# Macroeconomic impacts of infrastructure spending

Report to

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**Non-technical synthesis**

The objective of this paper is to quantify the macroeconomic impacts of investment in infrastructure in the UK. Using the National Institute's global economy model NIGEM we conduct a series of simulations illustrating the effects of infrastructure investment on the UK economy both in the short and in the long run. We look at the impacts on output, potential output, unemployment and fiscal balances, distinguishing between normal times and periods of abnormal monetary and credit conditions). Our results show that investment in infrastructure boosts growth, both in the short run and, on plausible assumptions, in the long run. While the short-run impact is an increase in the deficit, over the long run there may be a reduction in the debt-GDP ratio. The results are robust to a number of sensitivity tests.



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## 1. Introduction

Successive governments have emphasised the importance of infrastructure investment (publicly and privately financed) for growth. The Green Book and the National Infrastructure Plan emphasise the importance of investing in infrastructure for the future growth and productivity of the UK economy and set out principles for the assessment of projects in the areas of transport, energy, water, waste, flood risk and coastal erosion, solid waste management and communications. They argue that investing in infrastructure (road and railway networks, building new flood defences, improving communications industry, moving towards a “greener” economy (reducing carbon intensity of energy generation, increasing recycling rates, etc.)), and supporting science and innovation infrastructure (investing in R&D, and strengthening the UK’s competitive advantage in areas such as big data and energy efficient computing, synthetic biology, and advanced materials) will ensure better foundations for a stronger, sustainable and more balanced economy.

Theory would indeed suggest that increased investment, whether public or private, should boost growth, and the bulk of the economic literature suggests that public investment in infrastructure boosts growth (Egert et al., 2009, Canning, Pedroni, 2008, Demetriades, Mamuneas, 2000, Kemmerling et al., 2000). In the long term, social returns on infrastructure investment appear to be relatively high. Demetirades and Mamuneas, 2000, also find that public capital has positive effects not only on output but also on input demands. Increased infrastructure investment is also likely to be positive for growth in the short run, since multiplier effects are larger for public investment than for other fiscal changes. Holland, Portes, 2012, Bagaria et al., 2012, and Barrell, Fic, Liadze, 2009 show that this is particularly true during a “crisis”; that is when monetary policy is constrained by the zero lower bound when more businesses and households are credit constrained, and when unemployment is high. This suggests that current UK circumstances should be particularly favourable to infrastructure investment.

However, while the literature provides qualitative assessments of risks and benefits of infrastructure investment (eg, Frontier Economics, 2012), or looks at strategies of investing in particular types of infrastructure (Eddington, 2006), it does not offer quantifications of the macroeconomic impacts of investment in infrastructure in the UK taking account of current economic conditions. This report fills this gap. We attempt to quantify the macroeconomic impacts of investment in infrastructure in the UK both in the short run, and in the long run. Using the National Institute’s global economy model NIGEM, we conduct a series of simulations illustrating the effects of increased infrastructure investment on the UK economy. We look at the impacts on output, potential capacity, unemployment, fiscal aggregates and inflation distinguishing between normal and "crisis" conditions (see Holland, Portes, 2012, Bagaria et al, 2012, Barrell, Fic, Liadze, 2009).

## 2. Scenarios

We design a series of simulations to illustrate the different impacts of investment in infrastructure and other types of investment using the National Institute's global model NIGEM (for a short description of the model, as well as its modifications see Annexes 1 and 2). We consider the following scenarios:

(i) Effects of a 1 per cent of GDP increase for two years (approximately £30 billion over two years) in infrastructure investment
(ii) Effects of a 1 per cent of GDP increase in private sector investment for two years (business investment and housing investment)
(iii) Effects of a 1 per cent of GDP increase in government consumption for two years (for comparison)

In each case, the increased expenditure is financed through borrowing rather than taxes.

We also allow for positive effects of infrastructure on growth that go beyond the direct effects of the increase in potential output. These encompass economies of scale, network externalities and enhanced competition (see Egert et al., 2009). We calibrate a shock to technological progress resulting from the extra investment. This allows us to study the impact of the following further scenario:

(iv) Effects of a 1 per cent of GDP increase in infrastructure investment allowing for network externalities and enhanced competition (resulting from better infrastructure)

The effects of network externalities and enhanced competition resulting from better infrastructure are approximated by a 0.05 per cent shock to technological progress, spread over 5 years. It is difficult to estimate the impactof better infrastructure on productivity; we calibrate the size of the shock based on the available literature on estimates of the role of public capital stock for potential growth (IMF, 2010), and estimates of the impact of infrastructure on growth (Egert et al., 2009). However, while we believe the magnitude is realistic and plausible, this is clearly a matter of judgement; in practice the impact would depend on the nature and quality of the investment ("bridges to nowhere" are unlikely to represent technological progress; increased aviation capacity probably would). For illustration, it equates to a rate of return on investment of approximately [2.5 per cent] real, below the normal hurdle rate for government investment

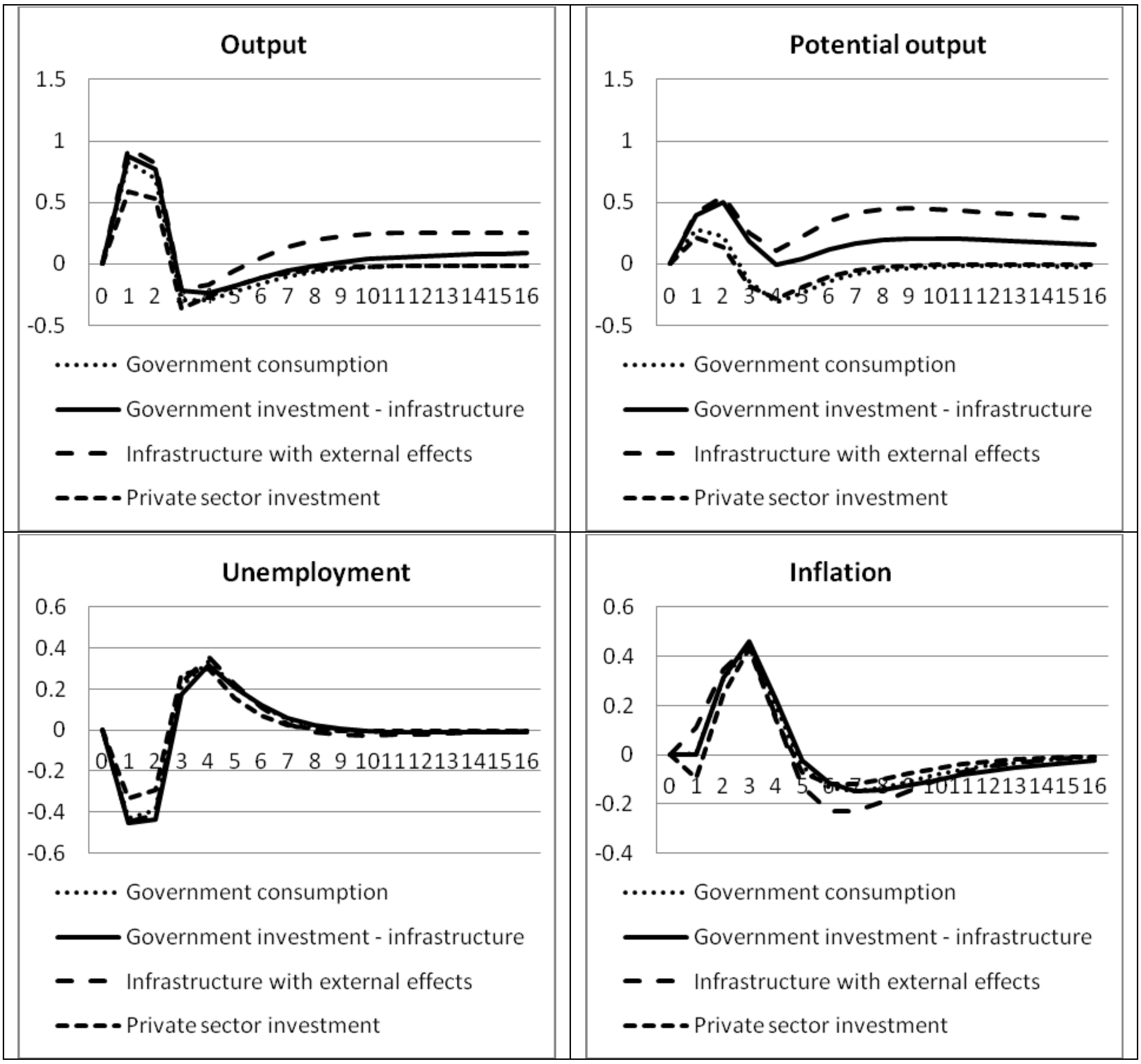
In all scenarios we assume that the infrastructure shock is temporary and lasts for 2 years, after which the shocked variables return to base. We consider two regimes: normal times and a crisis period, defined as a period of impaired functioning of the banking system resulting in higher liquidity constraints faced by both households and businesses.

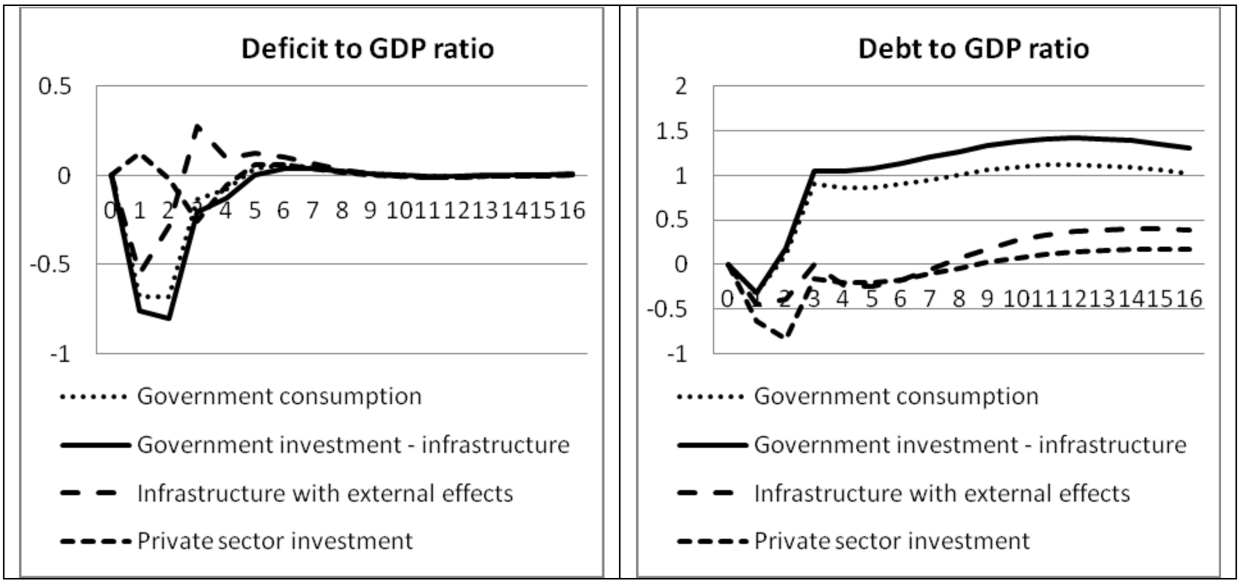
## 3. The impact of infrastructure on the UK economy

### *3.1. Normal times*

We simulate the four scenarios as described above using the National Institute’s global economy model NIGEM (for a short description of NIGEM see Annex 1). Figure 1 shows the results. We look at key macroeconomic indicators such as GDP and potential output (per cent deviations from baseline), unemployment and inflation (absolute deviations from baseline), and budget deficit and public debt to GDP ratio (absolute deviations from baseline).

Figure 1. Effects of infrastructure investment in normal times






Note: We show per cent deviations from baseline for output and potential output and percentage point deviations from baseline for inflation, unemployment, deficit to GDP ratio and debt to GDP ratio - over time (in years).

The simulations suggest that the economy would benefit significantly from investment in infrastructure both in the short and in the long run. Compared with private sector investment orincreased government consumption spending, public investment in infrastructure has a larger short-run impact, since the resulting increase in imports is smaller.  In all cases unemployment falls and inflation rises in the short term; these effects are transitory and are reversed relatively quickly after the stimulus is withdrawn.  Unsurprisingly, increased government spending boosts debt and deficits in the short run, and raises debt-GDP levels in the long run, although this increase is smaller than the magnitude of the increase in spending. These results are quantitatively and qualitatively similar to those found by Oxford Economics in their modelling of a similar policy experiment in the IFS Green Budget (Emmerson et al. 2012), suggesting that they are not dependent on the particular macroeconomic model employed.

However, when we take into account the impact of infrastructure spending on total factor productivity, the results are somewhat different: there is a significant permanent rise in the level of output, and essentially no impact on the long-run debt-GDP ratio; the increase in output and hence tax revenues mean that over the longer term increased public infrastructure spending essentially pays for itself, although, as noted above, this result depends on the infrastructure investments delivering economic benefits.

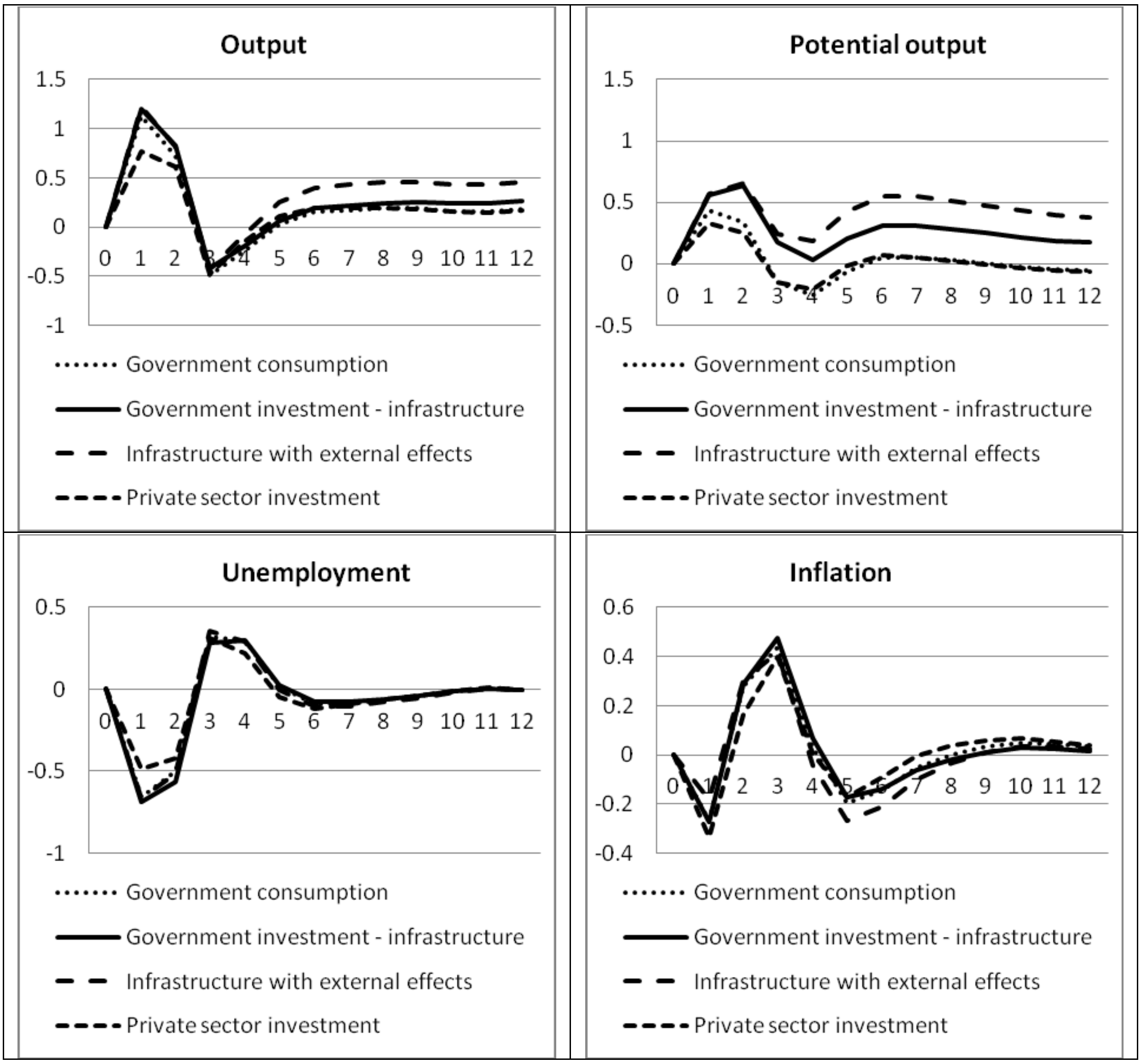
### *3.2. Crisis times*

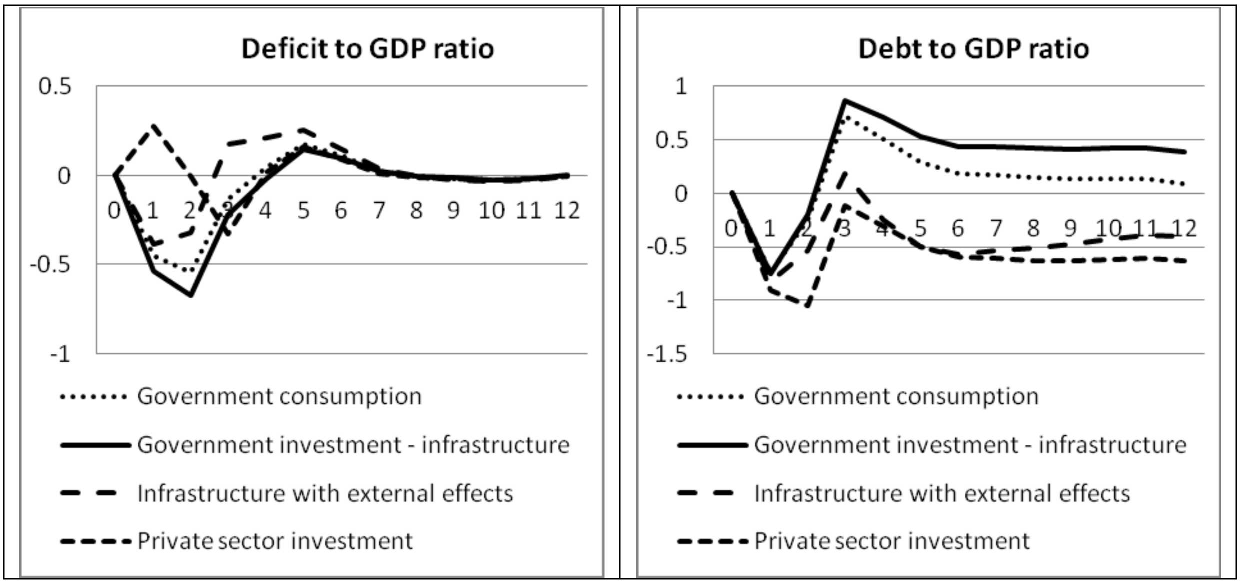
In a banking crisis, households and business are liquidity constrained. They have little or no access to borrowing, and face both higher than normal borrowing costs and an inability to borrow even at these costs (Barrell, Fic, Liadze, 2009). In effect their spending is restrained by the current income. In these circumstances the macroeconomic impact of increases in government spending ("fiscal multipliers") will be higher than normal, reflecting the fact that government spending does not "crowd out" private spending to the same extent that it would in normal times (Eggertson, Krugman, 2012).

This scenario assumes that both households and enterprises are significantly more liquidity constrained than in normal times. This implies that both households as well as businesses to a larger extent base their spending decisions on available income. Technical assumptions (concerning modifications of our consumption and capital stock equations) that capture the constraints on liquidity are described in Annex 3.

We conduct the same four simulations as in the scenario "normal times". Figure 2 presents the results.

Figure 2. Effects of infrastructure investment in crisis times.





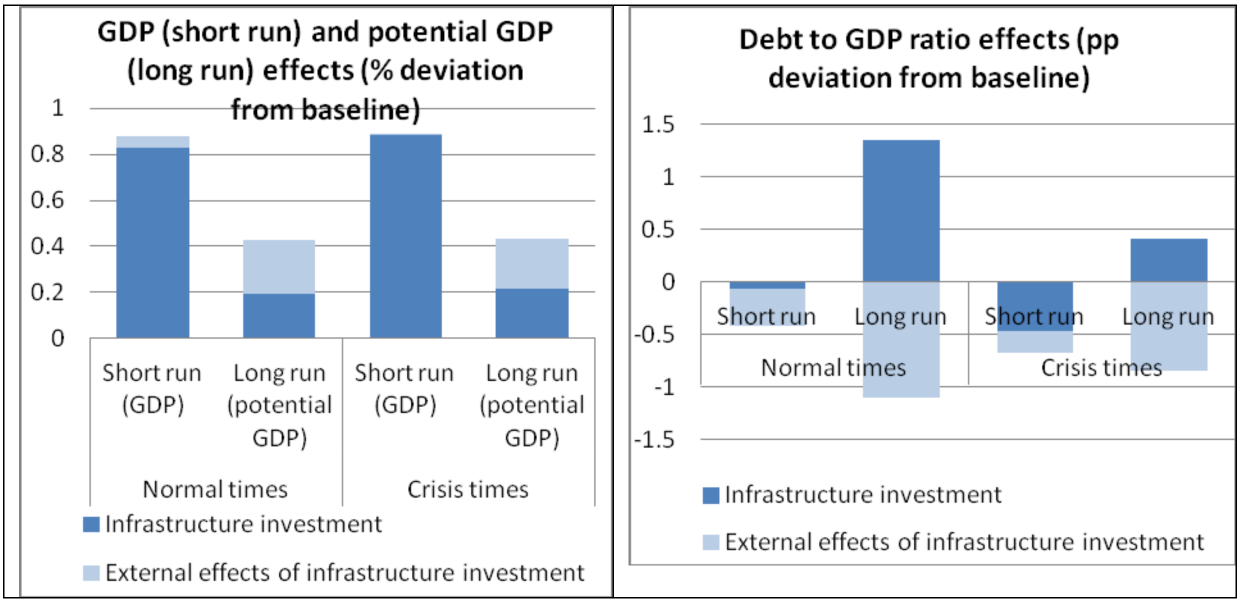

Note: We show per cent deviations from baseline for output and potential output and percentage point deviations from baseline for inflation, unemployment, deficit to GDP ratio and debt to GDP ratio - over time (in years).

The pattern of responses is qualitatively similar to the "normal times" scenario, however, the scale of the impact on output, in particular in the case of infrastructure investment, reflecting the absence of "crowding out" effects. As a result the impacts on the public finances are more benign; in particular, we now observe a modest decrease in the long-run debt GDP ratio as a result of the short-run increase in infrastructure investment.

## 4. Policy results – impacts on output and public finances

Our simulations show that increasing infrastructure investment in the UK has the potential to boost growth both in the short and long run (for a detailed sensitivity analysis see Annex 4). The impacts are even stronger in a crisis, as compared to normal times. Figure 4 compares the short and the long run GDP impacts of infrastructure investment in normal times and in a crisis (the short run is defined as the first two years after the shock starts, the long runs is defined as eight to sixteen years after the shock (by when most of the medium term movements are smoothed out)).

Figure 4. Long- and short run impacts of infrastructure on output and debt




Note: The short run defined as the first two years, the long run as eight to sixteen years

The simulations show that investing in infrastructure brings effects both in the short run, and in the long run. A 1 per cent of GDP increase in investment in infrastructure results in an increase in GDP of a little under 1 percent in the short run, and increases potential GDP by about 0.2 percent in the long run. Our assumptions about the impact on total factor productivity would add to potential GDP about another 0.2 per cent in the long run.

In terms of the impacts on public finances, the simulations suggest that investing in infrastructure in times of a crisis has a relatively low short-term cost, and may even lower the debt-GDP ratio over the longer run, as the positive impact of increased output on tax revenues largely offset, and may even outweigh, the initial extra spending. This materialises particularly in a crisis environment, when both households and businesses face tight credit conditions. This result is similar to that found by DeLong and Summers (2012) - fiscal expansion may be self-financing over the long run – although our mechanism (the impact on increased investment on long run output) is a specific case of theirs.

## 5. References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## 6. Annexes

### Annex 1. NIGEM description

For a macroeconometric model to be useful for policy analyses, particular attention must be paid to its long-term equilibrium properties. At the same time, we need to ensure that short-term dynamic properties and underlying estimated properties are consistent with data and well-determined. As far as possible the same long run theoretical structure of NiGEM has been adopted for each of the major industrial countries, except where clear institutional or other factors prevent this. As a result, variations in the properties of each country model reflect genuine differences in data ratios and estimated parameters, rather than different theoretical approaches.

*Production and price setting*

The major country models rely on an underlying constant-returns-to-scale CES production function with labour-augmenting technical progress.

$$Q = \gamma\left[s(K)^{-\rho} + (1-s)(Le^{\lambda t})^{-\rho}\right]^{-1/\rho} \qquad (1)$$

where Q is real output, K is the total capital stock, L is total hours worked and t is an index of labour-augmenting technical progress. This constitutes the theoretical background for the specifications of the factor demand equations, forms the basis for unit total costs and provides a measure of capacity utilization, which then feed into the price system. The elasticity of substitution is estimated from the labour demand equation, and in general it is around 0.5. Demand for labour and capital are determined by profit maximisation of firms, implying that the long-run labour-output ratio depends on real wage costs and technical progress, while the long-run capital output ratio depends on the real user cost of capital

$$Ln(L) = \left[\sigma \ln\{\beta(1-s)\} - (1-\sigma)\ln(\gamma)\right] + \ln(Q) - (1-\sigma)\lambda t - \sigma \ln(w/p) \qquad (2)$$

$$Ln(K) = \left[\sigma \ln(\beta s) - (1-\sigma)\ln(\gamma)\right] + \ln(Q) - \sigma \ln(c/p) \qquad (3)$$

where w/p is the real wage and c/p is the real user cost of capital. The user cost of capital is influenced by corporate taxes and depreciation and is a weighted average of the cost of equity finance and the margin adjusted long real rate, with weights that vary with the size of equity markets as compared to the private sector capital stock. Business investment is determined by the error correction based relationship between actual and equilibrium capital stocks.

Government investment depends upon trend output and the real interest rate in the long run. Prices are determined as a constant mark-up over marginal costs in the long term.

*Labour market*

NiGEM assumes employers have a right to manage. Hence the bargain in the labour market is over the real wage. Real wages, therefore, depend on the level of trend labour productivity as well as the rate of unemployment. Labour markets embody rational expectations and wage bargainers use model consistent expectations. The dynamics of wage-setting depend upon the error correction term in the equation, the split between lagged inflation and forward inflation, and the impact of unemployment on the wage bargain. There is no explicit equation for sustainable employment in the model, but as the wage and price system is complete the model delivers equilibrium levels of employment and unemployment. An estimate of the NAIRU can be obtained by substituting the mark-up adjusted unit total cost equation into the wage equation and solving for the unemployment rate. Labour supply is determined by demographics, migration and the participation rate.

*Consumption, personal income and wealth*

Consumption decisions depend on real disposable income and real wealth in the long run, and follow the pattern discussed in Barrell and Davis (2007). Total wealth is composed of financial and tangible (housing) wealth where the latter data is available.

$$\ln(C) = \alpha + \beta \ln(RPDI) + (1-\beta)\ln(RFN + RTW) \tag{4}$$

where $C$ is real consumption, $RPDI$ is real personal disposable income, $RFN$ is real net financial wealth and $RTW$ is real tangible wealth. The dynamics of adjustment to the long run are largely data based, and differ between countries to take account of differences in the relative importance of types of wealth and of liquidity constraints.

*Financial markets*

We generally assume that exchange rates are forward looking, and ‘jump’ when there is news. The size of the jump depends on the expected future path of interest rates and risk premia, solving an uncovered interest parity condition, and these, in turn, are determined by policy rules adopted by monetary authorities:

$$RX(t) = RX(t+1)[(1+rh)/(1+ra)](1+rprx) \tag{5}$$

where $RX$ is the exchange rate, $rh$ is the home interest rate set in line with a policy rule, $ra$ is the interest rate abroad and $rprx$ is the risk premium. We assume that bond and equity markets are forward looking, and long-term interest rates are a forward convolution of expected short-term interest rates. Forward looking equity prices are determined by the discounted present value of expected profits.

*Public sector*

Each country has a set of equations for the public sector. Direct and indirect taxes depend upon their respective tax bases and on the tax rate. Government spending on current goods and services and investment spending depend in part on current plans, and by default rise with trend output. Transfer payments depend upon unemployment and the dependency ratio as well as on policy. Government interest payments are determined by a perpetual inventory model based on the flow deficit and the stock of debt, with the appropriate structure of short and long-term interest payments on the debt stock. Budget deficits are kept within bounds in the longer term (Barrell and Sefton, 1997) through a targeted adjustment on income tax rates.

*External trade*

International linkages come from patterns of trade, the influence of trade prices on domestic price, the impacts of exchange rates and patterns of asset holding and associated income flows. The volumes of exports and imports of goods and services are determined by foreign or domestic demand, respectively, and by competitiveness as measured by relative prices or costs. The estimated relationships also include measures to capture globalization, European integration and sector-specific developments. Exporters are assumed to compete against others who export to the same market and domestic producers via relative prices; demand is given by a share of imports in the markets to which the country has previously exported. Imports depend on import prices relative to domestic prices and on domestic total final expenditure. As exports depend on imports, they will rise together in the model. The overall current balance depends upon the trade balance and net property income from abroad, comprising flows of income on gross foreign assets and outgoings on gross foreign liabilities. Gross national product is GDP plus net factor income from foreigners.

## Annex 2. NIGEM extensions/modifications

We modify the model to account for different impacts of infrastructure and other forms of investment. We re-estimate the import equation with respect to elasticities of imports to different components of total final expenditure and obtain the following equation (both the long run and the short run is re-estimated):

$$\ln(MVOL) = \ln(MVOL(-1)) \underset{(3.85)}{-2.02} - \underset{(4.46)}{0.33} *[\log(MVOL(-1)) + \underset{(2.06)}{0.15} *\ln(RPM(-1)) +$$

$$\underset{(9.89)}{-0.91} *\ln(C(-1)+PSI(-1)+DS(-1)) \underset{(2.24)}{-0.16} *\ln(GC(-1)+GI(-1)) \underset{(6.89)}{-0.39} *\ln(XVOLM(-1))]$$

$$- \underset{(1.83)}{0.13} *\ln(RPM / RPM(-1)) + \underset{(8.6)}{0.85} *\ln((C+PSI+DS)/(C(-1)+PSI(-1)+DS(-1)))$$

$$+\underset{(2.0)}{0.20} *\ln((GC+GI)/(GC(-1)+GI(-1))) + \underset{(10.04)}{0.43} *\ln(XVOLM/XVOLM(-1)) +$$

$$- \underset{(1.61)}{0.002} *DUTY$$

Where:
*MVOL – import volume; RPM – real import prices; C – private sector consumption; PSI – private sector investment; DS – stockbuilding; GC – government consumption; GI – government investment; XVOLM – exports of goods and services; DUTY – import tariff*

Sample: 1986q1-2012q4; Adj. R-sq. 0.72

We run a battery of sensitivity tests and find that the simulation properties of the model are satisfactory (the equation behaves well in the model).

## Annex 3. Liquidity constraints technical assumptions

The degree of liquidity constraints faced by both individuals and firms, is illustrated in table 1. We modify consumption and capital stock equations in NIGEM to reflect the increased liquidity constraints. In particular, we modify parameters (income elasticity and capital output elasticity) in our consumption and capital stock equations. Wassume that the share of liquidity constrained households increases from 0.17 to about 0.5. We assume that the short run capital-output elasticity of business and housing capital stocks goes up from 0.042 to 0.071 and from 0.015 to 0.026, respectively (for the basis for these assumptions, see Holland, Portes, 2012) – see table A3.

Table A3. Liquidity constraints

| **The degree of liquidity constraint of:** | **Normal times** | **Crisis** |
|---|---|---|
| **Households** | | |
| Short-run income elasticity of consumption | 0.17 | 0.5 |
| **Enterprises** | | |
| Short-run capital-output elasticity (business) | 0.042 | 0.071 |
| Short-run capital-output elasticity (housing) | 0.015 | 0.026 |

**Annex 4. Sensitivity analysis**

Table A4 below sets out our assumptions behind the simulations presented above.

Table A4. Assumptions

| | Assumption |
|---|---|
| The profile of the shock | 1 per cent of GDP per year distributed evenly over 2 years |
| Monetary policy assumptions | Monetary policy switched off for the duration of the shock, active afterwards |
| Fiscal policy assumptions | Fiscal policy switched off for the duration of the shock, active afterwards. Budget deficit targeting |

To test the sensitivity of the results presented in the previous section, we run two additional simulations. We modify the assumptions concerning:

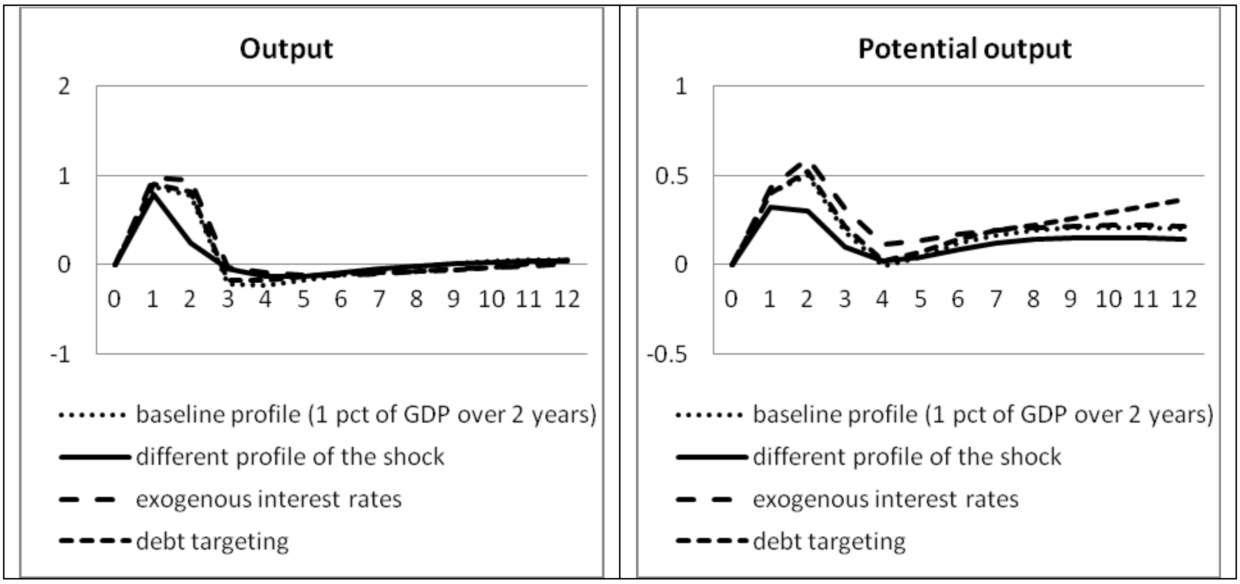
(i) The profile of the infrastructure shock – we assume a different distribution of investments over time. Instead of 1 per cent of GDP shock distributed evenly over the period of 2 years, we assume that the pattern of investment is as follows: 1 per cent of GDP in the first two quarters, 0.75 per cent of GDP in quarters three and four, 0.5 per cent of GDP in quarters five and sic, and 0.25 per cent of GDP in quarters seven and eight.

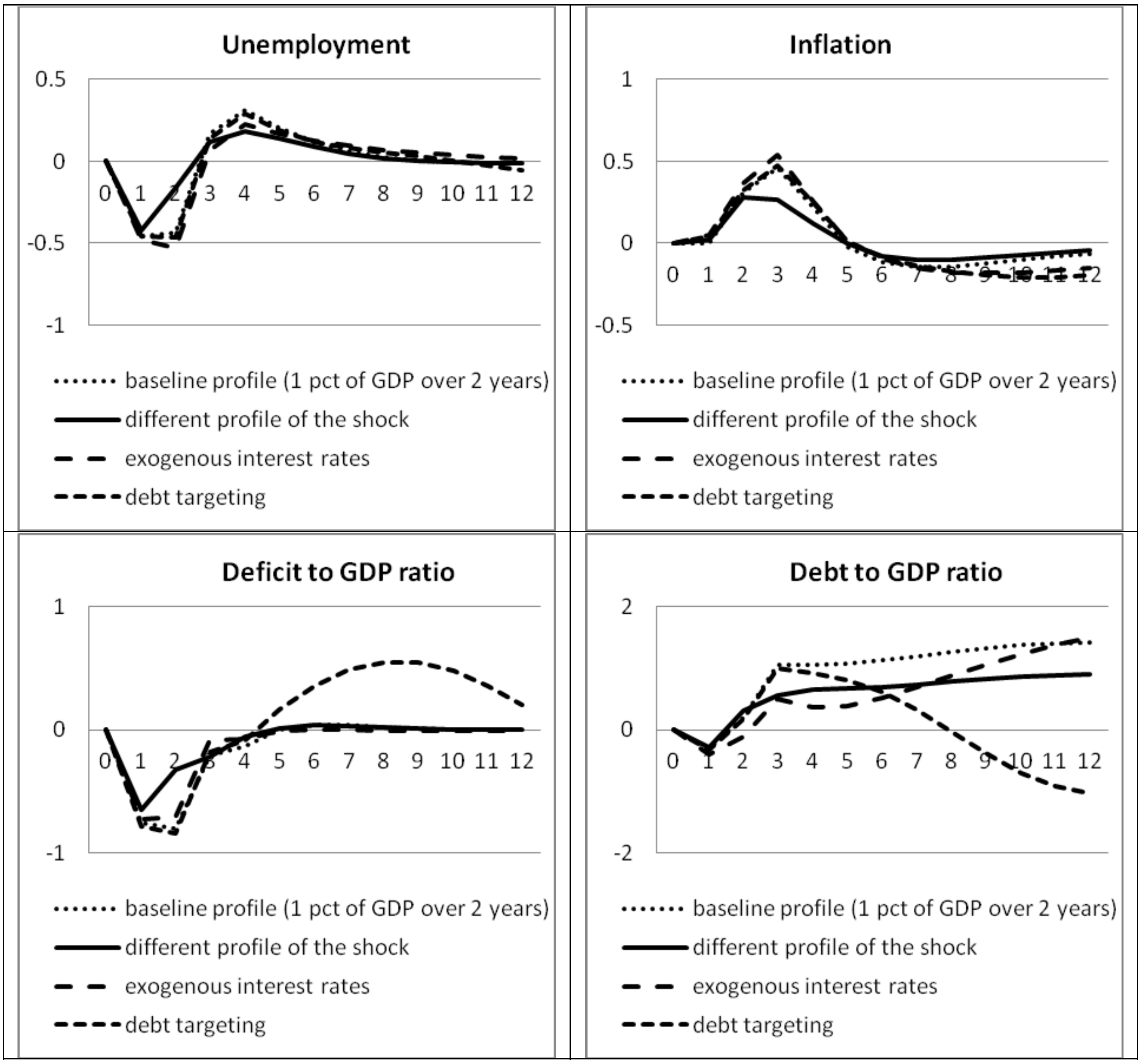
(ii) The response of monetary policy– we assume that monetary policy is switched off not only for the duration of the shock, but it remains inactive over the full simulation horizon

(iii)The response of fiscal policy – we assume that fiscal policy rule is switched off for the duration of the shock and then it targets the debt to GDP ratio

Figure A4 illustrates the results.

Figure A4. Sensitivity analysis






Note: We show per cent deviations from baseline for output and potential output and percentage point deviations from baseline for inflation, unemployment, deficit to GDP and debt to GDP ratio - over time (in years).

The sensitivity analysis confirms that the range of impacts of infrastructure investment in normal times oscillates around 1 per cent of GDP in the short term, and about 0.1-0.2 per cent in the long run (potential GDP impact).