Office for
Budget Responsibility

Discussion paper No.5

Public investment and potential output

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August 2024

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Abstract

This discussion paper sets out how public investment is accounted for in our fiscal forecast, before exploring the key transmission mechanisms through which it can affect potential output. It then outlines our proposed approach to modelling the impact of public investment on potential output. We assess the time lags between public investment and its impact on UK productive capacity and the scale of the long-run effect. We use a calibrated model to simulate the impacts of a stylised unit shock to public investment of +1 per cent of GDP. The impact of cuts to public investment can be estimated using the same tools and would be symmetric. In our initial, high-level, and partial equilibrium analysis, we find that a sustained 1 per cent of GDP increase in public investment could plausibly increase the level of potential output by just under ½ a percent after five years and around 2½ per cent in the long run (50 years). It then explores a set of further issues in assessing the effects of changes in a government's public investment plans. It concludes by setting out a range of questions on which we would welcome feedback.

We would like to thank the members of the Budget Responsibility Committee, Richard Hughes, Professor David Miles and Tom Josephs and our Office for Budget Responsibility colleagues, including Jim Ebdon, Saif Mirza, Bronwyn Garrett for their invaluable contributions to this paper. We would also like to thank the Congressional Budget Office, colleagues at the Treasury and Office for National Statistics for their support and expertise, and the members of our Advisory Panel. Finally, we would like to thank respondents to our Summer 2023 supply side consultation, including the Institute for Fiscal Studies, the Institute for Public Policy Research, NIESR, the Resolution Foundation, and the Social Market Foundation, and – particularly – the Institute for Government and the participants at the helpful discussion that they organised in response to our consultation.

Contents

1 Background

1.1 The evolution of potential output (or the 'supply-side') is the most important determinant of long-term economic prospects, is a key driver of our economic and fiscal forecasts and has been a major focus of economic policy under successive governments. In recent years, as both ONS data and our own models have developed, we have sought to be more explicit about how we construct our potential output forecasts and described how we decompose the forces behind changes in productive capacity into three main drivers: the labour supply, capital stock, and total factor productivity (TFP).[1] While these forecasts have always taken account of the impact of those policies which evidence suggests are likely to have a significant, additional, and durable effect on potential output, we have been more explicit about how we estimate these supply-side effects in recent *Economic and fiscal outlooks* (*EFOs*).[2]

1.2 Over the past three *EFOs*, our potential output forecasts have taken account of the previous government's policies in several areas. Our forecasts for the evolution of the labour supply have taken account of the impacts, both positive and negative, of changes to childcare provision, pensions taxation, national insurance contributions, and freezes in personal tax allowances and thresholds. Our forecasts of the evolution of the private capital stock have reflected the impact of the temporary super-deduction and then full expensing of qualifying business investments for corporation tax purposes. And we have published more detail on how we estimated the supply-side effects of these policies.[3]

1.3 While public sector investment policy has seen fewer significant changes over this period, it too can have a significant impact on the supply potential of the economy. As with private investment, public investment affects economy-wide potential output principally via its impact on the stocks of assets that support economic activity. These assets include infrastructure assets (such as the transport, energy, and water networks), public service assets (such as schools, hospitals, and public housing), and intangible assets (such as those created by research and development). And the investment itself can take the form of either direct investment in publicly-owned assets (public sector gross fixed capital formation) or indirect investment in privately-owned assets (in the form of net lending or capital grants to the private sector).

[1] See OBR *Briefing paper No.8: Forecasting potential output – the supply side of the economy,* November 2022.
[2] See OBR *Dynamic scoring of policy measures in OBR forecasts,* November 2023 and Boxes on *The economic effects of policy measures* in our *EFOs*.
[3] See OBR, *The economic effects of full expensing* and *The labour supply effects of the Autumn 2023 National Insurance Contributions cut*, February 2024.

1.4 This paper explores in greater depth how changes in public investment can affect potential output and seeks feedback on our proposed approach to reflecting this more explicitly in our forecasts. It is structured as follows:

- **Section 2** describes the composition and evolution of UK **public investment and the public capital stock** in historical and international context.
- **Section 3** considers how public investment affects the economy, in particular, via its **impact on potential output**.
- **Section 4** presents and discusses **illustrative scenarios** for the impact of a change in public investment on potential output.
- **Section 5** discusses some **issues for further consideration** in estimating the impact of a change in public investment on potential output.
- **Section 6** sets out a set of **questions for feedback** on our proposed approach.

1.5 To illustrate the dynamics of our modelling approach, we explore a stylised unit shock to public investment of +1 per cent of GDP. The impact of cuts to public investment can be estimated using the same tools and would be symmetric. While the quantitative analysis focuses on changes to direct investments in non-financial assets by general government, we consider a wider range of public investment vehicles, including via public corporations, and via loans or capital grants to the private sector in Section 5.

1.6 We have identified several challenges in estimating the effects of public investment on the economy, including how best to account for the effects of different types of investment and what is the appropriate lag structure with which to account for the likely gradual impact of changes in public investment on potential output. We do not provide definitive answers to all these modelling questions at this stage. We have listed them in Section 6 and welcome feedback both on our general approach to modelling the supply-side effects of public investment and on these specific issues, which can be sent to feedback@obr.uk.

2 Composition and evolution of public investment and capital stocks

2.1 This section explores the composition and evolution of UK public investment and capital stocks in both historical and international context, covering:

- definitions and concepts regarding investment and capital stocks;
- how these definitions and concepts relate to the public sector investment and capital stocks measures in our fiscal forecast;
- the path of UK public sector investment in historical and international context; and
- its impact on the evolution of the government's capital stock.

Key definitions and concepts

2.2 The ONS reports several different measures of investment. After accounting for any depreciation or retirement of existing assets, these investment flows accumulate into stocks of assets.[1] Important definitions and concepts for understanding what these different measures represent are set out below.

How investment is recorded: fixed capital formation and other investment

2.3 Investment is a broad term that captures spending that creates an asset. For the purposes of this paper, investment spending can be allocated to one of two buckets:

- **Gross fixed capital formation** (GFCF) is investment which adds directly to the non-financial capital stock of the entity doing the investment.[2] This includes tangible investments such as public spending on roads and bridges, which adds to the stock of physical assets owned by the public sector. But fixed capital formation also includes intangible investments (for instance, investment in software which adds to the public stock of software assets). The ONS judges whether or not to capitalise spending, according to international statistical guidance.[3]

[1] Assets can be financial or non-financial in nature, but the focus of this paper is investment in non-financial assets. Alongside our forecasts, for spending control purposes, the Treasury also sets out its plans for different measures of investment (capital departmental expenditure limits and capital annual managed expenditure), according to its own definitions.
[2] Within GFCF, other components of the non-financial capital stock include other produced assets (like inventories and valuables). GFCF is measured by the total value of a producer's acquisitions less disposals of fixed assets during the accounting period plus certain specified expenditure on services that add to the value of non-produced assets – an example here would be land improvements.
[3] When the ONS capitalises spending, it records it as investment rather than consumption.

- **Other investment** can include that which adds to the stock of financial assets held by the government. For instance, when the government issues student loans, this investment adds to the stock of student loan assets held by the public sector, but not the public fixed capital stock (which is made up of non-financial assets only). These other investments may also finance capital formation in other sectors, like equity injections or capital grants to the private sector, who undertake the government-supported investment themselves.

How capital stocks are recorded

2.4 Inflows of fixed capital formation add to the stock of capital assets, which is what matters for potential output. Capital assets can be valued in nominal terms or, by adjusting for price changes, in real terms. In practice, however, unlike many other financial assets and liabilities that the ONS measures, it does not observe the market value of most of the capital stock directly – in part because many fixed assets are so infrequently (or even never) traded. The ONS instead uses a perpetual inventory model (PIM) to construct an estimate of the capital stock that reflects past inflows and outflows.[4] The ONS reports two different measures of real capital stocks, on gross and net bases, depending on whether estimated outflows reflect depreciation or retirements:[5]

- **Net capital stocks account for depreciation**, the loss in value of an asset as it ages. This measure therefore captures the gradual wear and tear of the existing stock of assets, as well as the declining market value of assets as they approach retirement. Net stocks are therefore relatively close proxies for the market value of traded assets, and are what contribute to the broadest balance sheet measure in our fiscal forecast, public sector net worth.

- **Gross capital stocks account for the retirement or scrapping of assets** that have reached the end of their useful lives (but do *not* account for depreciation). This measure therefore depends on assets' expected lives. Because depreciation takes place before assets retire, gross stocks are typically larger than net stocks. As discussed in further detail in Section 3, while we focus on net stocks when producing our five-year fiscal forecast, we judge that gross stocks may be more closely linked to potential output.

How these different capital stocks measures are reflected in flow statistics

2.5 Because the National Accounts (NA) and Public Sector Finances (PSF) are produced on a stock-flow consistent basis, changes in these stocks are reflected in corresponding changes in flows:

[4] ONS, *Capital stocks user guide, UK,* July 2022.

[5] Depreciation is also known as consumption of fixed capital in National Accounts data. Both measures of stocks also account for other changes in volume like catastrophic losses (for example, through war) and reclassification (if the sector to which a capital asset's owner belongs is reclassified).

- **Gross investment** includes both direct investment (GFCF), which adds to the investor's own capital stock, and other investment, like capital grants, as set out above.
- **Depreciation** subtracts from the capital stock. It captures the loss in value of assets as they age, as set out above.
- **Net investment** flows are recorded as the difference between gross investment and depreciation flows. It provides a measure of the change in the stock of net capital over a given period.[6]

Public investment and capital stocks in our fiscal forecast

Institutional units that undertake public investments

2.6 Public investment can be undertaken by one of three groups of institutional units:

- **Central government** includes investments that are undertaken by central and devolved government departments and their agencies and are funded out of general taxation or Treasury borrowing. These include the investment projects and asset purchases undertaken by NHS hospitals, state schools, and the armed forces.
- **Local government** includes investments undertaken by local authorities across the UK and funded out of local government revenues, grants and loans from central government, or local borrowing. These include investment in local transport, housing, community amenities, and waste facilities. Together central and local government investment gives us **general government** investment.
- **Public corporations** include investments undertaken by government-owned or controlled corporations and funded out of their own revenues or borrowing. These include investments by the Post Office and Scottish Water. Together general government and public corporations comprise the **public sector.**

Public investment and capital stocks in our fiscal forecast

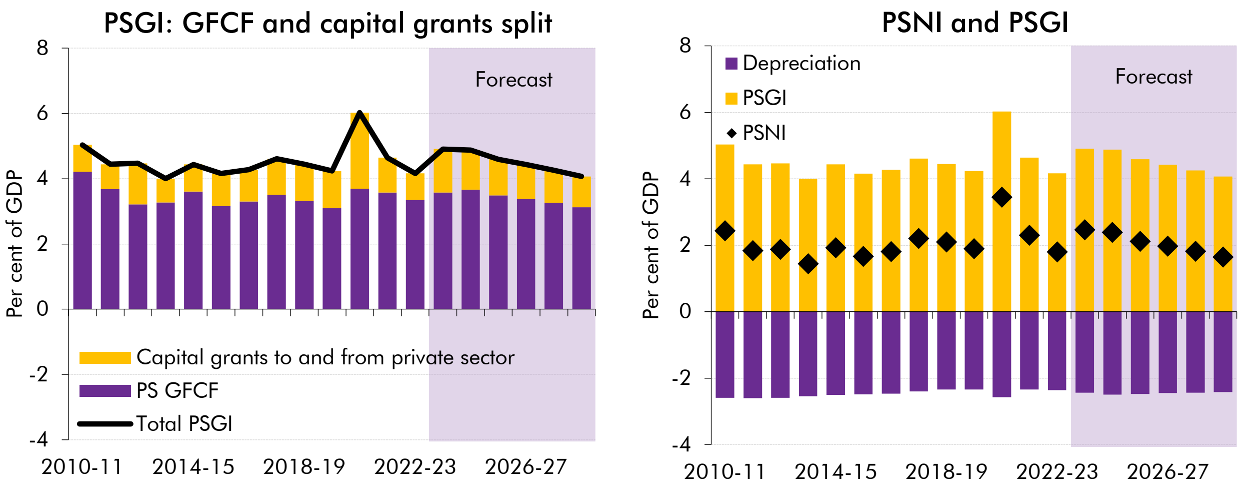
2.7 The public sector is most relevant for assessing the sustainability of the public finances, and is the focus of the government's fiscal rules; our fiscal forecast is produced at this level of aggregation. It is also the level of aggregation at which we assess the economic impact of fiscal policy. We forecast the public sector finance statistics produced by the ONS by adding investments undertaken by central and local government and by public corporations to produce a forecast for **public sector gross investment** (PSGI). As is shown in the left panel of Chart 2.1, this can be decomposed into gross fixed capital formation (about three-quarters of total investment), capital transfers to the private sector (about a quarter of total

[6] Equivalently, net fixed capital formation captures the difference between gross fixed capital formation and depreciation. An equivalent decomposition of the changes in gross capital stocks into gross investment net of retirements could be performed, but fiscal accounting convention dictates that the term 'net' generally means 'net of depreciation'.

investment), and changes in inventories, which in net terms are generally small over the medium-term. Since 2010-11, PSGI has averaged 4.5 per cent of GDP.

2.8 As shown in the right panel of Chart 2.1 we also forecast **depreciation** of the asset stock, and by subtracting it from PSGI we also derive a forecast for **public sector net investment (PSNI)**. Since 1997, most iterations of successive governments' fiscal rules have accounted in some way for at least one of these metrics. For instance, a cap on (average) PSNI existed between 2019 and 2022. And the current budget deficit (which adds depreciation to current expenditure before subtracting current receipts) was targeted from 1997 to 2009, 2010 to 2015, and 2019 to 2022. Since 2010-11, depreciation has averaged 2.5 per cent of GDP, or around half of PSGI. PSNI has averaged around 2.1 per cent of GDP since 2010-11.

Chart 2.1: Public sector gross and net investment



Source: HM Treasury, OBR

Evolution of PSNI and capital stocks

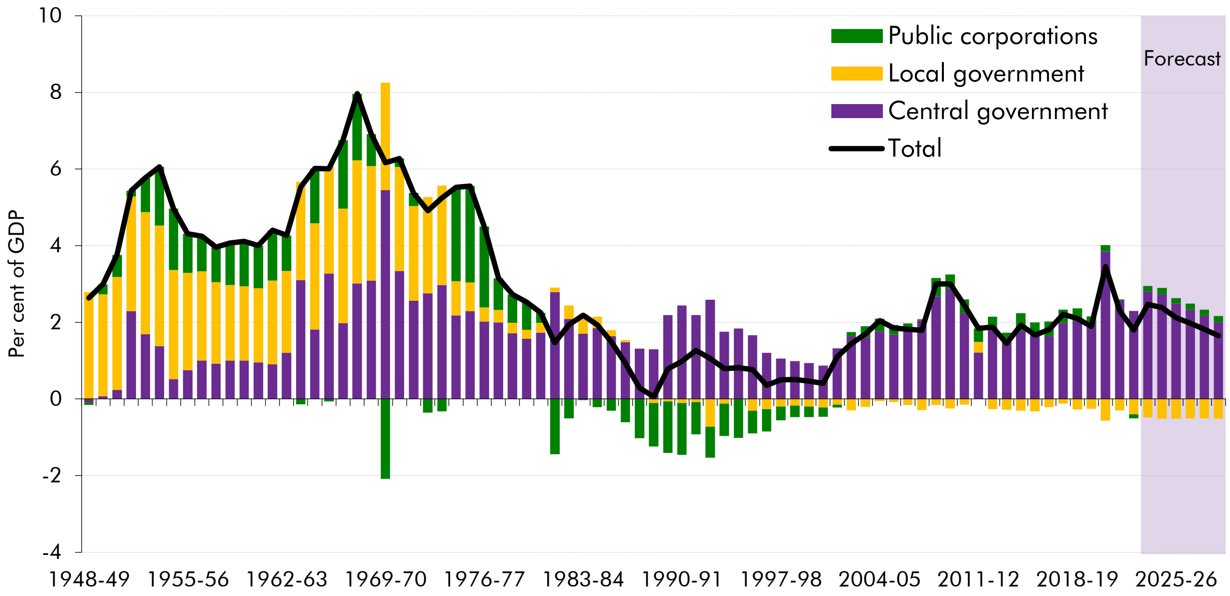
The evolution of PSNI and the public sector net capital stock

2.9 From a peak of around 8 per cent of GDP in the mid-to-late 1960s, PSNI steadily declined to a sustained post-war low of around ½ a per cent at the turn of this century. This decline in public investment was driven by three main factors: a decline in social housing investment starting in the 1970s; privatisation of major public utilities starting in the 1980s; and a reduction in investment in public services in the 1990s. The first two of these can be seen in the reduction in contributions to PSNI from local governments and public corporations in Chart 2.2. The third can be seen in the decline in central government investment.

2.10 PSNI rebounded over the 2000s to reach a three-decade high of 3 per cent of GDP in 2008-09, but the post-financial-crisis period saw a further half-decade period of retrenchment. Between 1998 and 2008, a focus of government policy was to raise public investment with much of the increase in public service assets such as schools and hospitals. The 2008 financial crisis that resulted in a huge rise in public sector debt saw a refocusing of fiscal policy onto deficit reduction and debt stabilisation, to which cuts in investment made significant contributions. Public investment recovered somewhat in the latter half of the 2010s, before spiking to 3.5 per cent of GDP in 2020-21, in part due to the collapse in GDP during the pandemic.

2.11 But the disruptions of the pandemic and energy crises brought about another period of planned retrenchment. Our March 2024 forecast, which was based on the previous Government's fiscal plans, sees PSNI decline steadily from around 2½ per cent of GDP in 2023-24 to 1¾ per cent of GDP in 2028-29. This is largely driven by the previous Government's assumption that departmental capital spending would be frozen in cash terms from 2025-26 onwards.

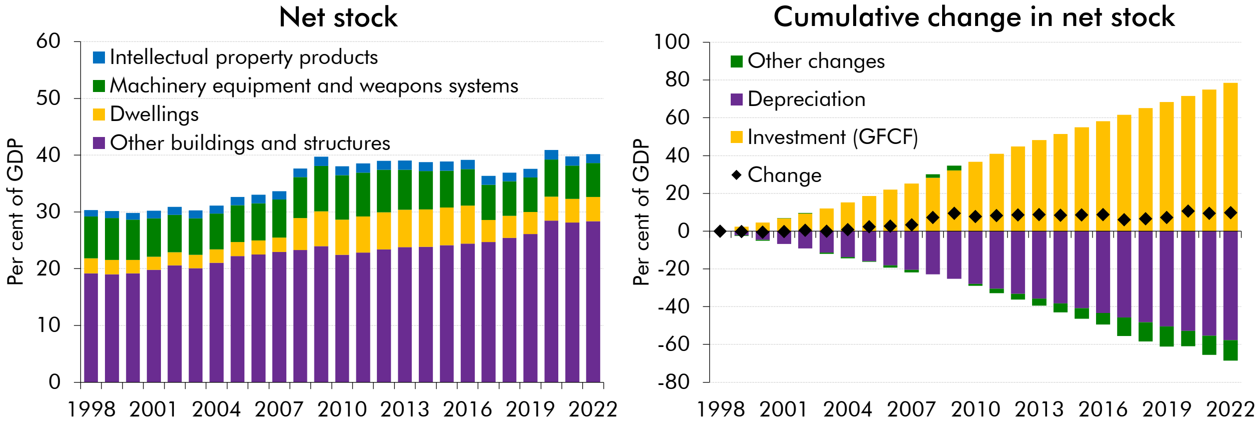
Chart 2.2: The evolution of public sector net investment in the UK



Note: Total public sector net investment excludes any capital transfers from the Asset Purchase Facility (APF) scheme.
Source: ONS, OBR

2.12 The public sector net capital stock has grown over the past quarter century. As the left panel of Chart 2.3 shows, it stood at 30 per cent of GDP (£677 billion in 2019 prices) in 1998 (the earliest year PSF data is available). It has since risen to 40 per cent of GDP (£898 billion in 2019 prices), almost entirely due to the rise in the value of 'other buildings and structures' reflecting large investments made in railways, roads, and other physical assets over the last three decades. The right panel shows an estimate of the decomposition of this cumulative change into an 80 per cent of GDP *positive* contribution from cumulative *investment* that outweighs a 60 per cent of GDP *negative* contribution from cumulative *depreciation* and a 10 per cent of GDP *negative* contribution from other changes.

Chart 2.3: Public sector net capital stock: per cent of GDP and decomposition



Note: Other changes in the right-hand chart therefore account for cumulative growth in the GDP denominator, relative price changes, and any changes in the volume of capital assets not accounted for in depreciation.
Source: ONS

UK public investment in historical and international context

The relative sizes of public investment flows and capital stocks

2.13 Public investment makes a relatively small contribution to the size of the public capital stock in any given year. In 2022, the value of the public capital stock in the UK economy was 40 per cent of GDP. But the annual flow of PSGI was 4 per cent of GDP in 2022-23, or around 10 per cent of the total public capital stock. And after accounting for depreciation, PSNI was only 1.8 per cent of GDP in 2022-23 – an even smaller 4 per cent of the stock – so, the capital stock typically grows relatively slowly.

2.14 Unless there is a very large increase or decrease in annual flows, changes to public investment are likely to have only a modest impact on the total capital stock, and therefore on potential output, within a given five-year forecast horizon. Impacts will be more apparent in the longer term, if the higher or lower rate of investment is sustained and its effect on the stock accumulates. Since comparable records began in 1948, the largest annual increase in PSNI, which was not a result of lower GDP following crises or a direct transfer of assets,[7] was 1.7 per cent of GDP in 1951-52. So the 1 per cent of GDP increase in government investment modelled in the next sections is a large change and would translate to a 50 per cent increase in net investment flows.

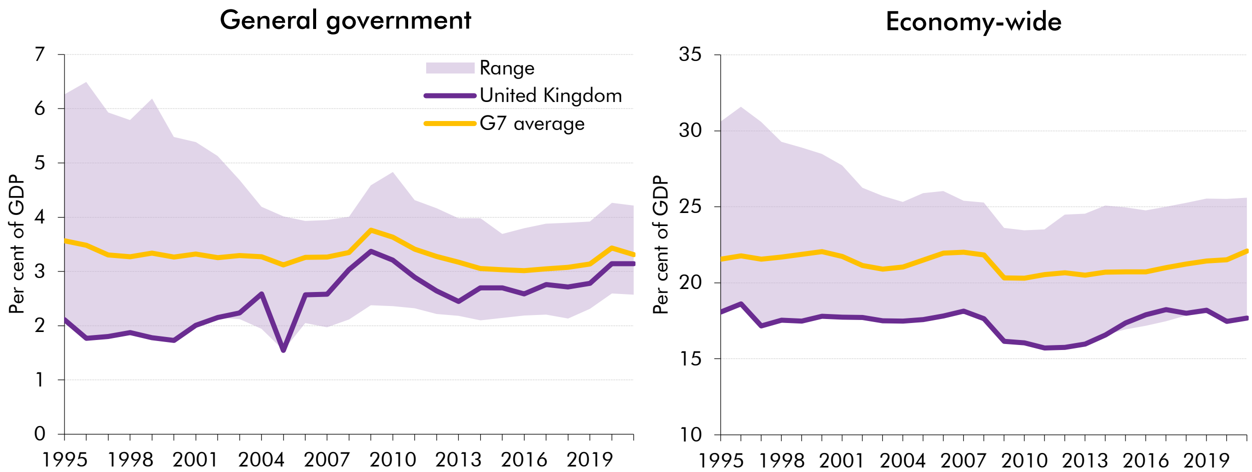
Government investment in the UK and other major advanced economies

2.15 Government investment in the UK, which was 3.1 per cent of GDP in 2021, is now broadly in line with the G7 average of 3.3 per cent of GDP (left panel of Chart 2.4).[8] However, the UK's overall investment (public and private) has consistently been materially weaker than

[7] Our forecast consistent measure of general government investment goes back to the late 1990s. Public investment increased by 0.9 per cent of GDP, between 2005 and 2006, following a decline in the previous year because of the transfer of nuclear reactors nearing the end of their productive lives from the British Nuclear Fuels plc to the Nuclear Decommissioning Authority.
[8] General government GFCF is often the measure for (public sector) investment that is reported by international organisations. For this reason, Chart 2.4 populates GFCF as the measure of investment as opposed to a more comprehensive measure like PSNI.

other G7 countries, averaging 17 per cent of GDP post-financial crisis compared to the G7 average of 21 per cent of GDP (right panel of Chart 2.4).

Chart 2.4: G7 comparisons of gross fixed capital formation



Source: OECD

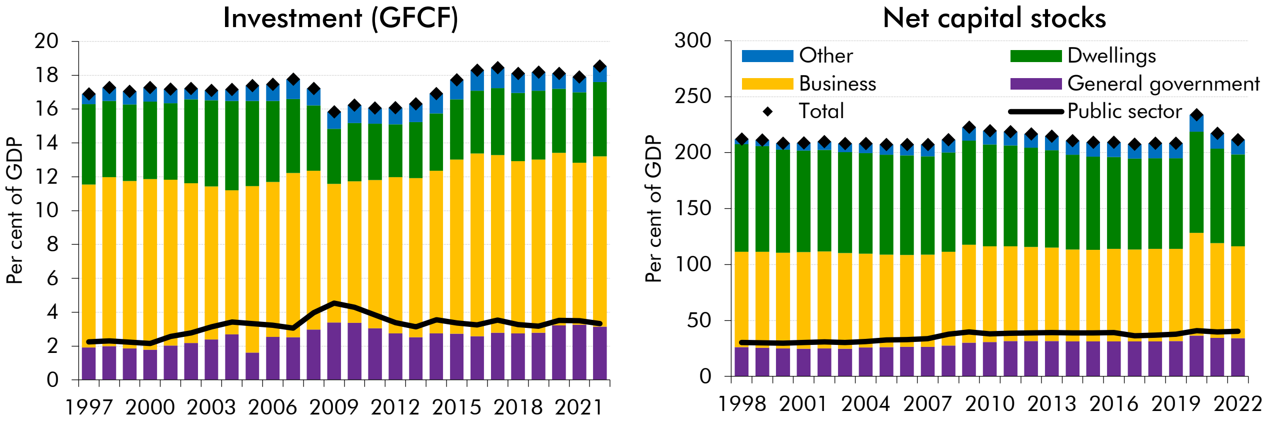
The relative sizes of public and private investment and capital stocks

2.16 When producing our economy forecast, we follow the ONS's National Accounts convention which classifies institutional units into 'government' and 'business.' Therefore, some investments classified as 'public investment' in our fiscal forecasts, namely those undertaken by public corporations or financed by equity injections or capital grants, are recorded as 'business investment' in our economic forecast. These investments add to the capital stocks of the business sector, as the entities that undertake the investments and own the resulting assets are businesses (albeit government-controlled or supported ones). These issues are discussed in further detail in Section 5. We also consider not just the nominal value of investments, but also how this is decomposed into the volumes of assets purchased (which are central to our assessment of potential output) and their prices (which affect their cost but not their economic impact).

2.17 The real general government net capital stock was valued at over 30 per cent of GDP in 2022 (£0.8 trillion in 2019 prices). It accounts for about one-sixth of the economy-wide capital stock, including dwellings, which had an estimated value of 212 per cent of GDP in 2022 (£4.8 trillion in 2019 prices).[9] Of the remainder, 82 per cent of GDP was in the market sector and 82 per cent of GDP in dwellings. Since the mid-1990s however, the private sector stock has fallen by 2 per cent of GDP compared to a 6 per cent of GDP rise in the public sector stock over that same time period (see Chart 2.5).

[9] These values are on a net, rather than a gross, basis, as described in paragraph 2.4. As we show in Chart 3.1 in Section 3, the capital stock is larger when valued on a gross basis. For instance, on a gross basis, the general government capital stock makes up 59 rather than 34 per cent of GDP in net terms, compared to an economy-wide figure of 393 rather than 212 per cent of GDP.

Chart 2.5: UK public and private sector investment and net capital stocks



Note: These charts use data from ONS's National Accounts data releases. For comparison, we have included lines for public sector statistics, as released in ONS's Public Sector Finances database, as a share of nominal GDP.
Source: ONS

3 How public investment affects demand and supply

3.1 This section sets out how we model effects of changes in public sector investment on UK output and productive capacity. We do so by showing:

- how public investment **temporarily affects demand** (i.e. the size of the output gap) and can **permanently affect supply** (i.e. the level of potential output);
- the transmission mechanism through which public investment **affects potential output**; and
- how the impact of public investment on potential output is affected by **lags** in: the purchase of investment assets, the completion of investment projects, and the realisation of their benefits.

How public investment affects demand and supply

3.2 Potential output (or 'supply') is the level of activity that an economy can attain when its productive resources are being utilised at their maximum sustainable rates. The output gap is the difference between actual GDP and potential GDP (or the difference between actual demand and potential supply) at any point in time, with a positive output gap implying that levels of domestic production exceed what can be sustainably produced from domestic resources. As set out in our recent *Briefing Paper*, fiscal policy can affect not only demand but also supply, by boosting either the quantity of resources available in the economy or efficiency with which they are combined.[1]

3.3 Likewise, the impact of public investment on overall output can be decomposed into these same two broad channels:

- An increase in public investment can **temporarily boost excess demand** in the economy. For example, a new infrastructure project may require additional workers during the period of its design and construction, potentially increasing employment, household incomes, and consumption. This effect is commonly captured via 'fiscal multipliers': positive demand multipliers might imply that these workers would not, in aggregate, otherwise have been employed on private infrastructure projects. In the medium term, the demand boost would be expected to dissipate to match only any

[1] OBR, No.8: *Forecasting potential output – the supply side of the economy, November 2022.* We have also discussed how changes in business taxation and personal taxation can affect potential output. See OBR, *The economic effects of full expensing* and *The labour supply effects of the Autumn 2023 National Insurance Contributions cut*, February 2024.

long-run increase in supply, as the exchange rate, wages and prices, and monetary policy adjust to bring the output gap to zero and inflation to target.

- A sustained increase in public investment can **permanently increase aggregate supply**, and in doing so have a sustained impact on incomes and expenditure. For example, a new infrastructure project may create a durable asset, such as a new transport link, which produces a flow of capital services. This asset can, in turn, support other forms of economic activity, such as greater domestic and international trade and investment. These supply-side benefits might be expected to materialise more slowly than any short-lived demand impact upon domestic production. It takes time for the asset to be created, the services it provides to begin to flow, and for the private sector to respond.

3.4 We have previously set out our approach to estimating the medium-term impact of public investment on aggregate demand and the output gap.[2] The next section focuses mainly on the transmission mechanisms through which public investment can affect aggregate supply.

How public investment can affect potential output

Public capital as an input to a production function

3.5 The economy's potential output reflects the inputs of different factors of production as well as total factor productivity ('TFP'), a measure of the efficiency with which they are combined. Our March 2024 economic forecast decomposed potential output into three principal components:

- **Labour supply** which is a function of the size of the population, the proportion willing and able to work (the participation rate), the share of those able to find work (the employment rate), and the average number of hours they work (average hours). This supply of labour is then typically hired by businesses, government, and other organisations and used to produce output.

- **Capital stocks,** which are functions of past levels of investment in tangible and intangible productive assets, the rate at which investment depreciates or is retired, plus the flow of new investment that adds to the stocks. This investment comes from both public and private sources. The services provided by the resulting public and private capital stocks may then be used by either their owners or by others to produce output.

- **Total factor productivity (TFP)** is a measure of the efficiency with which labour and capital are combined in the production process. This is a function of the state of global technology and knowledge, and the degree to which that technology and knowledge is effectively utilised domestically, which depends, to a significant extent, on the skill levels of the working population.

[2] We have discussed our multipliers several times, including in Box 2.1 of our November 2020 *EFO* and Box 2.2 of our 2019 *Forecast evaluation report*. We assume a demand multiplier of 1 on capital spending in the year it is announced that is then gradually tapered away to zero.

3.6 In considering the impact of public investment on potential output, it is appropriate to split the total capital stock into public and private stocks in order to consider their impacts separately.[3] How an economy then combines these four factors to determine the level of economic activity depends not just the level of each factor of production, but also how they combine. In practice, how economic activity is determined depends on many other factors, but one common and mathematically tractable modelling assumption is to assume they combine using a production function, like the simple 'Cobb-Douglas' function below. We use this to assess the economic impact of changes in public investment.

$$Y^* = AK_G^{\alpha}K_M^{\gamma}L^{\beta}$$

Where Y^* represents potential output, A represents total factor productivity, K_G and K_M represent public and private capital stocks, and L represents the labour supply.

3.7 The percentage change in output following a 1 per cent change in public capital is the output elasticity of public capital, ϵ_G:

$$\epsilon_G = \frac{\%\Delta Y^*}{\%\Delta K_G}$$

One property of the Cobb-Douglas production function is that the exponents α, γ and β are (almost exactly) the elasticities of output with respect to public capital, private capital and labour (rather than these elasticities depending in a more complex way on the factors of production or TFP).[4] So, $\epsilon_G \approx \alpha$. This is a partial elasticity holding other inputs fixed, and the full effect on the economy would depend on any other responses that occur in general equilibrium, including from the private capital stock (as discussed in Section 5).

What measure of capital is the best input to a production function?

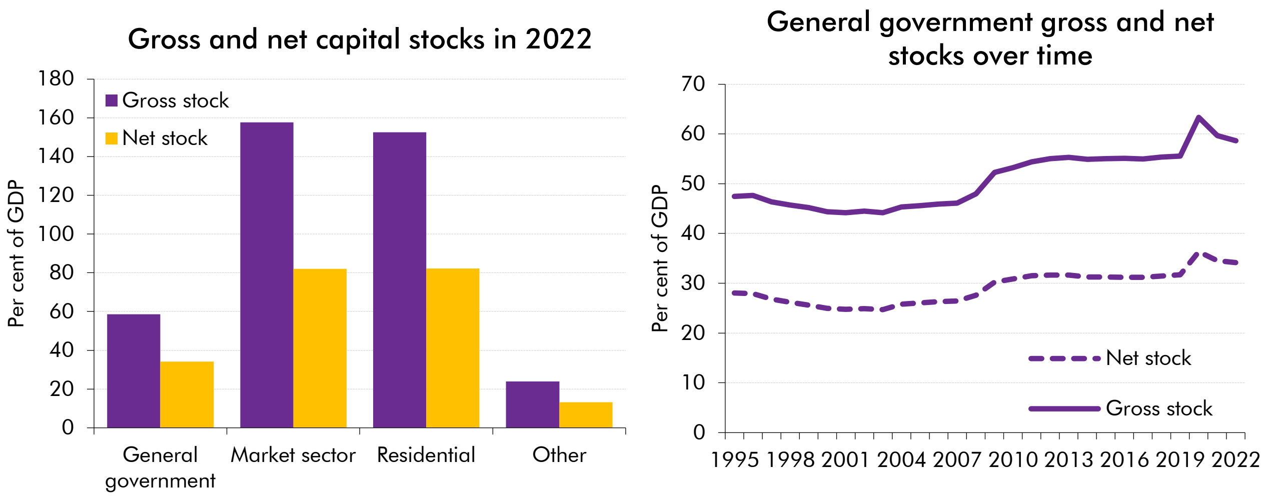
3.8 The market value of assets, the price at which an asset could be sold, is an important determinant of fiscal sustainability.[5] But as the discussion above highlights, the underlying input to the production process from a capital asset is the volume of services it provides, rather than its market value. For instance, the contribution of a lorry to GDP depends primarily on its ability to transport goods from one place to another (rather than, say, its age or mileage, even though those will be the main determinants of its price). The ONS reports experimental statistics that attempt to measure these flows of capital services provided by private sector assets.[6] But experimental statistics are only infrequently available, and only for the market sector. But public capital assets produce flows of capital services which can be used in production: hospital equipment treats patients, bridges enable river

[3] Consistent with our potential output forecast, capital stocks in this production function exclude dwellings and assets held by households.
[4] The use of a Cobb-Douglas production function, combined with positive exponents, means that in this modelling framework public capital, private capital, and labour supply are all complements to each other. If an individual exponent is less than one then that factor has diminishing returns: each additional unit of a given factor has a smaller impact on potential output. Finally, if the exponents sum to one then those factors exhibit constant returns to scale: this means that, for instance, doubling all the factors doubles output.
[5] As discussed in paragraph 2.4, many non-financial public assets are not commonly traded, and so these prices cannot be observed.
[6] See, for instance, ONS, *Volume index of capital services (VICS) QMI*, 2020. See also, OECD, *Measuring capital: OECD manual*, 2009.

crossings, trains transport passengers, and so on.[7] It is plausible that the services they provide are broadly proportional to the size of the stock, and so we use changes in real capital stocks as proxies for changes in public sector capital services.

3.9 As discussed in paragraph 2.4, the capital stock can be recorded at both net and gross values. Under both, inflows of fixed capital formation add to capital stocks, boosting capital services and hence GDP. But capital assets do not provide capital services indefinitely, and neither net nor gross capital measures capture this decline perfectly. Gross measures account for retirements, and so will not fully capture declines in the efficiency of capital assets as they age but before they are scrapped. Net measures capture these declines, but also capture the declines in the market value of older assets, even though they may still be providing a flow of service whose volume hardly falls up to the point they are scrapped.[8] Gross capital stocks measures are larger than net ones (left panel of Chart 3.1), although movements in both stocks relative to GDP track each other reasonably closely (as shown for the general government stock in the right panel of Chart 3.1). We judge that gross stocks better reflect changes in the volume of capital services than net stocks, and so use them in our modelling. But, as we describe in the next section, we use a somewhat higher scrapping rate for simulations than ONS data imply because we allow for some deterioration in efficiency prior to retirement that requires maintenance and repair.

Chart 3.1: Capital stocks



Source: ONS

Modelling the declining capital services provided by investments

3.10 We need to capture how quickly the volume of capital services provided by existing assets (and any future investments) declines. This broadly reflects the average *useful* lives of assets. It depends on the typical asset life (the period until it is scrapped) and whatever repairs are

[7] Capital services measure the flow of services that different types of assets provide to the production process. As they are challenging to measure, the capital stock, a related but distinct concept, is used as a proxy. Our current practice is to use National-Accounts-consistent measures of capital stocks as a proxy for capital services.

[8] For instance, to take the example above, the market value of a lorry might decline due to cosmetic changes or because buyers believe it is reaching the end of its life, even though its ability to transport goods is undiminished. Both measures of capital stocks also account for other changes in the volume of assets, such as those due to catastrophic losses or classification changes.

needed to keep it operational (a component of depreciation). Therefore, this decline in the capital services provided by a collection of assets is likely to be larger than scrapping. For example, for a collection of assets that on average have asset lives of 30 years, and also require 1 per cent annual maintenance and repair costs (as a percent of the asset cost) means that the effective capital services they provide decline at a rate of 4.3 per cent. (100*(1/30) + 1) per cent = 4.3 per cent).

3.11 We estimate that public sector capital services decline geometrically at a constant rate, δ_G, of 4 per cent.[9] This is a little smaller than the 5 per cent retirement rate reached by business assets toward the end of our forecast, reflecting the relatively long-lived assets that exist in the public sector (faster retiring assets such as computers will require more investment to maintain the current capital stock than a new road whose useful asset life could last for decades).

3.12 The ONS models depreciation and retirement using the asset-specific lives, age-efficiency, and age-price profiles in its perpetual inventory model.[10] Our estimate is higher than the *implied retirement rate*, which can be calculated from ONS data sources and averages 2½ per cent.[11] In an economy with a growing capital stock, this will underestimate the scrapping rate of a typical piece of capital, and under plausible assumptions this downward bias could easily be in the region of 1 percentage point.[12]

3.13 For simplicity, we refer to public sector capital stocks and retirement rates in what follows (rather than referring explicitly to the volume of and change in capital services). So, gross fixed capital formation adds to the stock of capital, and retirements subtract from it, following the law of motion:

$$K_{G,t} = (1 - \delta_G)K_{G,t-1} + I_t$$

Where $K_{G,t}$ is the gross public capital stock, δ_G is the effective retirement rate of government assets (adjusted for repairs and maintenance) and I_t is gross fixed capital formation, or investment.

What is the output elasticity of public capital?

3.14 Exactly how public investment affects output depends on the specific investment undertaken. They include physical investments to improve the road network, develop utility networks, or

[9] A geometric rate is appropriate for capturing the decline in capital services provided by a large collection of assets (although, of course, retirement means that the services provided by an individual asset would not necessarily decay at the average rate).

[10] For more information, see ONS, *Capital stocks and fixed capita consumption QMI*, January 2023 and ONS, *Dataset perpetual inventory (PIM) inputs*, June 2024.

[11] This implied 'effective' retirement rate is calculated as the change in real general government gross capital stocks that is unexplained by real gross fixed capital formation in the data: $\delta_g = -(K_{g,t} - K_{g,t-1} - I_t)/K_{g,t-1}$.

[12] To see this, assume that all investments last $n - 1$ years beyond the year they are made, so that retirements equal investment n years ago. The effective retirement rate is then exactly I_{t-n}/K_{t-1}. Without investment growth, the capital stock equals n years' worth of investment (including in-year investment), so the effective retirement rate is simply the reciprocal of the asset's life, $1/n$. But if real investment grows at a constant rate, g, so that $I_t = (1 + g)I_{t-1}$, then recent investments make up a larger share of the capital stock than distant ones do. Using a little algebra, it is possible to show that this effect pushes the effective retirement rate of capital down to $g/((1 + g)^{25} - 1)$. If assets last 25 years on average, investment growth of 2 per cent is enough to push the effective retirement rate down from around 4 per cent (the reciprocal of average asset lives) to around 3 per cent.

construct facilities to provide public services. But they also include intangible investments such as those in data, software, or research and development, which can also support growth or drive innovation. We discuss how different investments may have different effects on the economy in Section 5, but focus in this section on output elasticities that represent the effect of an 'average' change in investment on GDP.

3.15 The impact of the public capital stock on potential output can be captured in the elasticity term, α. The value of this output elasticity is informed by the empirical literature. One particularly comprehensive summary of the empirical evidence on output elasticities is provided by Bom and Ligthart (2014), which analyses 68 individual studies using a metastudy approach, that controls for a wide range of factors including estimation technique, country analysed, and several others.[13] It finds a headline elasticity of 0.122 of long-run market sector output with respect to the government capital stock. They also find that estimates which look at total output rather than market sector output are around a third larger.

3.16 As shown in Table 3.1, this result is broadly consistent with the range implied by other empirical estimates, which runs from 0.03 to 0.41. It is also near the median value surveyed. Ramey, in a recent study, reviews a range of studies and other estimates and concludes that the evidence "*suggests that the aggregate production function elasticity of output to public capital is probably between 0.065 and 0.12*".[14] And the US Congressional Budget Office (CBO) in a 2021 paper assumes an output elasticity for US Federal government investment of 0.08 (which they apply to the net infrastructure capital stock).[15] These conclusions and assumptions are informed by the finding in the Bom and Ligthart study that output elasticities have fallen significantly over recent years.

3.17 Given this evidence, we currently believe that a total output (GDP) elasticity of 0.1, applied to the general government gross capital stock, appears reasonable. As we detail in Section 4, the choice of this elasticity produces values for the economy-wide internal rate of return on general government investments of around 9 per cent, which are broadly in line with those observed in the market sector. Nonetheless, there is significant uncertainty around the estimate of the elasticity of UK output with respect to the public sector capital stock.

[13] Bom, P., and J. Ligthart, *What have we learned from three decades of research on the productivity of public capital?,* 2014.
[14] Ramey, V.A., *The macroeconomic consequences of infrastructure investment*¸ NBER Working Paper, July 2020
[15] CBO, *The effects of physical infrastructure spending on the economy and the budget under two illustrative scenarios*, August 2021

Table 3.1: Estimates of the output elasticity of government capital

Study or organisation	Methodology	Output definition	Sample regions	Public capital definition[1]	Elasticity estimate
Bom and Ligthart (2014)[2]	Meta-study	Private	US	Total	0.08 to 0.12
Núñez-Serrano & Velázquez (2017)	Meta study	Total	Global	Total	0.12 to 0.13
Melo et al. (2013)[3]	Meta study	Total	Global	Transport	0.03 to 0.41
Ramey (2020)		Total		Total	0.07 to 0.12
IMF (2006)	VAR	Total	OECD	Total	0.22
IMF (2015)	Simulations	Total	OECD	Core	0.17
OECD (2017)	Simulations	Total	Global	Total	0.05 to 0.25
CBO (2021)	Simulations	Total	US	Physical	0.08
OBR (2024)		**Total**	**UK**	**Total**	**0.10**

[1] 'Core' relates to infrastructure assets like roads, railways, airports, and utilities.
[2] The study is an international study but the headline elasticity reported here is for the US.
[3] As reported in Núñez-Serrano and Velázquez (2017).

Taking account of time lags

3.18 Time lags matter when estimating the impact of public investment on potential output. As explored in more detail below there can be significant time lags at three key stages of a public investment project:

- **time to spend**: the time between the project's announcement and investment spending occurring;
- **time to complete**: the time between spending occurring and the project being completed, and therefore beginning to generate capital services; and
- **time to use**: the time between when the project is completed and its impact on potential output reaching its maximum size.

Time to spend

3.19 Time to spend is the delay between the announcement of funding for a capital project and the point at which public money is actually spent on the project.[16] Delays arise for example because legal authorisation sometimes needs to be sought, delivery agents need to be appointed or established, and contracts need to be put out to tender. For instance, the Elizabeth line was originally proposed, in 2001 as 'Crossrail', with significant investment spending beginning in 2009 (when construction began) and continuing until full services opened in 2023.

3.20 As discussed further in section 5, when presented with the government's stated investment spending plans, we often make adjustments in our fiscal forecast to arrive at a central

[16] Our forecast is produced on a national accounts basis, so spending is generally recorded when the relevant activity takes place.

estimate of what is likely to be *actually* spent over the next five years. History suggests that departmental capital budgets are almost always underspent, on average, by around 10 per cent across one-, two-, and three-year horizons, based on an analysis of spending plans between 1998-99 to 2006-07.[17] These lags may be particularly big for large capital projects. For instance, the expected lifetime cost of all projects in the Infrastructure and Projects Authority's (IPA's) government's Major Projects Portfolio was over £800 billion in 2022-23, suggesting that average annual spending on that portfolio of major projects might be in the region of £80 billion per year. PSGI in 2023-24 was £135 billion.[18] In the scenarios below, we abstract from the time to spend lags (as we would capture any time to spend lags directly in our fiscal forecast). Nonetheless, this would be an important consideration when we assess government's announced investment plans.

Time to complete

3.21 Once investment expenditure has occurred, it may take time to construct a particular asset. Physical infrastructure projects are complex, and often all or most of the project needs to be completed before it can begin to deliver capital services. Even projects that are delivered on time can take years to complete, and there are several challenges in delivering large infrastructure projects at the current juncture, including global inflationary conditions, labour market pressures, and wider systemic issues such as in the planning system.[19]

3.22 Historically, many projects have been subject to significant delays, which can be due to difficulties in securing the permissions, materials, and labour required or problems encountered during the construction phase. Another reason for projects overrunning could be optimism-bias in the planning stage. The Treasury's *Green Book* guidance requires departments to account for optimism bias during spending reviews.[20] Recent UK public investment projects have revealed a mixture of good and bad project outcomes, signalling the importance of policy design and implementation effectiveness in determining the performance of investment projects. A study conducted by Bent Flyvbjerg, which is based on over 16,000 projects, finds only 8.5 per cent of major projects meet or exceed their time and budget expectations, while 91.5 per cent fail to stay within budget or meet deadlines, or both.[21] Compared internationally, one recent study conducted by the Boston Consulting Group (BCG) suggests that the US and Australia face relatively higher unit costs but have faster delivery times, while Europe experiences lower unit costs but slower delivery times. The UK, however, has been found to experience *both* high unit costs and slow delivery times, where cost overruns in the UK are one of the highest compared to peer countries.[22] [23]

[17] See Box 3.2 of our March 2020 *EFO* and the *Forecast Approach* section of the *Departmental Expenditure Limits* section of our website.

[18] Calculated by dividing schemes' whole-life costs by expected average durations. IPA, *Annual Report on Major Projects 2022-23*, 2023.

[19] IPA, *Analysis of the National Infrastructure and Construction Pipeline 2023*, February 2024.

[20] National Audit Office (NAO), *Over-optimism in Government projects,* December 2023, and HM Treasury, *The Green Book: central government guidance on appraisal and evaluation*, April 2023.

[21] Flyvbjerg, B. and Gardner, D., *How big things get done: the surprising factors behind every successful project, from home renovations to space exploration*, 2023.

[22] Boston Consulting Group, *Reshaping British Infrastructure: Global Lessons to Improve Project Delivery.* February, 2024.

[23] For instance, the High Speed 2 (HS2) high-speed railway project has experienced a combination of implementation delays and cost increases, causing the project to see a rise of 109 per cent in expected cost from £37.5 billion in 2009 to up to £78.4 billion at a 2019 review. The project was first conceived in 2009 and was initially intended to be rolled out in phases. However, a separate link between

Time to use

3.23 There will be further lags between the completion of a project and its full impact on potential output. This reflects time taken for economic agents (consumers and businesses) to adapt and respond to the economic opportunities generated by any newly completed capital asset. For example, the Elizabeth line saw more than 150 million passenger journeys in its first full year of operation, but this had risen to 210 million journeys by 2023-24. In addition, residential and commercial development around newly opened transport links may take several more years to be fully realised. We discuss these and other further 'general equilibrium' effects in paragraphs 5.7 to 5.11.

Capturing time lags in our estimates

3.24 There is considerable uncertainty about what would be an appropriate overall time lag to assume for UK public investments. In the US, the CBO assumed in its 2021 analysis that for every $1 billion increase in infrastructure spending, $400 million would affect the private sector's productivity one year after the spending, $800 million would fully affect productivity in the second year after the spending, and the entire amount of spending would have affected productivity seven years later.[24] However, one cross-country study of infrastructure delivery times suggests that project durations are, on average, about 50 per cent longer in the UK than in the US for comparable investments.[25] The CBO uses a significant time to spend assumption in their scenarios where funding is made available over 10 years, but it takes 25 years for the funds to be spent, with a 4 per cent underspend assumption.

3.25 The time lags, reflected in the parameters θ_i, that we apply in this discussion paper to any change in investment in our scenario are a combination of 'time to complete' and 'time to use lags'. θ_i is the fraction of investment done at time t that first becomes an effective part of the productive capital stock i periods later at date $t + i$. For simplicity, we call this 'completed investment', and is shown in the first two columns of Table 3.2. In our framework, 20 per cent of investment spending is assumed to become productive in the first year after the investment takes place, 40 per cent two years after, 55 per cent three years after, and so on, with 100 per cent of the effect felt after 10 years. This is informed by the CBO path for the US, but delayed slightly to reflect that investments may take longer to complete and affect potential output in the UK.

3.26 This assumption produces smoother and more delayed impacts on GDP than would be obtained by simply applying an output elasticity to capitalised investment. We judge that this is more consistent with microeconomic evidence on the time it takes for many investment projects' growth impacts to be realised. By delaying projects' benefits, this has material impacts on investments' rate of return (discussed in Section 4).

Birmingham and Leeds was scrapped in 2021, with a further announcement to scrap the link between Birmingham to Manchester arm in October 2023. Rising cost pressures and implementation delays have been associated with planning "*overoptimism*" and underestimation of the "*scale and complexity of the programme*". See Institute for Government. *HS2: Costs and controversies,* 2023.

[24] See CBO, *Effects of Physical Infrastructure Spending on the economy and the Budget under two illustrative scenarios*, August 2021.

[25] See BCG, *Reshaping British infrastructure: Global lessons to improve project delivery,* 2024.

3.27 This means, at any point in time, the addition to the productive capital stock in period t reflects investments made over the previous 10 periods, because of the lags described above as shown in the expression below:

$$\sum_{i=0}^{10}(1-\delta_G)^i\theta_i I_{G,t-i}^S$$

And it also means that the proportion of a given investment made in period t still affecting potential output i-periods later is given by the expression below (shown in the right column of Table 3.2):

$$(1-\delta_G)^i\left(\sum_{j=0}^{\mathrm{i}}\theta_j\right)I_{G,t}^S$$

Table 3.2: Lag structure for additional investment

	Per cent of initial investment					
	Completed investment, θ_i		Retired		Impacting productive capital	
Period	Per year	Cumulative	Per year	Cumulative	Per year	Cumulative
t	0.0	0.0	0.0	0.0	0.0	0.0
t+1	20.0	20.0	4.0	4.0	19.2	19.2
t+2	20.0	40.0	3.8	7.8	18.4	36.9
t+3	15.0	55.0	3.7	11.5	13.3	48.7
t+4	10.0	65.0	3.5	15.1	8.5	55.2
t+5	7.5	72.5	3.4	18.5	6.1	59.1
t+6	7.5	80.0	3.3	21.7	5.9	62.6
t+7	5.0	85.0	3.1	24.9	3.8	63.9
t+8	5.0	90.0	3.0	27.9	3.6	64.9
t+9	5.0	95.0	2.9	30.7	3.5	65.8
t+10	5.0	100.0	2.8	33.5	3.3	66.5

4 Economic effects of a change in public investment

4.1 This section demonstrates how a change in public investment can affect the supply side of the economy using the data outlined in the second section of this paper and the assumptions and parameters set out in the third. In doing so, we illustrate the dynamics of our simple model, by exploring a stylised unit shock to public investment of +1 per cent of GDP. The effects of a negative shock to investment would be symmetric. In doing so we:

- Discuss our **modelling approach**, including key parameters, assumptions, and data.
- **Produce two simulations** using this approach: we consider one scenario where the increase is permanent and one where the increase is temporary.
- Discuss **other metrics** for assessing the macroeconomic impacts of public investment, including the internal rate of return.

Modelling approach

Calibrating to National Accounts data

4.2 The ONS does not produce stock-flow consistent public sector capital stocks and investment flows data on a real-terms basis, at gross values, for the asset split we use in our economy forecast. The calculations in this section are calibrated using the ONS's National Accounts data on 'general government' and 'market sector' stocks data consistent with our March 2024 economy forecast, which in 2024-25 has the government capital to output ratio at 55 per cent.[1] Our output elasticity of 0.1 is also based on evidence relating to the general government sector. As we have not seen evidence to suggest that the per pound economic impact of investments by public corporations differs from investments made in the general government sector, in practice we would likely assume they have the same effect on the economy as those made by general government. We also intend to make the same assumption for the component of PSGI that reflects capital grants to the private sector, after accounting for whether it stimulates domestic output, the more indirect transmission mechanism, and the risk of deadweight, as discussed in paragraph 5.6.

[1] The March 2024 forecast is consistent with ONS, *Preliminary capital stocks and fixed capital consumption*, August 2023.

Key parameters

4.3 To briefly summarise our assumptions, the framework we use employs:

- An **output elasticity of the government capital stock** of 0.1, as discussed in paragraphs 3.14 to 3.17. We have assumed that the output elasticity of labour supply is 0.67, and the output elasticity of the market sector capital stock is 0.23, so that our production function exhibits constant returns to scale in all three factors.

- An effective **retirement rate** of 4 per cent per year, as discussed in paragraphs 3.10 to 3.13.[2]

- The **time lags** set out in Table 3.2, which reflect both time to complete projects and time for their effect on potential output to be realised.

Baseline assumptions and analytical approach

4.4 We produce a path for the baseline level of the capital stock, $K^B_{G,t}$, accounting for investment and retirements.[3] This assumes government investment in our baseline is consistent with our March 2024 forecast and then held as a constant share of GDP. Our scenarios change government investment and government capital stocks and keep all other factors of production the same as in the baseline.

4.5 The difference between the *productive* government capital stock in the scenario and the baseline is given by $K^S_{G,t}$. This reflects the difference in the previous period, $K^S_{G,t-1}$, adjusted for retirements (which occur at the rate δ_G) and the difference in government investment between the baseline and the scenario, $I^S_{G,t}$. The latter is adjusted for the effect of time lags, as discussed in paragraph 3.27:

$$K^S_{G,t} = (1-\delta_G)K^S_{G,t-1} + \sum_{i=0}^{10}(1-\delta_G)^i \theta_i I^S_{G,t-i}$$

4.6 We then use the production function discussed in paragraph 3.6.

$$Y^* = A\, K_G^{\frac{1}{10}}\, K_M^{\frac{1}{3}-\frac{1}{10}}\, L^{\frac{2}{3}}$$

[2] This reflects a hybrid of actual retirements and some repairs and maintenance.

[3] For simplicity, in the remainder of this section, we refer to fixed capital formation as 'investment' and vary spending around this baseline. We refer here to the productive public sector capital stocks and retirement rates in what follows (rather than referring explicitly to the volume of and change in capital services).

Long-run impacts on potential output

Permanent increase

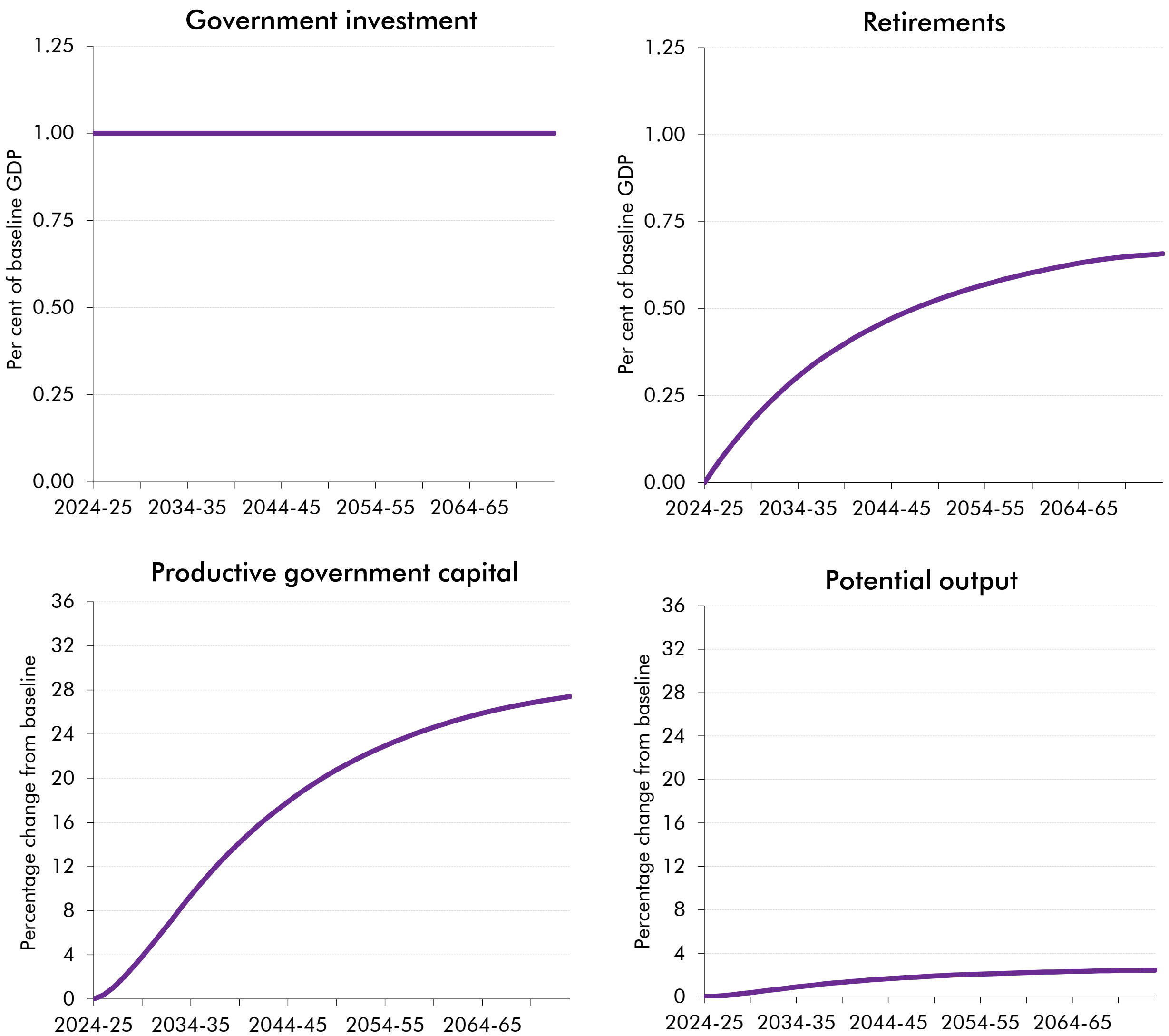
4.7 Using the modelling approach described above, we first illustrate the supply-side impact of a *permanent* 1 per cent of GDP increase in public investment, as shown in Chart 4.1.

- This is a sustained increase in **government investment** of 1 per cent of GDP.
- **Retirements** of the capital stock is 0.7 per cent of GDP higher in this scenario at the 50-year horizon, as there is more capital stock to retire.
- Combined, this increases the **productive capital stock** (as outlined in paragraph 4.5), relative to our baseline by 4 per cent after 5 years and 27 per cent at the 50-year horizon.
- This raises the level of **potential output** by 0.4 per cent after 5 years, and by 2.4 percent at the 50-year horizon. The impact on GDP increases over time, as the increase in government investment flows through to an increased government capital stock (and therefore capital services) as assets are gradually constructed and deployed in the economy. If there were no time lags, the effects on GDP would be 0.6 percentage points higher, or about 3 per cent, at the 50-year horizon.

4.8 The capital stock converges towards a new steady state value, where the extra retirement from the higher stock rises toward the higher level of gross investment. To illustrate this key dynamic, abstracting from time lags, with the retirement rate at 4 per cent, and the government capital stock around £1,200 billion, a constant £5 billion increase in investment in perpetuity would eventually increase the capital stock to the point where $\Delta K_G^* = \Delta I/\delta_G$, or by around 10 per cent (£125 billion), and potential output by 1 per cent.[4]

[4] As well as abstracting from time lags, which cause some investment to retire before becoming productive, this example also abstracts from another feature of our scenario: that the increase in investment being constant as a share of GDP means the volume of investment grows slightly over time rather than remaining constant. With growth in GDP and investment, the capital accumulation equation can be re-expressed as (approximately) $\Delta k_t = -(\delta + g)k_{t-1} + i_t$, where lower case letters express the variables described above as shares of GDP. Past investments making up a lower share of the capital stock than current ones, pushes down steady state k_t relative to i_t. This explains why retirements as a share of GDP (δk_t) starts levelling off at a lower value than investment in Chart 4.1 below.

Chart 4.1: Effects of a permanent increase in investment



Source: OBR

Temporary scenario

4.9 In addition to modelling the permanent investment shock above, we also illustrate the supply-side impact of a temporary, 1 per cent of GDP increase in public investment lasting only one year:

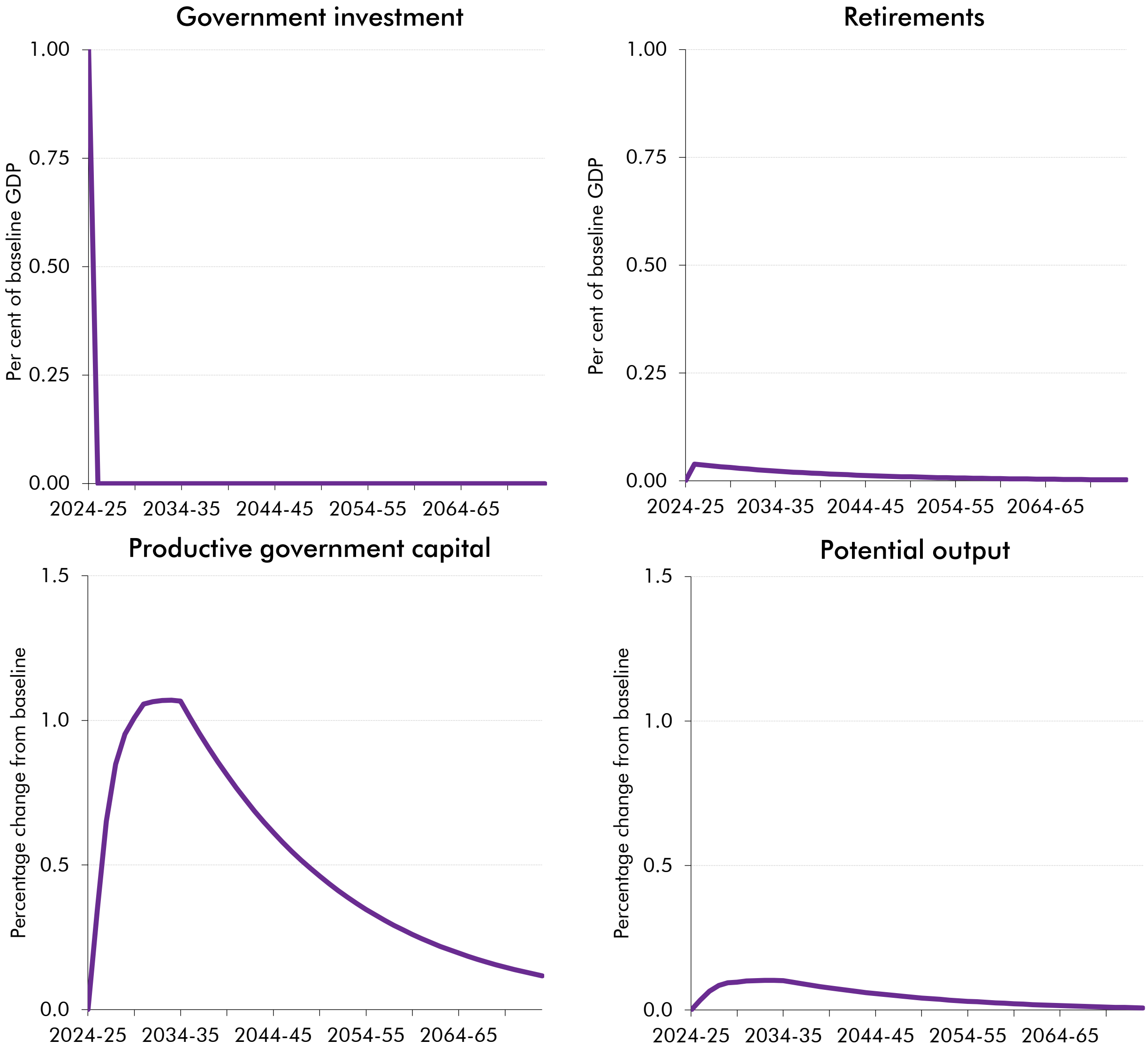
- Government **investment** is 1 per cent of GDP higher than in the baseline in the year it takes place.

- **Retirements** for overall capital stocks peak at 0.04 per cent of GDP in 2025-26, before attenuating towards baseline levels.

- In 5 years, the **productive capital stock** is increased by 1 per cent relative to our baseline. The impact on the productive capital stock peaks at 1.1 per cent in 2033-34, before returning towards the baseline level as the additional capital retires away.

- The impact on **potential output** is 0.10 per cent after 5 years, and peaks at a similar level in 2033-34, before attenuating to 0.01 per cent at the 50-year horizon. If there were no time lags, the effect on potential output would peak at a higher level of 0.18 per cent in the year in which the investment takes place but still falls to 0.01 per cent of GDP at the 50-year horizon.

Chart 4.2: Effects of a temporary increase in investment



Source: OBR

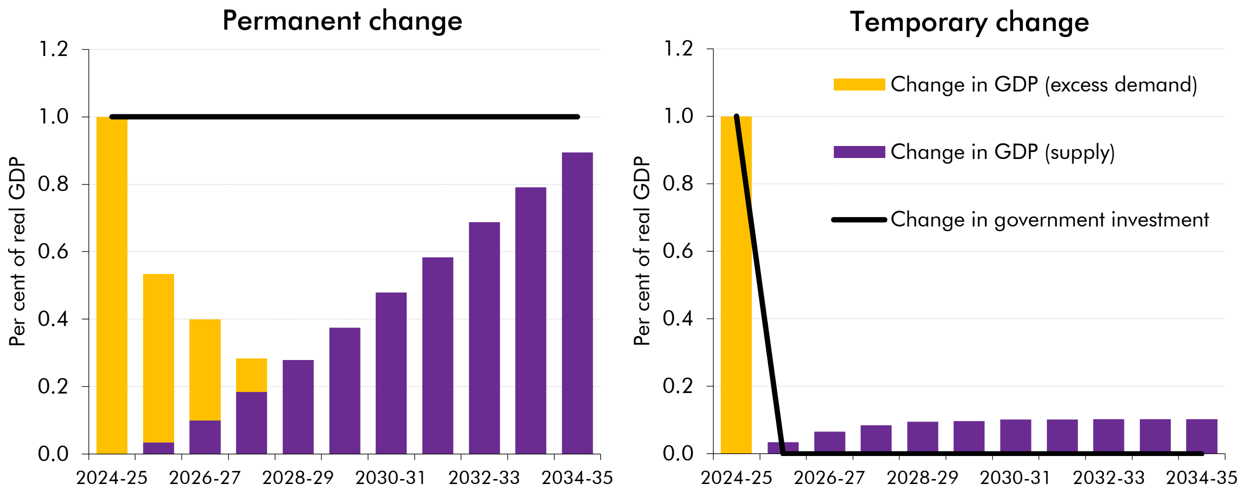
Overall impact of public investment on GDP

4.10 As discussed in paragraph 3.3, the increased investment also increases excess demand in the near-term. We would take this channel into account, as shown in Chart 4.3 and Table 4.1:[5]

- Our fiscal multipliers assume that the demand-side impact (yellow) from a **permanent increase** in government investment at 1 per cent of GDP tapers from 1 per cent of GDP in the first year to 0 by the fifth year of our forecast (left panel), as monetary policy responds to offset the resulting increase in inflation. The effect on supply (purple) continues to build over the forecast period, overtaking the demand effect by the fourth year of the forecast.

- The right panel of the chart demonstrates the same dynamics for a one-off **temporary increase** of 1 per cent of GDP. There are no second-year demand effects (yellow), as the fiscal stimulus is only present in the first year. The supply-side impacts (purple) gradually build as the stock of public assets starts producing capital services. The one-off increase in government investment gradually increases potential output based on the time lags assumed in our modelling framework. As shown in Chart 4.2 above, this effect attenuates beyond the forecast horizon, as the increase in the government capital stocks is retired (as discussed in paragraph 4.9).

Chart 4.3: Impacts on demand and supply



Source: OBR

4.11 The table below shows these impacts on demand and supply as proportions of the change in real investment in a given year. The 'excess demand effect' row for a permanent shock

[5] Our starting assumption is that the increase in potential output would feed through to actual output (i.e., that Say's law applies).

therefore represents our standard demand multipliers.[6] The 'supply effect' is based on the modelling framework described above.

Table 4.1: Impacts on demand and supply

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Permanent shock scenario											
Investment	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Excess demand effect	1.00	0.50	0.30	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Supply effect	0.00	0.03	0.10	0.18	0.28	0.37	0.48	0.58	0.69	0.79	0.89
Total effect	1.00	0.53	0.40	0.28	0.28	0.37	0.48	0.58	0.69	0.79	0.89
Temporary shock scenario											
Investment	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Excess demand effect	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Supply effect	0.00	0.03	0.06	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10
Total effect	1.00	0.03	0.06	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10

Other metrics for assessing the macroeconomic impacts of public investment

4.12 Another way to quantify the effect of a one-off public investment on potential GDP, as informed by our framework, is to calculate the investment's implied internal rate of return (IRR). We identify an economic rate of return (based on its impact on potential GDP, net of the initial investment cost) and a separate fiscal rate of return (based on the additional tax revenues generated, net of investment cost).

Defining the net present value and internal rate of return

4.13 Formally, the internal rate of return is defined as the discount rate that would make the present value of the future benefits from an investment equal to the initial cost of the investment. The IRR can also be interpreted as the annual compound rate earned from every unit of investment made for each period. The term "internal" refers to the fact that the calculation *excludes* external factors, such as the risk-free rate, inflation, the cost of capital, or financial risk (i.e., it is a measurement of the yield of an investment only, so it accounts for depreciation but not financing costs).

4.14 To calculate the IRR, we begin by first defining the net present value, NPV, of an investment project. This equals to the discounted sum of all future benefits it generates, B_n, which in financial terms are the income streams it produces and are valued in today's terms using a discount rate, r. The NPV accounts for the investment's cost (which is assumed to be one-off and has been normalised to 1 below):

[6] As the focus of this paper is on the long-run impact of changes in public investment on potential output, we have not reassessed whether our first-year demand multipliers could be too high given the economy's current degree of spare capacity. Some recent evidence suggests that this could be the case, such as Ramey, V., *The macroeconomic consequences of infrastructure investment*, 2021. Our current multipliers reflect top-down judgements that are informed by the wide range of evidence produced by a large number of studies, and there is a high degree of uncertainty around them. As usual we will consider their appropriateness in future forecasts.

$$NPV = \sum_{n=0}^{\infty} \frac{B_n}{(1+\mathrm{r})^n} - 1$$

4.15 The IRR is then the discount rate, $r = r^*$, that solves the following equation:

$$NPV = \sum_{n=0}^{\infty} \frac{B_n}{(1+r^*)^n} - 1 = 0$$

Calculating the economic net present value of a public sector investment

4.16 A public sector investment project also has near-term costs that generate future benefits (in the form of the higher output or of tax receipts that it generates). We can therefore calculate the IRR implied by an investment in our modelling framework above. Using the Cobb-Douglas production function as explained in paragraph 3.6 and by taking the partial derivative of potential output (Y) with respect to government's capital stock (K_G), we find the marginal contribution to GDP of an additional unit of capital:[7]

$$\frac{\partial Y}{\partial K_G} = \frac{\alpha Y}{K_G}$$

4.17 Assuming a constant output-to-capital ratio ($\frac{Y}{K_G}$) and by accounting for the retirement rate, and a discount factor, r, we get the expression below.[8] Here, the equation expresses the net present value of the GDP net of the initial investment cost, NPV_E, produced by an extra unit of investment (when the investment is made at $t = 0$, and for the moment we assume immediately produces benefits):

$$NPV_E = \frac{\alpha Y}{K_G}\left(1 + \left(\frac{1-\delta_G}{1+r}\right) + \left(\frac{1-\delta_G}{1+r}\right)^2 + \cdots + \left(\frac{1-\delta_G}{1+r}\right)^n\right) - 1$$

4.18 Assuming a sufficiently long-enough time horizon (i.e., as $n \to \infty$), we can simplify the above equation to:

$$NPV_E = \frac{\alpha Y}{K_G}\frac{1}{1-\frac{(1-\delta_G)}{(1+r)}} - 1 = \frac{\alpha Y}{K_G}\frac{1+r}{r+\delta_G} - 1$$

Calculating the economic internal rate of return of a public sector investment

4.19 With the above equation, we can choose the discount rate to set the NPV equal to zero. This is then the economic IRR, r_E^*:

[7] This calculation does not capture any costs or benefits not reflected in potential GDP, which could raise or lower the NPV and IRR.
[8] The modelling that underpins the previous sub section does not assume a constant capital share in the baseline projection; this does not have a large effect on the GDP benefits.

$$NPV_E = \frac{\alpha Y}{K_G}\frac{1 + r_E^*}{(r_E^* + \delta_G)} - 1 = 0$$

4.20 Given that r_E^* is likely to be relatively small, the above equation can be approximated as the spread between the marginal product of public capital (which depends on the initial output-to-public-capital ratio and the output elasticity of public capital) and the retirement rate on public capital:

$$r_E^* \approx \frac{\alpha Y}{K_G} - \delta_G$$

The fiscal net present value and internal rate of return

4.21 Public investment also affects the public finances through the additional tax receipts it generates. The NPV and IRR can be adjusted to take this into account, by assuming that any extra GDP produced by the investment is simply taxed at the economy-wide effective tax rate, τ.[9] Calculations for the fiscal net present value, NPV_F, and fiscal IRR, r_F^*, are equivalent to that above and so we do not repeat their derivation:

$$NPV_F = \tau\frac{\alpha Y}{K_G}\frac{1 + r}{(r + \delta_G)} - 1$$

$$r_F^* \approx \tau\frac{\alpha Y}{K} - \delta_G$$

4.22 As the second expression highlights, the fiscal rate of return is not simply the economic rate of return scaled down by the effective tax rate. This is because only being able to recoup a proportion of the benefits of holding a unit of capital lowers the benefits it generates over that period of time. But because both calculations assume the same cost to the government, this does not reduce the investment's upfront cost (or, more correctly, the per period cost of holding a unit of capital implied by the rate at which it loses value over time).

Rates of return with and without time lags

4.23 The equations above illustrate how economic and fiscal internal rates of return can be calculated and illustrate the key dynamics at play. But they do not include the up to ten-year time lags, θ_t, described in paragraph 3.25 and incorporated in the simulations above. By incorporating these, we arrive at the following expressions for the economic and fiscal rates of return on a unit of extra investment at time t=0:

$$NPV_E = \left(\sum_{t=0}^{10} \theta_t \left(\frac{1 - \delta_G}{1 + r_E^*}\right)^t\right)\frac{\alpha Y}{K_G}\frac{1 + r_E^*}{(r_E^* + \delta_G)} - 1 = 0$$

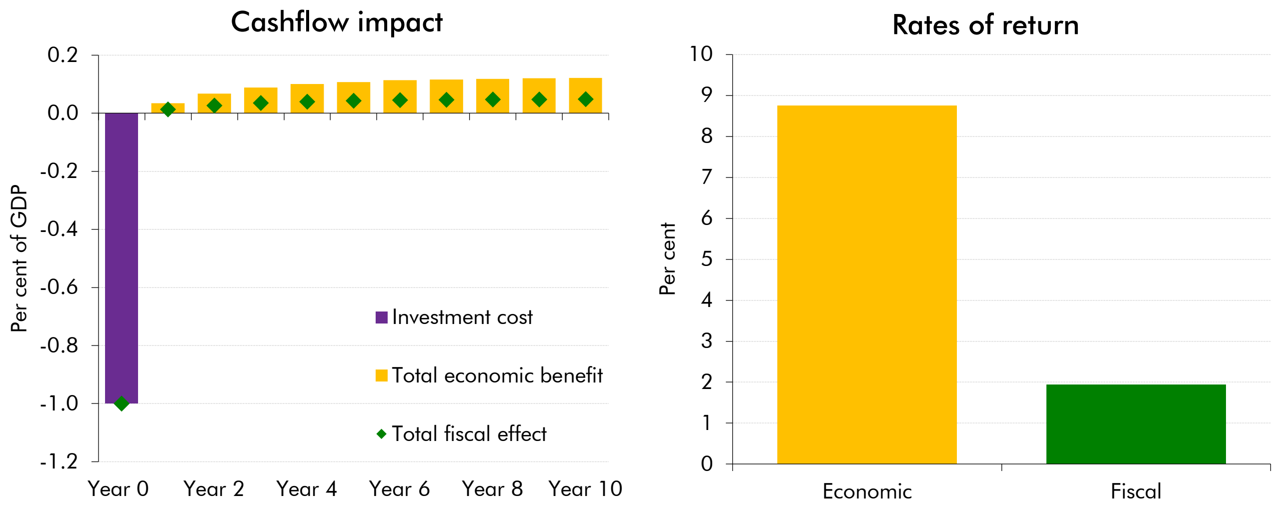
[9] This does not capture any direct fiscal impacts on current spending or receipts, which could raise or lower the NPV and IRR.

$$NPV_F = \tau\left(\sum_{t=0}^{10} \theta_t \left(\frac{1-\delta_G}{1+r_F^*}\right)^t\right)\frac{\alpha Y}{K_G}\frac{1+r_F^*}{(r_F^*+\delta_G)} - 1 = 0$$

Rates of return

4.24 On the basis of the assumptions above, for a one-off 1 per cent of GDP increase in public investment, this methodology implies an 8.7 per cent real economic IRR and 1.9 per cent fiscal IRR, as shown in the right panel of Chart 4.4. Within our framework, the government incurs all the costs of a public investment (the purple bar in the left panel of Chart 4.4). The benefits to the economy after accounting for retirement rates and time-to-growth lags increase gradually (the yellow bars, which would fall away only gradually beyond the chart's 10-year horizon). The implied economic rate of return (the yellow bar shown on the right panel of the chart) is derived by calculating a discount rate such that these upfront costs and future benefits are equalised (i.e., the net present value equation outlined in paragraph 4.23 holds). The real fiscal IRR reflects that the fiscal benefits are lower, as the government only directly reaps 40 per cent of the economic benefits in tax receipts (green diamonds, reflecting an assumed economy-wide effective tax rate of 40 per cent). A lower rate of return is then required to equalise the costs and these direct benefits (green bar).

Chart 4.4: Calculating the rates of return on public investment



Source: OBR

Cost-benefit analysis

4.25 A second way to summarise the implications of our modelling approach is through a Benefit-Cost Ratio (BCR) framework. The BCR is the net present value of the benefits of an investment project, as a ratio of the net present value of its cost across the infinite time horizon. We have assumed that investments have one-off upfront costs that have been normalised to one, so economic and fiscal BCRs for our approach can be calculated as:

$$BCR^E = \left(\sum_{t=0}^{10} \theta_t \left(\frac{1-\delta_G}{1+r}\right)^t\right)\frac{\alpha Y}{K_G}\frac{1+r}{(r+\delta_G)}$$

$$BCR^F = \tau\left(\sum_{t=0}^{10} \theta_t \left(\frac{1-\delta_G}{1+r}\right)^t\right)\frac{\alpha Y}{K_G}\frac{1+r}{(r+\delta_G)}$$

4.26 By varying the discount rate, different sets of BCRs can be generated. The fiscal BCRs suggest that public investments may not necessarily pay for themselves in purely fiscal terms, and may, at times, generate fiscal losses. They are illustrative and used only to sense-check the results of our modelling approach for an aggregate increase in public investment:

- At the **economic rate of return** of 8.7 per cent, derived using our IRR methodology, we find an economic benefit-cost ratio of 1:1 from a one-off increase in investment of 1 per cent of GDP. At a discount rate of 1.9 per cent (the **IRR in fiscal terms**), the fiscal benefit to cost ratio is also 1:1.

- At the Treasury's **Green Book social discount rate** of 3.5 per cent, the implied economic BCR is 1.9:1**.** This discount rate reflects a term to account for time preference (society's preference "*for value now rather than later*") and a term to account for expected growth in per capita consumption (given that "*future consumption will be higher relative to current consumption and is expected to have a lower utility*"). Under this assumption, the implied fiscal BCR is 0.8:1.[10]

- **At an assumed real gilt rate of 2.4 per cent**, the economic BCR is 2.3:1 and the fiscal BCR is 0.9:1.[11] This discount rate is our market-expectations-based March 2024 forecast for the weighted-average nominal interest rate on conventional gilts in 2028-29, minus 2 percentage points to account for expected inflation. This reflects the government's expected average real financing costs and therefore an alternate use of the investment's financing.

Comparison of results to empirical evidence

4.27 Overall, an implied 8.7 per cent internal rate of return is broadly in line with, but slightly lower than, the 10.4 per cent average rates of return seen since 2013 in the private sector.[12] It is also significantly above the government's financing costs, where the forecasted effective real gilt rate is around 2½ per cent in 2028-29 from our March 2024 forecast. An IMF paper also suggests a fiscal BCR that is close to 1:1.[13] The evidence of falling output elasticities over time suggests that some past investments, like building the road or sewage networks, likely resulted in significantly greater rates of return than this.[14] Of course, not all public investment would be expected to achieve the average outcome. For instance, a 2021 report on Highway England's second Road Period project to improve England's strategic

[10] HM Treasury, *The Green Book: central government guidance on appraisal and evaluation,* April 2023.
[11] We currently derive the real gilt rate from the 4.4 per cent nominal gilt rates forecasted for 2028-29 in the OBR's March 2024 EFO publication, adjusted for annual CPI inflation of 2 per cent.
[12] ONS, *Profitability of UK companies: April to June 2023*, 2024. This is calculated using the average net rates of return on capital held by private non-financial corporations: 10.4 per cent was the average between the first quarter of 2013 and the second quarter of 2023.
[13] The IMF modelling of the effects of public investment shocks on output finds a fiscal BCR that is close to 1, but with a broad confidence interval. IMF, *Chapter 2 growth impact of public investment and the role of infrastructure governance,* September 2020.
[14] Bom, P., and J. Ligthart, *What have we learned from three decades of research on the productivity of public capital?,* 2014, and IMF, *Chapter 2 growth impact of public investment and the role of infrastructure governance,* September 2020.

road network found expected benefit-cost ratios between 1.9:1 (for constructing bypasses) to 2.4:1 (for building 'smart' motorways).[15]

Conclusion

4.28 The results and key parameters shown in this chapter are summarised in Table 4.2. Our empirically-based modelling framework generates material long-run effects on GDP from additional public investment, if it is sustained (the impacts of a reduction in public investment would be correspondingly negative). The implied internal rates of return are positive, although the return to the exchequer is likely to be much smaller than the return to the economy. We would not blindly apply the results in Table 4.2 to assess the economic impacts of all possible future changes in public investment. In particular, we would need to consider the type and mode of investment, source of financing, general equilibrium effects, and policy-specific factors, which we discuss in the next section.

Table 4.2: Economic and fiscal internal rates of return

	Per cent			Internal rate of return, per cent		
	Capital[1]	Retirement rate	Output elasticity	Economic	Fiscal	Long-run GDP impact[2]
Government	55	4.0	0.1	8.7	1.9	2.4

[1] Capital stocks are expressed as gross capital stocks, as a percentage of GDP, in 2024-25.

[2] Impact at the 50-year horizon of a sustained 1 per cent of GDP increase in government investment.

[15] Highways England, *Economic analysis of the second road period,* July 2020. This analysis uses Green Book appraisal techniques.

5 Further considerations

5.1 The modelling framework described in the previous section enables us to illustrate how a stylised 1 per cent of GDP increase in public investment would affect potential output in a partial equilibrium framework. But there are four further considerations that we would encounter, when faced with changes in planned levels of public investment. These include:

- the **type of assets** to be purchased, including whether to distinguish between economic infrastructure and other types of public investment;
- the **mode of investment**, including whether to distinguish between direct investment in the public sector's own assets and support for investments that are held privately;
- any **general equilibrium effects**, including those potentially stemming from the choice of financing and from impacts on the supply of other factors of production; and
- the **delivery and effectiveness of public sector investment**.

Investment in different types of assets

5.2 Public capital affects output through two main channels:

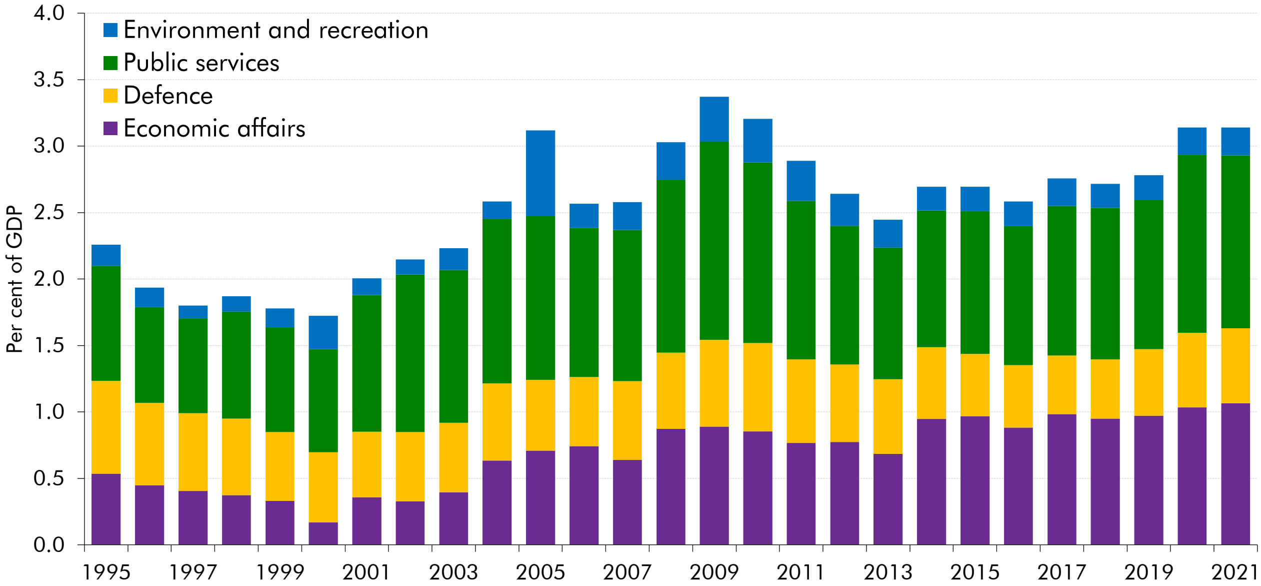
- First, investments that improve the quality, quantity, or cost-effectiveness of **publicly-provided inputs to production in the private (and public) sectors**. In particular, the Bom and Ligthart metastudy looks at studies which focus on the provision of economic infrastructure such as *"roads, railways, airports, and utilities, such as sewerage and water facilities"*, which they term 'core' capital. It suggests that they may find over one-third larger estimated effects on private sector output than average investments do.[1] However, the relevance of this result for future changes in economic infrastructure spending the UK is not straightforward, given that many of the papers that they draw on focus on the US or other countries, that in many studies the infrastructure considered is transport networks specifically, and due to the mixed availability of data on public sector infrastructure stocks and flows in the UK.[2] Evidence suggests some

[1] Bom, P., and J. Ligthart, *What have we learned from three decades of research on the productivity of public capital?,* 2014.
[2] The ONS has made significant progress in its measurement of capital stocks in its main investment and capital stocks data releases, which are split into selected industries and asset types. See ONS, *Capital socks and fixed capital consumption*, December 2023. 'Core' capital broadly corresponds to the data-led functional definition employed in ONS's experimental economic infrastructure series, ONS, *Infrastructure in the UK, investment and net stocks*, July 2024. But, again, this is just for general government (excluding energy), and there is no consistent stock series, except for the market sector. The Treasury's *Whole of Government Accounts* (*WGA*) and *Public Expenditure Statistical Analysis* do report public sector stocks, but on different cycles and bases, with the latest WGA data only for 2021-22.

other sorts of public sector investments, such as in R&D, may also boost production elsewhere in the economy too.[3,4]

- Second, investments that improve the production of **public sector output that is provided for and/or consumed by households**. This might include greater output of public services (such as healthcare and education) or defence. The Bom and Ligthart metastudy suggests that estimated elasticities that only look at spillovers from public capital to private GDP might be around 20 per cent smaller than those that do not, which might appear to suggest that the proportionate response from public sector output was larger than from the private sector.[5] But again interpreting this result or its implications for fiscal sustainability is not straightforward, partly due to differences in the size and measurement of public sector output in different countries.[6] Chart 5.1 shows that over a third of public investment by function is in public services and around a fifth in defence (with a third in the economic affairs category that corresponds most closely to economic infrastructure).

Chart 5.1: Government gross fixed capital formation by function



Note: Economic affairs includes spending on general economic affairs, labour and commercial affairs, transport, and other categories. Public services includes spending on housing, health, public safety, social protection, and education.
Source: OECD

[3] For instance, Fieldhouse A., Mertens, K.,, *The Returns to Government R&D: Evidence from U.S. Appropriations Shocks*, May 2023, which found an elasticity of 0.1 for research and development assets in the US with respect to private sector productivity. And in the UK Haskel et. al., *The contribution of public and private R&D to UK productivity growth*, 2015 suggests that a 10 per cent increase in public research and development is associated with a 0.03 per cent increase in private sector TFP growth.
[4] We have focused in this paper on the impact of investment, as defined in our forecast, using internationally-agreed statistical definitions of investment flows and capital stocks. Current spending such as on education and skills or healthcare, could also support productivity by boosting the knowledge and health of the workforce, but is therefore outside the scope of this paper.
[5] Again, see Bom, P., and J. Ligthart, *What have we learned from three decades of research on the productivity of public capital?,* 2014
[6] For instance, some public output is recorded at cost, and so simply increases with public spending rather than with the volume of public services. As we discussed in Box 2.4 of our March 2021, *EFO*, more public output (including in education and healthcare) is directly measured in the UK than in most other countries. In practice, the effect on wages and salaries from an increase in the volume of public output would depend on whether a larger response from directly-measured public sector output might alter the relative productivity of workers in the public and private sectors, whether workers in these sectors are able to capture these changes in productivity, whether they are complements or substitutes, and whether they can move between sectors in response to these changes.

5.3 Given our resources, the OBR cannot undertake a full bottom-up analysis of all types of public sector investment, so will need to apply judgment at a more aggregated level. Reflecting these challenges, we intend to use a single elasticity which relates the change in total GDP to the change in the public capital stock. In effect, this assumes an average rate of return on all investment. But we would welcome feedback on our approach, as we discuss in Section 6.

5.4 It is also worth emphasising that the aggregate approach set out in this paper cannot replicate the granularity of results provided by detailed cost benefit analysis of individual economic infrastructure projects. This type of analysis, which is produced by government departments and arm's length bodies could be used in conjunction with this top-down approach to better understand the effects of investment plans on the economy.

Indirect investment

5.5 In the analysis above, we illustrate how the public sector could increase potential output through direct government investment in its own capital stock (i.e., public sector fixed capital formation). But public sector gross fixed capital formation made up around 75 per cent of overall public sector gross investment between 2010-11 and 2023-24. As discussed in Section 2, the remainder is known as 'capital grants'. This includes fiscal transfers to the private sector intended to support, fund, or finance private sector investment (comprising grants themselves, as well as any fiscal transfers recorded when equity injections, loans, or guarantees are extended).

5.6 Our starting point will be to assume this spending would have the same impact on GDP as direct investment, after accounting for three issues, which we would deal with on a case-by-case basis:

- A substantial proportion of existing capital grants are **not intended to stimulate domestic investment**. For instance, the concessionary element of student loans and transfers related to tax litigation, make up around a quarter of all capital grants, but this spending is unlikely to have an immediate impact on the formation of national accounts measures of private sector capital stocks in the UK. Capital grants also often capture other unique or one-off items, such as EU exit payments, that we would often want to exclude from the analysis in this framework, for the same reason.

- **Capital grants are a less direct means of promoting investment spending**. This makes assessing additionality provided by capital grants more complex than with direct government fixed capital formation. For instance, if government capital grants are used as a substitute for privately financed investment that would have happened without them, rather than funding or financing additional investment in assets, the net effect of public spending on potential output would likely be reduced.

- **Government and private investors may not be perfect substitutes.** On the one hand, private companies may not be adept as at delivering some forms of policy-driven investments. On the other hand, incentivising investment via the private sector may boost its impact on output by instilling stronger commercial discipline in the management of the relevant projects. We do not have a firm basis for assessing which of these effects would dominate.

General equilibrium effects

Sources of financing

5.7 In the analytical framework described in the previous section, the impact of public investment on potential output does not depend on how that investment is financed. It does not distinguish between public investment that is funded via higher borrowing versus by increases in taxes or reductions in current spending. In a 2021 analysis, the CBO found that the economic effects of changes in the US Federal government investment spending depended on the source of funding.[7] Specifically:

- Where this investment was financed by additional **borrowing**, the level of GDP was unchanged at their 30-year horizon, as higher borrowing led to higher interest rates, which offset the effects of the additional investment via 'crowding out', where increased interest rates offset the boost to GDP from the additional public investment by reducing funds available for private investment.

- Where the additional investment was financed by **a reduction in other spending** ('non-investment purchases) the level of GDP was 0.1 per cent higher at the 30-year horizon. This reduction in other spending was assumed to not directly affect incentives to work and have no net effect on demand for goods and services in the economy.

5.8 Our medium-term economy forecasts are typically conditioned on market expectations of future interest rates. So, if the features of a deficit-financed fiscal announcement were broadly in line with market participants' expectations, our economy forecast may incorporate some 'crowding out' of the funds available for private investment (although isolating whether and how this reflects the effect of specific policies would require a departure from our current approach). In exceptional cases, we have judged that the fiscal event itself will reveal significant new information on fiscal policy that would move the market curve. But the possibility of additional borrowing pushing interest rates up applies to all changes in fiscal policy, including changes to the level of taxation and current spending.

5.9 Changes in levels of taxation or current spending may have their own effects on potential output, which we look to capture in our forecast. For example, we assumed that the 6 percentage point increase in corporation tax announced alongside our March 2021 forecast would reduce potential output by 0.3 per cent over the long-term. And the recent decisions to leave tax thresholds frozen in the face of higher inflation decreased labour supply by 0.4 per cent (130,000 workers in full-time equivalent terms). This underscores the importance of

[7] CBO, *Effects of Physical Infrastructure Spending on the economy and the Budget under two illustrative scenarios*, August 2021. See also: Nelson, J., and K., Phillips, *The Economic effects of financing a large and permanent increase in government spending*, 2021.

looking at the net supply-side effect of all policy changes announced in a given event in the round, rather looking at an increase in public investment in isolation.

Factor supply

5.10 To isolate the impact of direct (or indirect) public investment in capital stocks, the analysis in this chapter uses a 'partial elasticity', holding other factors of production fixed. But by raising the marginal product of private capital, greater public capital could raise returns in the private sector and labour market. Our production function enables us to incorporate 'crowding in' along this channel: if business investment then increases in response to these higher returns, GDP would be boosted via capital deepening. The degree to which this would be expected to occur would depend on the extent to which public and private investment are complements or substitutes. (A response from labour supply is also possible, but less likely to be significant as largely offsetting income and substitution effects render labour supply relatively inelastic.)

5.11 Our near-term business investment forecast is typically based on survey indicators and industry reports, so we would need to consider whether the combined effect of changes in public investment and any other policy changes would induce a further response. Any effect could have significant further lags. In any case, discussion of these sorts of responses falls outside the scope of the paper, and applies to the net effect of all fiscal policy interventions, rather than changes in public investment specifically. They are another form of general equilibrium response that we may explore in further work.

Scrutinising the fiscal impact of investment plans

5.12 This paper has focused on how we will assess the economic impact of changes in the overall level of public investment spending. This overlaps with several issues that we consider when scrutinising the size and profile of the fiscal cost of a given set of government spending plans, including whether they appropriately reflect the 'time to spend' and 'time to complete' lags outlined in Section 3. We can consider all these issues using elements of our standard approach to scrutinising government policy costings.[8]

5.13 On the level of public spending, our fiscal forecast reflects any other associated 'direct' effects on the public finances of changes that accompany changes in investment spending, such as any ongoing impacts on current spending, that may be required to deliver the investment's effect on productivity. The additionality of new public investment is also important to consider, especially in the case of indirect investment in sectors where there is a mix of public and private investors. As discussed above, public investment may substitute for or crowd out private investment that would have happened in the absence of government intervention. In other cases, public investment may act as a complement or catalyst for additional private investment.

5.14 On the timing of public spending, particularly for operational measures, we often consider issues around deliverability and effectiveness of the government's spending plans. This

[8] See OBR, *Briefing Paper No.6: Policy costings and our forecast,* 2014.

includes reflecting likely lags for recruitment and training, staff turnover, optimism bias in modelling, and project plans for key components such as the rollout of any required IT programmes. For instance, our assessment of the economic impact of the 2023 increases to childcare funding assessed the ability of the sector to deliver the additional places, as well as the incentives for individuals that the funding provided.

5.15 Our assessment of 'time to spend' also considers whether to adjust our spending forecasts to reflect the likelihood of underspends against announced public investment plans. This could lower or delay spending, as past analysis suggests that, in general, rapid increases in capital expenditure are delivered more slowly than originally planned.[9] Project delays can feed through directly to shortfalls in overall planned spending. But they can also lead to funding being diverted to other projects, which therefore may not affect the overall level of underspend. To effectively monitor any judgements we make, we will therefore need to ensure we receive robust information from the Treasury and other departments on any material delays and whether any funding is diverted to other projects.

5.16 As with the economic impact of project-level investment plans, we are not resourced to undertake detailed project-level assessment of deliverability risks. As a result, our approach will depend on the provision of sufficiently robust and transparent information on these risks from the Treasury and government departments, and we will draw on external expertise where that is possible. But inevitably we will still need to do a substantial degree of aggregation and apply top-down judgements. We can also take a risk-based approach involving a greater degree of ongoing scrutiny for larger and more complex projects.

Concluding remarks

5.17 This paper set out to quantify the magnitude of the effects of public investment on potential output and discuss the speed at which these effects might be expected to occur. This section has set out several of the further considerations that would be associated with an actual set of changes in public investment plans. We hope that this discussion paper transparently explains the approaches we are currently taking. We will continue developing our modelling and analysis as the evidence base improves further and in response to any further feedback that we receive, as we discuss in the next section.

[9] See Box 3.2 of our March 2020 *EFO*

6 Discussion questions

6.1 In developing the modelling framework for estimating the impact of public investment on potential output, we have identified a number of areas in which we would welcome your feedback.

6.2 Regarding the **general modelling framework** as it currently stands and is described in Sections 3 and 4, we welcome comments and suggestions concerning our assumptions on

- how the public capital stock affects potential output via an **assumed elasticity**;
- the **retirement rates** used;
- the **lag structure** in which investment affects potential output; and
- the internal economic and fiscal **rates of return** they imply.

6.3 Regarding the further development of that framework, Section 5 raised four specific areas for further consideration. In that context, we welcome comments and suggestions on:

- How to develop our modelling to account for the effects of **different types of public investment** in different sectors of the economy, including how best to scrutinise the impact that a given profile of investment spending will have on our economy forecast.
- How to account for **different modes of investment,** including indirect investments.
- Whether to make further adjustments for **general equilibrium effects** in response to public investment changes, such as changes in interest rates or responses of other factors of production.
- How best to **scrutinise the impact on our fiscal forecast** of changes in public investment, and whether there are elements of our standard approach to costing policies and forecasting spending that we would need to adapt.

6.4 Finally, we would welcome comments and suggestions on any other considerations that you think we should take into account in analysing the economic and fiscal implications of changes in public investment.

6.5 Please send all suggestions to feedback@obr.uk.