constant rate of fuel duty going forward.

A common set of underlying assumptions was incorporated into all four scenarios:

- All scenarios were run starting in 2012q4, so planned changes in 2013q1 are anticipated by forward-looking agents
- The income tax rate is held fixed for the first two years (from 2012q4 to 2014q4) so there is no endogenous correction to the improvement/worsening of the fiscal position in the short-term (see discussion around equation (10) above).
- Consumers and firms are faced with heightened liquidity constraints. Following the approach in Bagaria, Holland and Van Reenen (2012), we allow for moderately high liquidity constraints, so assume that the number of liquidity constrained agents is roughly double what it is in normal times (see model 4 in the Appendix to Bagaria, Holland and Van Reenen (2012)).
- We use an augmented wage equation to allow for hysteresis effects, as described in Bagaria, Holland and Van Reenen (2012).

In scenarios 1, 3 and 4, monetary policy does not react to the changes in the economy for the first six quarters (from 2012q4 to 2014q1). From 2014q2, the Bank of England is assumed to follow a policy rule that responds to deviations of inflation from target and also deviations of a nominal aggregate as described in equation (11) above. In scenario 2, the interest rate is allowed to react over the full sample period, so rises immediately in response to the inflationary effects of the rise in fuel duty.