The macroeconomic impact of government innovation policies:
A quantitative assessment

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We intend this framework to inform the debate about the direction of economic growth and the use of mission-oriented policies to confront social and technological problems. Our work will feed into innovation and industrial policy, financial reform, institutional change, and sustainable development.

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Executive summary

The slow growth experienced by the UK and other advanced economies since the financial crisis of 2007-08 has led to renewed policy interest in the role of government policy in stimulating investment, productivity growth and innovation. The UK's industrial strategy places particular emphasis on the role of research and development (R&D) spending in achieving such an outcome, noting that the UK significantly lags behind its competitors in both public and private R&D spending.

But beyond this, there is also a need for more joined-up thinking between macroeconomic—especially fiscal—and innovation policy in the UK. In particular, there is an opportunity to use the Industrial Strategy Challenge Funds to steer innovation towards solving big problems. This requires a 'mission-oriented' innovation lens; that is, innovation focused on concrete societal problems that can only be solved by multiple sectors interacting in new ways. Using such an approach, public policy can shape and co-create new markets and directions for innovation and investment-led growth (Mazzucato 2016; 2017; UCL Commission on Mission-Oriented Innovation and Industrial Strategy 2019).

Appraising and evaluating the economic impact of such policies effectively is a key challenge. Conventional microeconomic evaluation tools derived from welfare economics such as cost-benefit analysis (CBA) and discounting assume that government interventions should be limited to where there are clear instances of market failure and can only have short-run effects on the economy, with long-run (or 'trend') growth driven by supply-side factors. Meanwhile, the conventional macroeconomic approach to fiscal policy considers public investment as beneficial mainly in the short run as a countercyclical demand-side instrument during recessions, or to ameliorate frictions, market rigidities and market failures. This view also argues that public expenditure 'crowds-out' private investment by artificially raising the rate of interest, which is considered as the main determinant of business investment.

These types of approaches—focused on marginal change and 'market-fixing'—are not well suited to evaluating the impact of mission-oriented policy. This report instead argues for a 'market-shaping' approach to fiscal and innovation policy appraisal and evaluation that is able to capture the longer term structural changes to the economy that directed innovation spending can have on the demand side as well as the supply side of the economy, including dynamic spillover effects (see also Kattel et al. 2019).

We propose an alternative macroeconomic view based on the notion of a 'supermultiplier', a model that accounts for both multiplier and accelerator effects from directed (mission-oriented) public sector innovation spending (Deleidi and Mazzucato 2018; 2019).

This perspective can be summarised as follows: (i) private investment—rather than being primarily influenced by interest rates—is determined by demand, expectations of future growth and technical progress; (ii) innovation is endogenous and determined by targeted public policies that positively stimulate private initiative (crowding in rather than crowding out); and (iii) expansionary fiscal policies generate positive effects on output, effects which can have long-run impacts when they are driven by persistent and systemic policies geared towards structural transformation.

Using this framework, the report empirically examines several alternative fiscal policies in terms of their impact on GDP growth and private investment using the structural vector autogression (SVAR) econometric technique. We study United States spending data as this gives us a long enough time series with quarterly observations to enable rigorous econometric estimates. UK data is on an annual basis only and for a shorter time period.

The policies we study are: (i) tax cuts; (ii) investment in 'shovel-ready' projects and infrastructure; and (iii) directed spending aimed at structural transformation through innovation across multiple sectors—or 'mission-oriented innovation'. The latter we proxy with U.S. military R&D spending which is well established as having impact on multiple different sectors in the economy (Mowery 2010; Foray et al. 2013).

Table 1 summarises our results for a range of different types of government spending. We use two different measures to capture this impact. The first is the 'GDP multiplier'. This shows the impact on the national economy of a £1 (or $1 in the US case) increase in the respective type of public spending. This measure captures both public and private additional spending across the whole economy. So the GDP multiplier for 'investment including (R&D)' in Table 1 means that every additional £1 of public spending of this type generates an increase of £2.12 in total national output.

Secondly, we show a 'private sector R&D multiplier'. This shows how much private R&D spending is generated by £1 of public spending of different types. These multipliers are lower because they only capture one type of spending in one sector (R&D in the private sector). To take an example, we find that an additional £1 of military R&D spending generates £0.51 in additional private sector R&D spending.

Our results show large variation in the economic impact of different types of public investment. As expected, public investment spending (including R&D) generates a higher multiplier than public consumption spending. But R&D spending generates a much higher GDP multiplier and mission-oriented, directed innovation spending (proxied by military R&D in the US) generates the largest 'supermultiplier' effect, around ten times higher than standard government spending excluding R&D. Mission-oriented spending also generates the highest private sector R&D multiplier (0.51) suggesting it generates the highest expectations of growth. It 'crowds in' private investment, rather than crowding it out.

Table 1. Economic multiplier of different types of government spending (based on quarterly US data from 1947-2017).

Type of government spending	GDP multiplier	Private sector R&D multiplier
Total government spending (excluding R&D)	0.82	0.05
Consumption	1.12	0.03
Investment (including R&D)	2.12	0.08
Non-military R&D	7.76	0.25
Military R&D	8.82	0.51

The report provides a first systematic quantitative assessment of the effects of directed innovation spending within an industrialised developed country. Our findings suggest the impact on this type of spending may be significantly higher and with longer term effects than other forms of government spending. In addition, our findings suggest that such policies produce permanent rather than temporary effects on the level of output and could have major economic benefits anywhere in the economic cycle and not just during recessions as counter-cyclical measures.

There are important differences between the US and British economy that mean one cannot assume these figures translate exactly to the UK case. Nevertheless, the large orders of magnitude differences in the multipliers clearly demonstrate the potentially enormous value of mission-oriented innovation policy in leveraging in spending from other sectors of the economy. They also suggest the need for further research into how to more effectively appraise and evaluate such policies. This will likely be aided by greater coordination between government departments in charge of fiscal policy and industrial policy.

1. Introduction

The slow growth experienced by the UK and other advanced economies since the financial crisis of 2007-08 has led to renewed policy interest in the role of government policy in stimulating investment, productivity growth and innovation. The UK Government's white paper, *Industrial Strategy: Building a Britain fit for the future*, notes that the UK significantly lags behind both the US and Europe in regard to total—including both public and private—R&D spending, and suggests a spending target of 2.4% of GDP by 2027 and 3% in the longer term (HM Government 2018: 66).

The current focus on industrial strategy opens the door for more joined-up thinking between macroeconomic—especially fiscal—and innovation policy in the UK. In particular, there is an opportunity to use the Challenge Funds to steer innovation towards solving big problems. This requires a 'mission-oriented' innovation lens (Mazzucato 2016; 2017; UCL Commission on Mission-Oriented Innovation and Industrial Strategy 2019); that is, innovation focused on concrete societal problems that can only be solved by multiple sectors interacting in new ways.

This report challenges existing approaches to the economic appraisal of public investments at the project (microeconomic) level based on the use of tools such as cost-benefit analysis (CBA) and discounting. This approach assumes that government interventions should be limited to addressing market failure and can only have short-run effects on the economy. The report also challenges the conventional macroeconomic approach to fiscal policy, which considers public investment as beneficial mainly in the short run as a countercyclical demand-side instrument during recessions, or to ameliorate frictions, market rigidities and market failures.

The report analyses the macroeconomic impact of different types of fiscal policies in terms of gross domestic product (GDP) and private investment growth using a new theoretical framework. It combines key insights from the industrial economics literature on innovation (public and private) with the macroeconomics literature on the effects of fiscal policies on economic growth. The report aims to: (i) understand which types of fiscal policies are most efficient in terms of GDP growth; and (ii) to better conceptualise the role that public policy can play in shaping and creating new markets and directions for innovation and investment-led growth.

We analyse the relationship between different forms of public spending and the macroeconomy by conducting an empirical analysis using the Structural Vector-Autoregression (SVAR) econometric method. The empirical analysis is based upon US time series data for the different categories of spending. US data is superior to that in other countries due to its quarterly availability which allows us to estimate statistically robust economic multiplier estimates and because the time series is available over a much longer time period, enabling a long-term assessment of the impact of innovation-related public spending. We use innovation spending on defence (military R&D) as a proxy for 'mission-oriented' innovation, that is innovation that is more 'directed' and requires cross-sectoral interactions (e.g. encompassing aerospace, textiles, biotech, arms etc.) following previous academic studies (Mowery 2010; Foray et al. 2013).

There are important differences between the US and British economy that mean we cannot assume these figures would be exactly the same in the UK context. Nevertheless, the results provide a first systematic quantitative assessment of the effects of directed innovation spending within an industrialised developed country. Our findings suggest the returns on this type of spending may be significantly higher and with longer term effects than other forms of government spending. The findings from our econometric estimations are further supported by similar results from a numerical simulation of the supermultiplier theory which we report in Appendix 4.

The remainder of the report is structured as follows. In Section 2, we review and critique the existing UK practice and policy framework for analysing the economic impact of public policy, including innovation policy, which is mainly focused on the microeconomic impacts of particular policy programmes rather than wider macroeconomic outcomes. In Section 3, we examine the existing perspectives on the macroeconomic impact of public spending. In Section 4, we empirically analyse the different forms of fiscal policy (taxes, capital investment and mission-oriented policies) using the SVAR method. Section 5 concludes with a discussion of policy implications and suggestions for further research. Further technical information on the empirical methodology is provided in the Appendix to this report.

2. The economic return on public spending and innovation policy—current theory and practice in the UK

2.1 The UK Government's approach to economic appraisal

The UK Government's main approach to appraising the value created by public spending is based upon cost-benefit analysis (CBA) and net present value (NPV) approaches, as laid out in The Green Book (HMT 2018).[1] The Green Book states that, 'Economic appraisal is based on the principles of welfare economics—that is, how the government can improve social welfare or wellbeing' (ibid. p.5). The latter is often described as 'social value' and 'value for money'.

The Green Book and outlines the main 'rationales for government intervention' as being driven by market failures, where market failure is defined in terms of Pareto efficiency (when nobody can be made better off without someone else being made worse off) (ibid. p.13). [2] The guidance states that, 'To provide a useful rationale which will support development of the intervention it is necessary to identify the specific market failure being addressed, rather than describing this is general terms.' (ibid.).

Market failures mentioned include public goods, imperfect information, moral hazard, externalities and market power (ibid. p.14). The guidance also states, however, that the rationale can also be based on 'strategic objectives', 'improvements to existing policy' or 'distributional objectives' that the government wishes to meet. It is possible that mission-oriented innovation policy could be described as a 'strategic or distributional objective'.

The Green Book encourages the consideration of an initial wide range of options for intervention. These should then be whittled down to a shortlist by taking into account 'strategic fit to wider policy objectives, potential value for money, affordability and achievability' (ibid. p.5). Shortlisted options are then subjected to a social cost-benefit analysis (SCBA) process with 'business as usual' (i.e. no change) as the base case. SCBA requires that all impacts—social, economic, environmental and financial—are assessed. Costs to society are given a negative value and benefits a positive value.

The costs of using assets and resources are defined by its opportunity cost, i.e. the value which reflects the best alternative use a good or service could be put to. The opportunity cost of labour should include the total value of the output produced by employees. Alternatively, where there is

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[1] Guidance on how to evaluate public policy is provided in The Magenta Book (HMT 2013). BIS, the predecessor to Department for Energy and Industrial Strategy (BEIS), has also published evaluation guidance (BIS 2014). Neither of these publications contain guidance on economic appraisal, however.

[2] See Kattel et al. 2018for a more detailed examination of the 'market failure' approach to government policy with its origins in neoclassical welfare economics.

difficulty in monetising values, a social cost-effectiveness analysis (SCEA) —which compares the costs of alternative ways of producing the same or similar outputs—is used.

The guidance favours the monetising of the SCBA in market prices to allow for comparison, but also allows for non-monetizable costs and benefits to be presented instead of—or complementing—the monetised evaluation when needed. The relevant costs and benefits are those for 'UK society overall', not just the public sector, including households, businesses, individuals and the not-for-profit sector. SCBA should be calculated 'over the lifetime of the intervention or asset' with a time horizon of ten years being suitable for many interventions (ibid. p.6), whilst for certain assets, such as buildings, 60 years may be necessary (ibid.).

To enable price comparison of interventions whose return will vary in terms of time, all SCBA should be discounted using a social time preference rate (STPR) of 3.5% (in real terms) for the first 30 years and reducing thereafter to 3% and then 2.5%. The STPR has two components: (i) 'time preference', capturing the preference for value now rather than later, and (ii) 'wealth effect', reflecting the fact that future consumption is expected to have lower utility as prices rise (Ramsey 1928). After adjusting for inflation and discounting, costs and benefits can be added together to calculate the net present social value (NPSV) for each option (HMT 2018 p.21).[3]

The Green Book recommends applying specific adjustments for 'optimism bias' which is 'the proven tendency for appraisers to be too optimistic about key project parameters, including capital costs, operating costs, project duration and benefits delivery' (ibid. p.6). Cost estimates are increased by a set percentage to reflect evidence of underestimation from previous similar interventions. Adjustments should be based on an organisation's own evidence base for historic levels of optimism bias. Risk analysis and sensitivity analysis involving the estimation of 'switching values'—the values an input would need to change in order to make an option no longer viable—are encouraged (ibid. pp.6-7).

2.2 Problems with the standard appraisal methodology when assessing the economic value of innovation policies

At a theoretical level, there are problems with the 'market-failure' framework used in *The Green Book* as a rationale for government intervention. Many economists have rejected the approach since the concept that markets by themselves lead to efficient outcomes is dependent on conditions—perfect information, completeness, no transaction costs or frictions—that have never been empirically demonstrated (Coase 1960; Stiglitz 2010; Kattel et al. 2018). Rather, markets are always incomplete and imperfect and hence not 'constrained Pareto efficient', i.e. they are never in a situation where a government (a central planner) may not be able to improve upon a decentralised market outcome, even if that outcome is inefficient (Greenwald and Stiglitz 1986).

The market-failure justification also implies that pure private markets/private goods can exist independently of public or collective action, but again there are very few examples of such phenomena, calling into question the usefulness of the dichotomy between public vs. private or state

[3] For a recent discussion of the latest approaches to social time preference theory, see Freeman et al. (2018).

vs. market (Nelson 1987). As an example, historical research demonstrates that sophisticated monetary and exchange systems existed thousands of years prior to the establishment of formal markets and that state or hierarchically organised administrations (e.g. temples or tribal orders) created the rules and customs that enabled the functioning of these exchanges (Graeber 2012; Wray 2004).

A related critique applies to the use of 'business as usual' or 'do nothing' as the base case for measuring social value created by innovation policy in CBA approaches. This anchors decision-makers to prefer small-scale, marginal interventions (Allas 2014: 89). Yet there is considerable evidence that innovation systems exhibit increasing returns or 'S-curve'-type effects. Mission-oriented innovation policies which shift incentives across multiple sectors may be more likely to achieve such increasing returns (Mazzucato 2017; Kattel 2018). So arguably if there is to be any bias around innovation policy, it should be *in favour* of large-scale interventions.

Indeed, *The Green Book* recognises that cost-benefit analysis and cost-effectiveness analysis are 'marginal analysis' techniques when the 'broader environment can be assumed to be unchanged by the intervention' and that '...these techniques work less well where there are potential non-marginal effects or changes in underlying relationships' (HMT 2018 p.21). This is due to the 'difficulties inherent in pricing such changes'. *The Green Book* suggests that significant non-marginal issues need to be appraised and considered at the longlist stage (ibid.). However, there is little guidance provided for how such interventions are then compared against other interventions which are more easily subjected to SCBA at the shortlisting stage.

The Green Book provides some guidance as to how to incorporate non-market values in regard to environmental and distributional impacts including, for example, cumulative impacts on natural capital and also impacts on land values and human wellbeing (ibid. pp.61-81). However, no guidance is provided on evaluating innovation policy specifically. Indeed, the term 'innovation' only appears twice in *The Green Book*, once in reference to risk assessment (ibid. p.95) and once in reference to the design of public-private partnerships. Here the guidance suggests examining the 'removal of constraints by the public sector' in order to stimulate innovation in the design of the solution or provision of services (ibid. p.84). The implication is that it is the private sector that will innovate if it is allowed to do so by the public sector.

Furthermore, the strong emphasis on risk assessment/optimism bias is likely to mitigate against the creation of a mission-oriented approach where failure is viewed as a learning process integral to the achievement of important technological breakthroughs (Mazzucato 2013) and vitally important for stimulating the necessary innovation required to meet the grand challenges facing the UK economy and society.

2.3 Innovate UK's approach to evaluating innovation policies

Innovate UK has recently published a framework for how it evaluates its major funding programmes which sets out further challenges in evaluating the impact of innovation policies using standard economic appraisal approaches (Innovate UK 2018). The focus is on 'innovation support policies' aimed at improving the performance of UK businesses in adding value to the UK economy, including through wider economic and social benefits (ibid. p.6). Innovate UK outlines an SCBA-type analysis which also includes the opportunity costs to businesses of the intervention (eg. the match-funding that businesses have to provide to receive innovation grants). Specific challenges for measuring impact include:

- Data paucity: In particular a lack of readily available data on companies' R&D activities and outputs.
- Statistical methodology concerns: Typically, innovation policy supports a very small, selected, but heterogeneous sample of the UK business population, unlike other areas of government policy, reducing the statistical power of analysis. Relatedly, there is likely be a highly skewed distribution of impacts, with a small number of companies enjoying increasing returns and a 'long tail' of low or no-impact projects which can bias results. Finally, there are likely to be variables which may cause endogeneity bias, e.g. a firm's ambition, which may be difficult to observe and control.
- Spillover effects: Knowledge created by innovation support flows between individuals and firms are very difficult, if not impossible, to observe and track in a cost-effective fashion.
- Attribution issues: Whereby it can be challenging to prove it was Innovate UK's support that led to particular impacts as opposed to other government or non-governmental developments.
- Lagged effects: Typically, the impacts of innovation support can take many years to materialise and companies that are innovating may appear less productive than those that are not, as they are investing resources before realising revenues and efficiencies (ibid. p.12). In order to attract public funding, companies may also exhibit short-term strategic behaviours which they may abandon in the longer term. Again, this can be difficult to track using standard short-to-medium term evaluation timeframes.

Innovate UK is developing a number of techniques to meet these challenges. These include improved monitoring employing a logic model with an explicit 'theory of change' (ibid. p.16), capturing more comprehensive data, conducting evaluations over a longer time period and with larger cohorts, and using third-party or 'linked data' to improve the understanding of attribution.

In addition, Innovate UK is using qualitative approaches, in particular case studies which 'tell the story' of the impact and are useful when programmes are complex, where there are many forms of impact and where quantification is challenging (ibid. p.31). For example, Innovate UK used the technique of 'contribution analysis', involving in-depth interviews and case studies as well as statistical analysis, to examine the extent to which the Catapult Programme is supporting innovation (ibid.).

Innovate UK's evaluation framework is mainly focused on the impact of each of its programmes on business performance. However, it also notes that it is important to evaluate 'innovation platforms', described as 'strategic package of investments and activity designed to help solve a specific societal challenge' and notes that it will be reporting on two innovation platforms in 2019. The logic model used for these interventions should allow for the capture of unexpected impacts, including spillovers, and may be more suited to mission-oriented innovation policy, in particular from strategic industrial policy.

2.4 Productivity and multiplier effects

The Innovate UK evaluation framework does not consider the potential wider macroeconomic impacts of mission-oriented innovation. *The Green Book* is also mainly focused on project-level evaluation. However, it does have a brief discussion of the productivity and multiplier effects from policy interventions that have a stronger macroeconomic dimension (HMT 2018 pp.39-40). It states that productivity effects should be included in the calculation of SCBA 'where they can be objectively demonstrated.' These may arise from:

> '…movement to more or less productive jobs, changes in the structure of the economy, benefits from dynamic clustering or agglomeration, private investment, product market competition or the generation and flow of ideas.'

This latter statement seems to recognise that certain forms of policy may lead to step changes in the performance of the economy. However, there is little guidance offered as to how the above developments should be measured. Indeed, the only guidance provided is to say that productivity improvements can be calculated from 'the different levels of total employment costs under different options' with the assumption being that higher productivity will come through higher wages rather than higher employment. Furthermore, the guidance states that:

> 'Any macro level effects not resulting from productivity or labour supply effects only contribute to temporary deviations from trend growth… and any difference in labour demand between individual types of spending within a portfolio of programmes and projects… cannot generally be reliably observed or measured from a UK perspective… they should not be counted in the overall appraisal of UK social value unless they can be demonstrated to have supply side effects.' (ibid. p.39)

The Green Book further defines 'multiplier effects' as 'economic activities which result from either labour supply or direct labour demand effects.' These are 'likely to have limited additionality and the effects are generally already accounted for at a macro level by aggregate decisions to spend at a particular level' and 'it is usually not possible to reliably observe or measure differences between programmes at a UK level.' It is therefore recommended that they 'should not be included in estimates of social value' (ibid. p.40). The only exception here is local level analysis when 'robust, objective evidence of supply chain effects may be used' to measure 'first round labour demand effects' (ibid. p.78) after accounting for deadweight, substitution and displacement.

The above statements follow the neoclassical economics approach to fiscal policy which assumes all forms of spending can have only have short-run demand effects on the economy and that ultimately long-run (or 'trend') growth is driven by changes in supply only. However, as we discuss in the following chapter, different types of government spending can have quite different and long-term economic impacts. We argue that directed, mission-oriented innovation policies (e.g. public R&D spending) may lead to the creation of higher levels of total employment and more productive employment where new high-value added sectors emerge or where multiple sectors change direction. This can feed into permanently higher levels of demand and consumption (Perez 2002; Mazzucato 2013).

It is widely accepted in economic theory that private R&D spending can lead to rates of return well above those expected on standard capital investment. The question is whether public innovation policies, which may crowd in private sector R&D, can produce such effects. If they can, governments should clearly be incorporating such macroeconomic impacts into their policy and evaluation frameworks, rather than simply assuming they do not or cannot exist, which seems implicit in *The Green Book* guidance and more generally the 'market failure' rationale for government intervention. We explore this question in the next two sections of the report.

3. The macroeconomic impact of public spending and innovation: an overview

According to conventional macroeconomic literature, government spending and public investment are considered necessary only in the short-run as a countercyclical instrument. In particular, government is supposed to intervene in the market only in order to reduce frictions and market rigidities, as well as during periods characterised by deep falls in GDP and massive unemployment.[4] All these issues are theorised as creating a Keynesian problem of insufficient aggregate demand, thus hindering the economic system to reach a full-employment equilibrium in which labour and capital are fully utilised.

Only in these periods will expansionary fiscal and monetary policies increase GDP and employment through their effects on aggregate demand. In contrast, in the long run market forces and the market clearing mechanism—unhindered by rigidities and frictions—are presumed to lead to a full-employment equilibrium in goods, capital and labour markets. In 'normal times' and more generally in the long run, public spending is theorised as detrimental to economic growth and productivity, and is viewed as 'crowding out' private investment and consumption.

This perspective is questioned by several schools of thought which admit the role played by government intervention, not only in the short run but especially in the long run (Deleidi and Mazzucato 2018), when the possibility of creating new resources and new productive capacity increases and it becomes particularly relevant (Trezzini and Palumbo 2016). According to this view, a permanent increase in the level of demand (e.g. driven by expansionary fiscal policies) generates positive and permanent effects on the output level. Such an effect occurs through changes in the degree of capacity utilisation in the short run and in the long run by means of changes in the investment level (Garegnani 1992).

Within this alternative approach, the 'supermultiplier' model of growth describes a long-term relationship between the level of demand and the level of output (Cesaratto et al. 2003; Deleidi and Mazzucato 2018). This model proposes a positive relationship between the autonomous components of aggregate demand and the level of output, combined with a function in which investment is endogenously determined by the level of actual and expected demand. Expansionary fiscal policies generate a positive and persistent effect on output and private investment (Deleidi and Mazzucato 2018). However, different fiscal policies affect output and investment in different ways, by generating different multiplier effects.

[4] Sticky prices and wages, imperfection, asymmetric information and market failures, a monetary policy constrained by a zero lower bound and a 'liquidity trap' are the main phenomena that justify government intervention.

3.1 Crowding in or crowding out?

The conventional macroeconomic literature considers the interest rate as the main variable affecting the investment level: a decrease in interest rate is supposed to increase investment and vice versa. The assumption of a downward-sloping investment demand curve—incorporated in the aggregate demand curve (Romer 2000) and grounded on the well-known substitution mechanism between labour and capital—leads investment to adapt to full-employment savings when a decrease in real interest rates occurs.

In the long run, any increase in public expenditure is supposed to raise the real interest rate (Taylor 1999). That in turn is supposed to crowd out private investment. Therefore, the role played by aggregate demand (Keynes 1936) and by more systemic fiscal policies is relegated to a short-run analysis or to a study of economic business cycles, recessions and depressions (Tobin 1975). On the contrary, long-run output and economic growth are determined by price flexibility and related to supply-side forces.

In contrast, an alternative view is that private investment is affected by other factors, such as the current level of demand, the expectations of future growth opportunities and by the effects of innovation processes on methods of production used by firms (Garegnani 2015; Deleidi and Mazzucato 2018). Subsequently, an increase in certain forms of government spending and public investment can engender a *crowding-in* rather than a crowding-out effect. Because these policies are systemic and focused on the creation of structural transformations, they are more likely to crowd in the R&D spending of private firms by generating spin-offs through which research and innovation are developed and diffused to other sectors (Mazzucato 2013; 2016; 2017). With this perspective, public investment creates a new landscape and new markets (rather than simply fixing market failures), which increases the expectations of business, resulting in an increase in private expenditure (UCL Commission on Mission-Oriented Innovation and Industrial Strategy 2019).

The UK Government's 2018 *Industrial Strategy* white paper recognises this fact, stating that, 'R&D is an example of public spending stimulating rather than displacing private spending: economies with high levels of public investment in R&D also typically have high levels of private investment' (HM Government 2018: 61). Furthermore, with the Government and opposition party both committing to targets for gross spending on research and development as a proportion of GDP, determining the correct multiplier is crucial for delivering on these commitments.

In contrast, public investment in 'shovel-ready' projects and government consumption expenditure have a lower multiplier effect compared to mission-oriented innovation policy because they generate lower expectations of economic growth and a lower level of private investment. In particular, these kinds of spending have a very low or negligible influence on the R&D of private firms since they do not create either structural transformations or spin-offs and collaborations between public-private sectors.

In this view, interest rates may be less significant in determining the level of investment relative to expectations of future growth, which themselves may be driven by government investment.

3.2 Current debates on the fiscal multiplier

The issue of the long-run effects of fiscal policy and 'fiscal multipliers' has been the subject of considerable debate in recent years. In particular, there has been a focus on the impact of the fiscal consolidation policies employed by many countries in the aftermath of the financial crisis of 2007-08. Most notably, institutions such as the International Monetary Fund (IMF) appear to have softened their position on the conventional neoclassical position that fiscal policy interventions (including fiscal consolidation) can only ever have short-run effects on output, as outlined above.

In a 2016 article, for example, IMF authors argue that, 'The short-run costs in terms of lower output and welfare and higher unemployment have been underplayed, and the desirability for countries with ample fiscal space of simply living with high debt and allowing debt ratios to decline organically through growth is under-appreciated' (Ostry et al. 2016 p.40). This view builds on an earlier IMF study which found that, on average, a consolidation of 1% of GDP increases the *long-term* unemployment rate by 0.6% and raises by 1.5% the Gini measure of income inequality over a five year period (Ball et al. 2013).

In regard to fiscal multipliers in particular, the empirical literature has shown that an increase in government spending and a decrease in taxes can have a positive effect on output (Blanchard and Perotti 2002). A more recent empirical study showed that the fiscal multipliers estimated in forecasts for European countries during the recession that followed the financial crisis were systemically lower than the actual ones (Blanchard and Leigh 2013). Whilst forecasters assumed fiscal multipliers of about 0.5, Blanchard and Leigh's estimations, based on panel data for 26 European countries, found that during economic crisis the multiplier assumes a positive value equal to 1.5, meaning that a one-euro public expenditure decrease leads to a fall in real GDP of EUR 1.5.

There have also been studies examining the size of multipliers from different types of government spending (that is, public investment, government consumption and defence expenditure). Perotti (2004) finds, surprisingly, that increases in government investment are not more effective than public consumption expenditure in stimulating the output level. Deleidi et al. (2019a) find that investment fiscal multipliers tend to be larger than one and an increase in public investment engenders a permanent and persistent positive effect on the GDP level. Auerbach and Gorodnichenko (2012) find that military spending has the largest multiplier compared to the remaining class of fiscal policies. Despite these sectoral differences, overall these authors find an increase of government expenditure generates positive and expansionary effect on GDP.

Even though some mainstream economists seem to have shifted their position on fiscal consolidation policies, in particular during recessionary periods, the general policy view remains that fiscal policy can only support long-term growth via enabling macroeconomic stability (e.g. by reducing public and private debt) or, at the micro level, through tax and spending policies that stimulate the supply-side (e.g. see IMF 2015). For instance, a recent comprehensive review of fiscal policy and long-term economic growth by the IMF made no mention of demand-side macroeconomic stimulus supporting long-term growth (ibid.). Instead, in this view, a long-run increase in aggregate demand leads to a rise in prices without engendering any changes in output and employment. This view is aligned with *The*

Green Book view discussed above, according to which demand shocks only contribute to temporary deviations from trend growth or generate temporary effects on the output level.

In contrast, a recent stream of literature maintains that recessions lead to protracted and prolonged falls in output that in turn affect potential output (Ball 2014; Fatás and Summers 2017). For instance, a fall of aggregate demand can lead to permanent effects on both aggregate supply and potential output by means of a mechanism that is typically termed 'hysteresis' (Yellen 2016).[5] This view is better aligned with the 'supermultiplier' approach.

[5] The term 'hysteresis' was initially applied to models concerning the labour market (Blanchard and Summers 1986).

4. Empirical analysis of the impact of public innovation spending

In the present report, we undertake empirical analysis of the economic impact of different types of fiscal policy in terms of output and investment growth to test the above-described alternative hypotheses around the effects of government spending. To do so, we implement the structural vector-autoregressive (SVAR) methodology, which has numerous advantages compared to other kinds of econometric models. In particular, SVAR enables: (i) the evaluation of a broad set of fiscal interventions; (ii) overcomes problems relating to the simultaneous determination of variables, but without imposing restrictive theoretical assumptions; and (iii) assesses the effects of a fiscal stimulus over different time horizons accounting for a range of possible dynamic interactions and feedback.

In addition to the empirical analysis, we also undertake a numerical simulation of the supermultiplier macroeconomic model developed by, among others, Deleidi and Mazzucato (2018) and Deleidi et al. (2019b) through a stock-flow consistent (SFC) macroeconomic model. The results of the simulation are reported in Appendix 4 of this report.

A meaningful empirical investigation on the dynamic macroeconomic consequences of different fiscal policy interventions requires a sufficiently long time series on the relevant variables. In addition, quarterly data is needed for the restrictions on the contemporaneous effects between variables (the SVAR identification strategy—see Section 4.2 below) to be meaningful, so that endogeneity bias can be removed (e.g. the fact that the government may change the level of spending in response to lower GDP growth).

For the UK, unfortunately, the only data for government R&D spending is available on an annual basis and only for 36 years. To calculate statistically meaningful estimates of the economic multipliers, it is essential to have a larger sample size.[6] Quarterly data allows to have longer time series, as well as enabling shifts in government spending within the course of a year to be captured. We found that the US is the only country with good quality quarterly R&D time series and with a long enough historical experience in terms of innovation-oriented public spending. Hence we study this country.

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[6] A previous study commissioned by BEIS in 2015 estimated that, at the national level, every £1 of public R&D generated £1.40 of private R&D spending (Economic Insight 2015). However, the sample size for this study was very small—just 16 observations—limiting it statistical robustness. The report provided estimates at sectoral levels with a larger number of observations.

The outcome from this empirical study remains relevant for the UK because it will provide a quantitative assessment of the effects of certain government interventions emerging within an industrialised, developed country. Data availability permitting, we leave for future research a more detailed analysis of the macroeconomics effects of government spending that explicitly takes into account the features of the UK economy.[7]

4.1 Data

The quarterly data for the US is seasonally adjusted and obtained from the Bureau of Economic Analysis. The variables we consider are the gross domestic product (Y), total government expenditures (G), current tax receipts (T), and private research and development expenditure (R_D). In order to distinguish the effects of different classes of spending, we break down the total government expenditure as follows:

1. the total government gross investment in research and development (G_I), composed by:
    a. Federal national defence government gross investment in research and development (G_ID), which we use as our proxy of 'mission-oriented' innovation policy following Mowery (2010), Auerbach and Gorodnichenko (2012), and Foray (2013)
    b. State and local, and federal non-defence gross investment in research and development (or 'civil innovation spending') (G_IND);
2. state and local, and federal total gross investment and consumption expenditures (excluding research and development spending) (G_R).

A description of the variables is displayed in Table 2. We use the largest time span available, from 1947:Q1 to 2017:Q3. Variables are expressed in real terms per capita by dividing them by the implicit price deflator (with 2008 as base year) and by total population. Finally, as the variables enter the VAR in logarithms, which means that original estimates are in terms of elasticities, it is necessary to multiply each estimated parameter by the sample average of the corresponding ratio to get a partial derivative, which expresses dollar-change in response to a one-dollar increase.

[7] We also implemented a SVAR estimation using model 3 on UK annual data, from 1981 to 2016, but we obtained highly uncertain estimates of most parameters, and a not significant government spending multiplier. This is not surprising given the identification issues that are present with annual data, as discussed in the text.

Table 2. US Data and Description

Data	Description
Y	Real GDP
G_ID	Federal national defence government gross investment in research and development
G_IND	State and local, and federal non-defence gross investment in research and development
G_INV	State and local, and federal government total investment
G_C	State and local, and federal government total consumption expenditures
G_R	State and local, and federal total gross investment and consumption expenditures (excluded research and development spending)
G_I	Total government expenditure in research and development (G_ID+G_IND)
G	Total government expenditure (G_ID+G_IND+G_R)
T	Current tax receipts
R_D	Private research and development (R&D) expenditure

4.2 Methodology

We use the first difference of the logarithm of each of the variables in order to remove trends from the dataset (see Appendix 1 for a technical discussion). We estimate four alternative models, which allow us to construct a comparative analysis in terms of different aggregate classes of government spending. This empirical analysis also serves as a robustness check on the estimated magnitude of the resulting multipliers.

All four models include output (Y) and taxes (T) because we are interested not only in the direct effects on output, but also in the possibly important relationship with taxes over time. We also always include private sector R&D (R_D) to specifically explore the implications that different policies have for the amount of investment that the private sector devotes to research and development.

In the first model we estimate the standard government spending multiplier, that is the effects on Y and R_D of an increase in generic public expenditures. In the second model we explore whether government investment (G_INV) rather than government consumption (G_C) provides a stronger stimulus to output. The third model discriminates government innovation spending (G_I) from all the other forms of spending (G_R) to investigate whether the public involvement in innovation activities can have a significant distinctive influence on aggregate production. Finally, in the fourth model we examine in more detail which type of government investment in innovation is more successful in stimulating output growth, comparing mission-oriented innovation spending (defence R&D) (G_ID) with all other industry categories (health, space, science, energy and nature (G_IND)). The set of variables included in the four models is as follows:

Model 1: G, R_D, T, Y

Model 2: G_INV, G_C, R_D, T, Y

Model 3: G_I, G_R, R_D, T, Y

Model 4: G_ID, G_IND, G_R, R_D, T, Y

4.3 Results

Following standard practice in the field, we deem a parameter estimate significant if its one-standard deviation band does not include the zero (*p*-value below 0.32), but we also show in more detail the p-value of each multiplier at different horizons. The focus will be on three aspects that we believe are important: 1) what kind of dynamics does government spending follow after an exogenous positive shock and what is the dynamic relationship between different types of government expenditure; 2) what is the response of GDP and private R&D spending to a shock (increase in) to government spending; and 3) what is the response of GDP and private R&D spending to a tax shock (a tax cut).

The SVAR captures in a general way the dynamic relationships between all variables which is important because an exogenous increase (a shock) in government spending is potentially accompanied by persistent dynamics in all variables, including government spending itself. This implies that an initial increase in G may build up over time and fade out only after a long period. This clarification is important in order to understand the difference between what we call the 'impulse response' of, for instance, Y to G_I, that is the value that Y takes on as time passes after an initial shock to G_I; and the 'multiplier', which is instead the response of Y per unit of government spending on G_I. This latter, in particular, is calculated as the ratio between the cumulative response of Y to a shock to G_I and the sum of the cumulative response of all types of G (G_I and G_R) to the same shock to G_I.

For all four models, a table is presented for the contemporaneous effects of each shock (impact multipliers) and the plot of the relevant impulse response functions (IRFs). A summary of the overall results follows at the end discussing the value of the multipliers.

Estimation of model 1

In this specification, we include total government spending, G, and examine the effects of a one-dollar increase in generic public expenditure. An exogenous shock to G generates persistent and rather rich dynamics in G itself, which attains a value of 2 after a year and remains at that level even after six years (Figure 1). An exogenous shock to both G and T yields a significant effect on Y at virtually all horizons. The contemporaneous effect (Table 3) on Y of an increase in G is sizable, being equal to 0.806, and strongly significant given a p-value that is virtually zero, but the peak of 1.836 is reached after two years, before stabilising later on around a value of 1.

The effects of a G shock on R_D (private sector R&D) is significant only after two quarters, but is not of great magnitude given that it reaches a maximum of 0.10 after almost two years. This is mostly due to the fact that R_D does not depend contemporaneously on G (by assumption) and neither on Y (not significant). The rise in T after a G shock is the consequence of the significant positive coefficient on Y in the equation for T.

A tax shock has almost no effect on R_D, but a rather strong impact on Y, being equal to almost -1 by the first quarter. This effect increases in absolute value up to -1.5 after three quarters, remaining permanently at this new level. Over the long run it appears that both G and T exerts a permanent effect on Y. The numerical values of the IRFs over a period of 24 quarters is collected in Table 3.1 in Appendix 3.

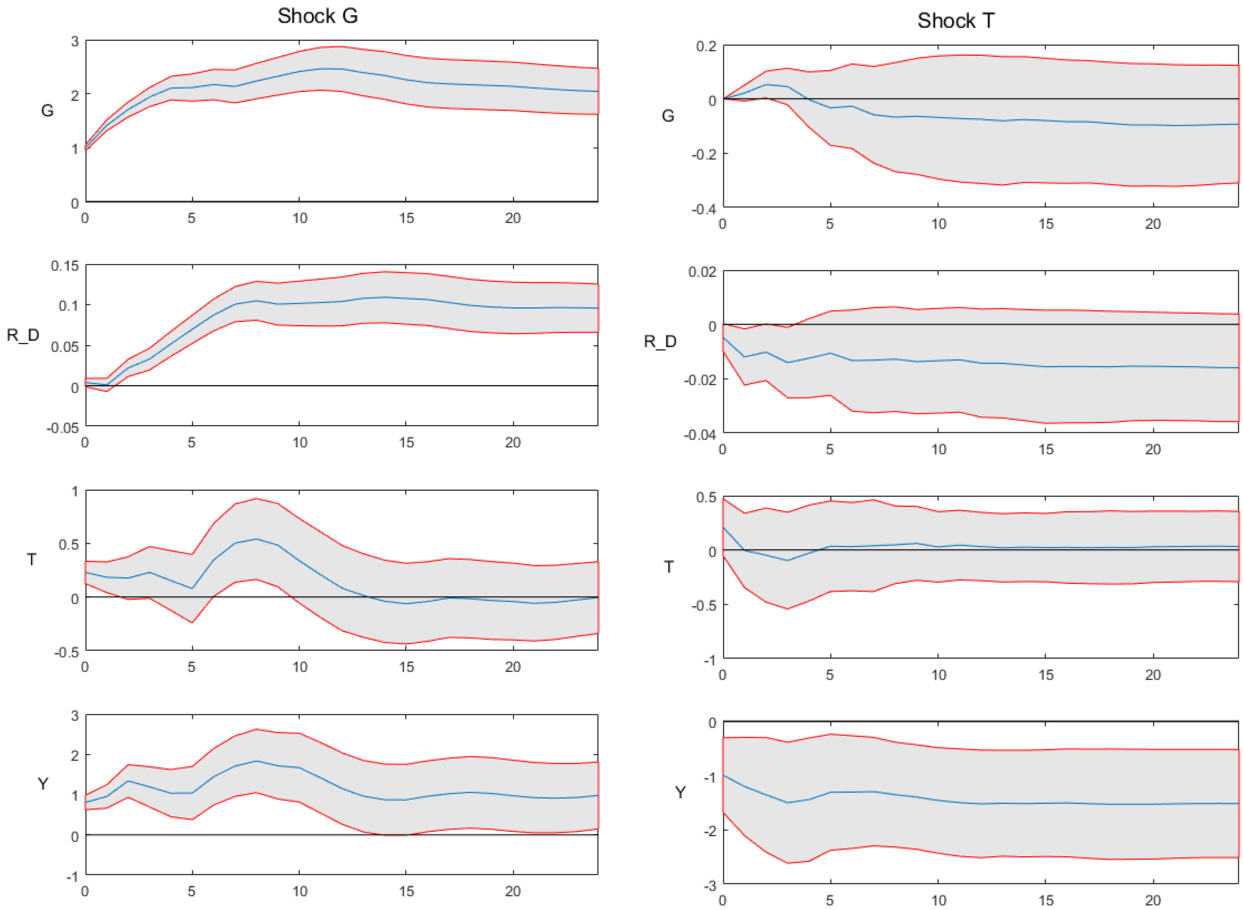
Table 3. Impact multiplier, model 1

	Shocks			
Response of	G	R_D	T	Y
G	**1.000** (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)
R_D	0.004 (0.45)	**1.020** (0.00)	-0.005 (0.35)	0.001 (0.57)
T	**0.229** (0.03)	3.826 (0.36)	0.210 (0.43)	**0.184** (0.07)
Y	**0.806** (0.00)	4.764 (0.74)	**-0.992** (0.15)	**0.230** (0.03)

Entries are the estimates of impact multipliers, while the numbers in brackets are the p-values.
Significant estimates are indicated in bold.

Figure 1. Impulse response function, model 1

Box 1 Box 2



Estimation of model 2

In this specification we distinguish two types of government expenditure, investments (G_INV) and consumption (G_C), so as to be able to characterise their potentially different dynamic features. Both types of government spending present substantial persistence, with a positive correlation between them (see Figure 2). In other words, an exogenous increase in one type of spending is accompanied by an increase in the other type. However, when the shock occurs on G_INV, the response of total government expenditure is stronger and far more G_INV-intensive.

After six years they both remain at a level of about 1.6 in response to a one-dollar exogenous shock. Their effect on Y is strongly significant at the impact (see Table 4), that is 1.97 for G_INV and 0.43 for G_C, but this difference in magnitude is reversed at longer horizons, given that the response of G_C after six years is 1.99 and still significant, whereas that of G_INV is 1.57 and not significant (see Figure 2 and Table 3.2 in Appendix 3).

This difference is the consequence of the fact a shock to G_INV is followed by a significant and substantial increase in T, which offsets the initial stimulus, while this does not happen in the case of a shock to G_C. The peak response of Y is 4.56 after one and a half years and 1.99 after two years, for G_INV and G_C respectively. Also, R_D responds more vigorously to a G_INV shock, with a peak of 0.23 after four years, than a to G_C shock, in which case it reaches just 0.06 after two years. Moreover, the stimulus on R_D appears to have permanent effects in the case of G_INV, while it dies out, becoming not significant after four years, in the case of G_C (Figure 2). The effects of a tax shock are not significantly different from zero for both Y and R_D.

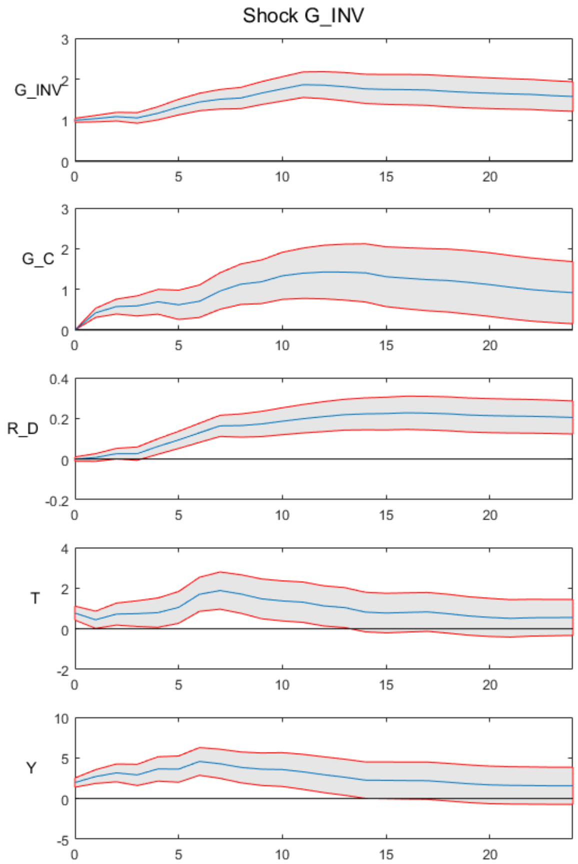
Table 4. Impact multiplier, model 2

	Shocks				
Response	G_INV	G_C	R_D	T	Y
G_INV	**1.00**	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
G_C	0.00	**1.00**	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R_D	0.000	-0.001	**0.970**	0.001	-0.002
	(0.98)	(0.90)	(0.00)	(0.91)	(0.88)
T	**0.773**	0.014	**6.697**	**0.885**	**0.313**
	(0.03)	(0.91)	(0.30)	(0.00)	(0.11)
Y	**1.969**	**0.432**	18.217	-0.315	**0.855**
	(0.00)	(0.06)	(0.42)	(0.60)	(0.00)

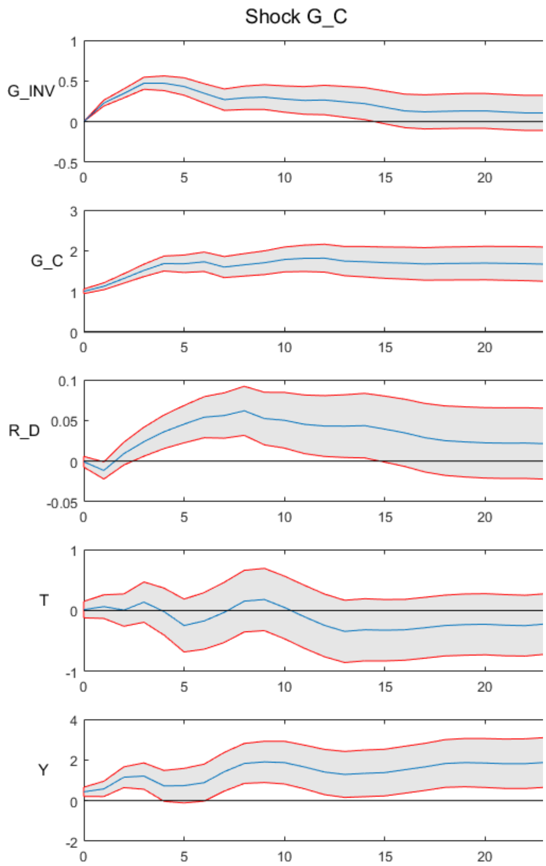
Entries are the estimates of impact multipliers, while the numbers in brackets are the p-values. Significant estimates are indicated in bold.

Figure 2. Impulse response function, model 2

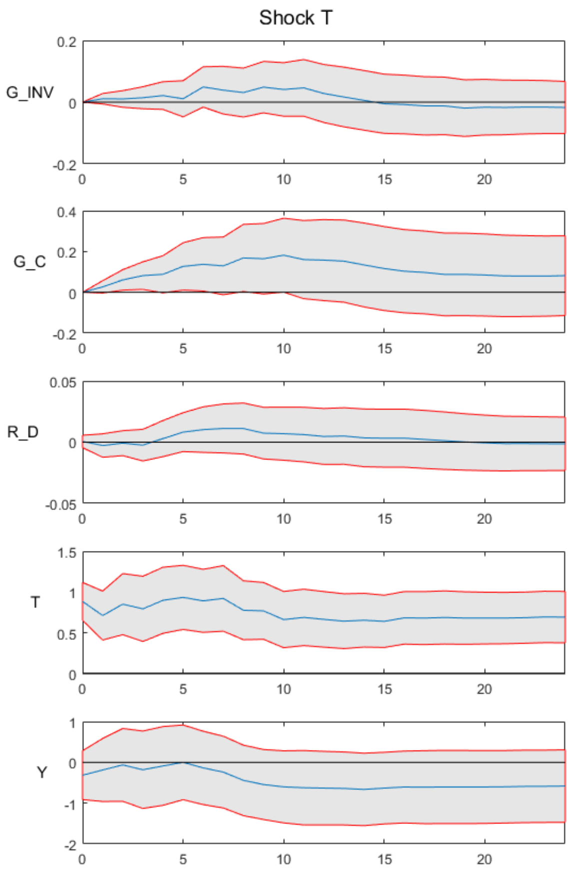
Box 1



Box 2



Box 3



Estimation of model 3

In model 3, by introducing innovation-oriented government spending (G_I), as opposed to all the other government spending (G_R), the aim is to explore whether the first category is capable of producing a stronger stimulus on output and private R_D investments.
The answer is undoubtedly positive because both at the impact and over time a shock to G_I generates a considerably larger response of Y and R_D than that which is produced by a shock to G_R. Indeed, the effect of a one-dollar exogenous increase in G_I yields a contemporaneous significant increase in Y of 8.85 dollars, as opposed to a 0.81 dollars increase from a shock to G_R (see Table 5). Both types of spending have a significant effect on Y as time passes, but the G_I stimulus produces a massive peak response of 28.77 after three quarters, remaining significant at longer horizons, while that of G_R, though significant at all horizons, peaks after two years at a value of only 1.7 (Figure 3 and Table 3.3 in Appendix 3).
This difference in magnitude is partly explained by the fact that a shock to G_I is accompanied by a considerable increase in G_R, which takes on two-thirds of total government spending, while the reverse does not occur when there is a shock to G_R. Hence, the greater performance of G_I in raising Y is explained both by the higher scale of the ensuing total government spending it stimulates, as well as by a higher G_I-intensity.
Also, we highlight how a shock to G_I is characterised by a steady build-up over time, which appears to stabilise only after six years around a value of 6, whereas G_R is characterised by a smaller though permanent rise that reaches only 2 after the same span of time. The effect on R_D is significant over time for both types of spending, but it is significant at the impact only for G_I and what really distinguishes the two shocks is the magnitude of the R_D response, being 3 and 0.10 after six years for G_I and G_R respectively.
Noticeable is the fact that the contemporaneous response of R_D to a G_I shock is direct and not via an increase in Y. A positive tax shock has a sizable and significant impact on Y, -0.9, which increases slightly in absolute value as time passes, but there is also a rather small negative effect on R_D at shorter horizons.

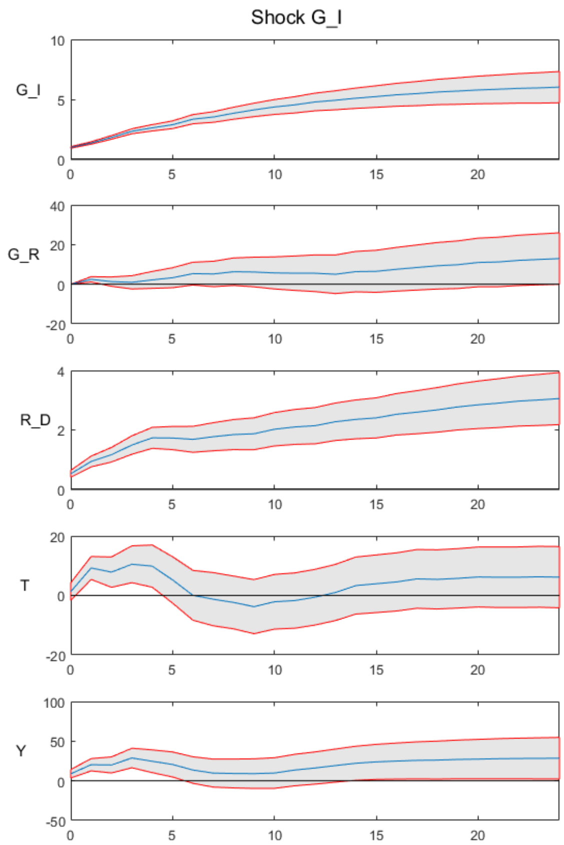
Table 5. Impact multiplier, model 3

	Shocks				
Response	G_I	G_R	R_D	T	GDP
G_I	**1.00**	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
G_R	0.00	**1.00**	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R_D	**0.527**	0.004	**1.012**	**-0.004**	0.000
	(0.00)	(0.44)	(0.00)	(0.24)	(0.65)
T	1.300	**0.216**	3.242	**0.075**	**0.089**
	(0.66)	(0.05)	(0.41)	(0.71)	(0.06)
Y	**8.855**	**0.815**	3.128	**-0.900**	**0.086**
	(0.10)	(0.00)	(0.81)	(0.10)	(0.07)

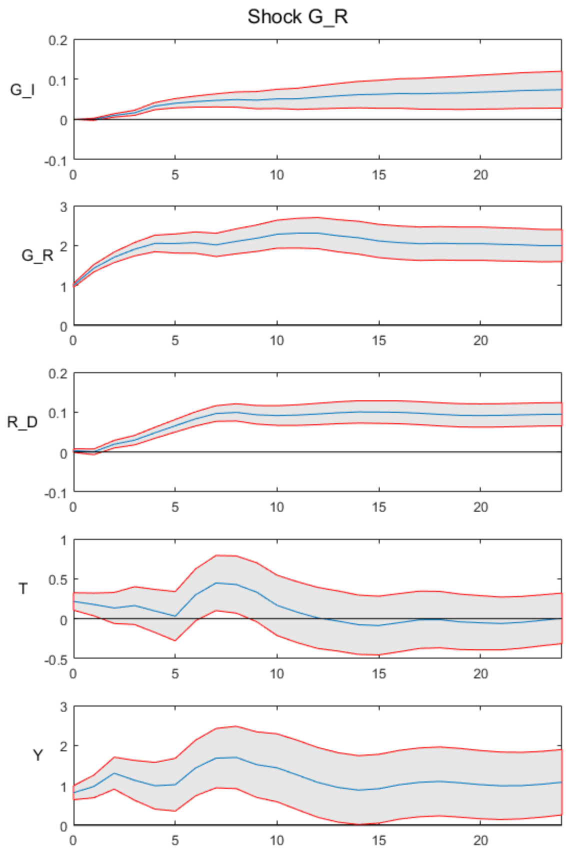
Entries are the estimates of impact multipliers, while the numbers in brackets are the p-values. Significant estimates are indicated in bold.

Figure 3. Impulse response function, model 3

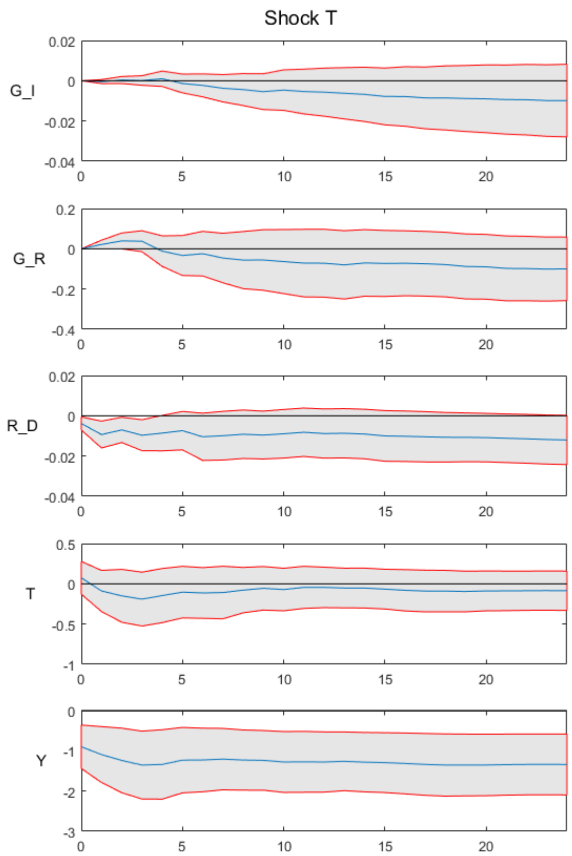
Box 1



Box 2



Box 3



Estimation of model 4

This specification aims to examine whether mission-oriented innovation spending, proxied by US government spending on military R&D (G_ID), differs from civil sector innovation spending (incorporating health, space, science, nature and energy) (G_IND).

Both types of spending display substantial persistence, though the G_ID increase is of larger magnitude, reaching 7 dollars after six years while G_IND arrives at 2.7 over the same period. Interestingly, while a shock to G_IND is accompanied by a small increase in G_ID, an increase in G_ID causes a negative response of G_IND, at least up to five quarters.

Both types of spending result in a huge increase in Y but over different time periods. At the impact only a G_IND shock generates a significant increase in Y, equal to 7.11 (see Table 6), and reaches its maximum of 14.38 after three quarters (Figure 4 and Table 3.4 in Appendix 3). On the contrary, the effects of G_ID become significant after one quarter with a multiplier of 23.6, and a maximum response of 45 after one year.

Despite these extremely large values, at longer horizons the value of the responses is rather uncertain so that we cannot exclude that they are zero. The effect of a spending shock on R_D is also different in magnitude, though persistent in both cases. There is a strong and significant increase in R_D over all horizons, with a value of 4.76 for G_ID and 1.46 for G_IND after six years. As was the case in model 3, the highly significant response of R_D to a contemporaneous shock in either G_ID or G_IND is direct, and not via an increase in Y. This set of results is in striking contrast with the effect of a shock to routine government spending, G_R, which yields a contemporaneous rise of 0.81 dollars in Y and a peak response of 1.56 after two years, while the effects for R_D are tiny, amounting to a maximum of almost 0.10, though significant. A tax shock causes a drop in Y, but this becomes significant only at longer horizons, and a negative insignificant effect on R_D.

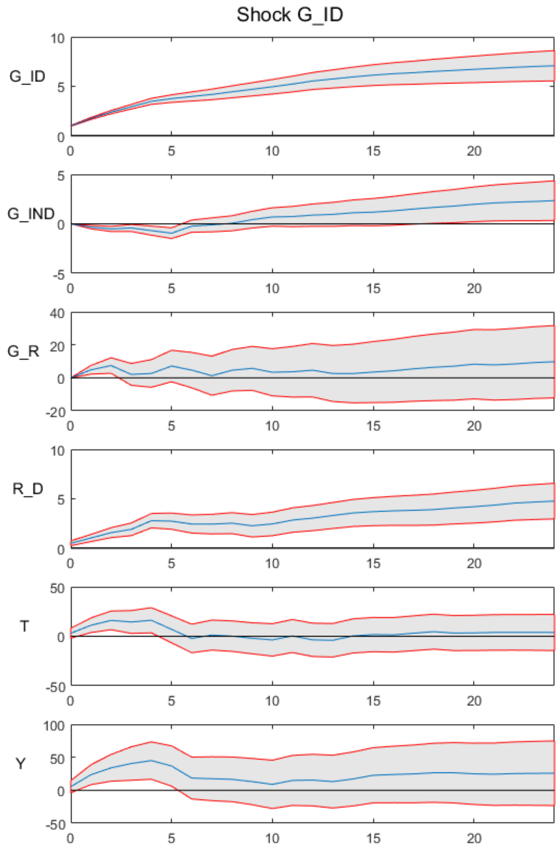
Table 6. Impact multiplier, model 4

	Shocks					
Response	G_ID	G_IND	G_R	R_D	T	Y
G_ID	**1.00**	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
G_IND	0.00	**1.00**	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
G_R	0.00	0.00	**1.00**	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R_D	**0.501**	**0.247**	0.002	**1.018**	-0.002	0.001
	(0.04)	(0.00)	(0.71)	(0.00)	(0.70)	(0.70)
T	3.108	2.415	**0.271**	**4.471**	**0.591**	**0.315**
	(0.54)	(0.32)	(0.03)	(0.24)	(0.02)	(0.09)
Y	5.405	**7.110**	**0.813**	8.606	-0.794	**0.608**
	(0.56)	(0.11)	(0.00)	(0.53)	(0.32)	(0.00)

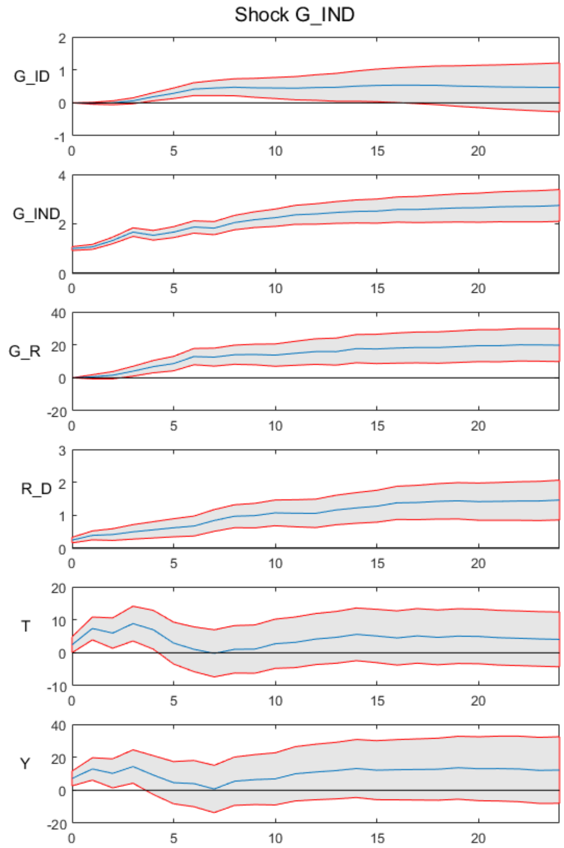
Entries are the estimates of impact multipliers, while the numbers in brackets are the p-values. Significant estimates are indicated in bold.

Figure 4. Impulse response function, model 4

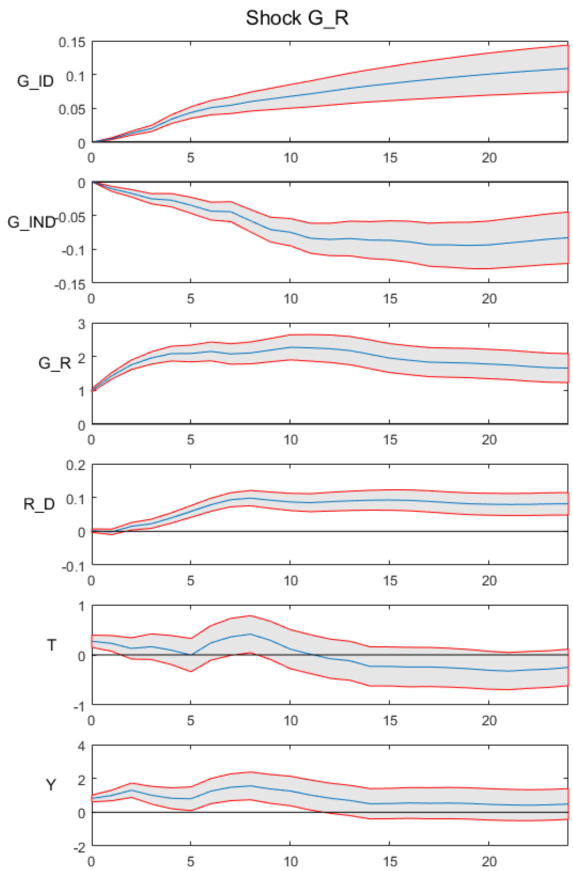
Box 1



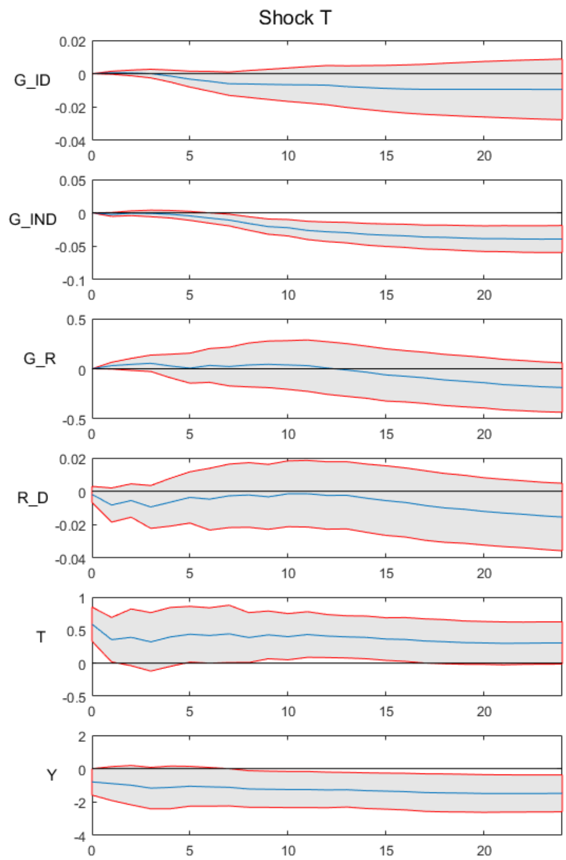
Box 2



Box 3



Box 4



4.4 Discussion

We can summarise the results from the empirical analysis as follows:

1. The composition and direction of government spending matters considerably for the size of the fiscal multipliers.
2. Public expenditure in the form of investment rather than consumption goods is more effective in stimulating aggregate demand and GDP.
3. Public spending specifically directed at innovation activities is the most powerful class of public intervention.
4. Mission-oriented innovation policy—proxied by public R&D in the defence sector—has produced, in the US experience, the largest stimulus of output growth.
5. Public sector R&D crowds in private R&D.

With respect to the last point, it is worth emphasising that public investment in R&D activities yields a significant increase in private R&D investment within the same quarter and this effect is direct, that is, not mediated by an increase in GDP.

The greater performance of innovation-oriented public spending in fostering output growth can be explained by two factors. First, by the scale of the increase in total government spending that accompanies an increase in innovation spending. We show that this type of spending is characterised by a steady build-up over time and is typically followed by an increase in other types of spending, generating a considerable increase in the total amount of government expenditure. A plausible explanation for this dynamic relates to the fact that often the final user of the inventions generated by the public R&D investments is the government itself.

Second, the higher relative share of innovation spending during these episodes implies stronger effects in terms of positive externalities—likely to consist of the spillovers discussed in Section 2—generated towards the private sector.

The fact that a larger GDP stimulus was found from mission-oriented innovation policy (defence R&D) supports the findings from our simulation and wider supermultiplier hypothesis outlined in Section 3. Military R&D in the US was more focused on early stage R&D process, with likely larger implications in terms of spillovers to other sectors and structural transformations of the economy than civil innovation spending, as found in the academic literature. Moreover, the fact that an increase in non-defence innovation spending is accompanied by increases in defence spending as well—but not vice versa—might simply reflect the higher priority, also in terms of budget, of defence-related purchases. In other words, military spending in general may be less affected by changes in overall government spending.

To assess the effectiveness of the different classes of government spending in producing an increase in output we calculate the response per unit of spending (multipliers), as defined above, and summarise these estimates in Table 7.

Table 7. Multipliers in the four models

	Y		R_D	
	Impact	Peak	Impact	Peak
Model 1	G: **0.81**	G: **0.82** (8)	G: 0.00	G: **0.05** (16)
Model 2	G_INV: **1.97** G_C: **0.43**	G_INV: **2.12** (6) G_C: **1.12** (24)	G_INV: 0.00 G_C: -0.00	G_INV: **0.08** (24) G_C: **0.03** (7)
Model 3	G_I: **8.86** G_R: **0.81**	G_I: **8.86** (0) G_R: **0.82** (7)	G_I: **0.53** G_R: 0.00	G_I: **0.53** (0) G_R: **0.05** (7)
Model 4	G_ID: 5.40 G_IND: **7.11** G_R: **0.81**	G_ID: **8.82** (3) G_IND: **7.76** (1) G_R: **0.81** (0)	G_ID: **0.50** G_IND: **0.25** G_R: 0.00	G_ID: **0.51** (4) G_IND: **0.25** (0) G_R: **0.04** (16)

Significant estimates are indicated in bold. Within brackets we indicate the number of quarters after which the peak is attained.

When we include total government spending (model 1), we obtain a contemporaneous impact on GDP of 0.81, which is very close to the 0.84 and 0.90 that Blanchard and Perotti (2002) obtain in their two fiscal multiplier models.

We also find a larger GDP multiplier for government investment spending as compared to consumption spending, both contemporaneously and at longer horizons. This result is in sharp contrast with Perotti (2004), who finds that the maximum multiplier for government consumption is 2.32 after five years, while it is only 1.68 at quarter one for government investment. Our estimates in this respect appear more plausible and coherent with the expected spillover effects that government investment entails when it is directed towards capital goods. Auerbach and Gorodnichenko (2012) [8] estimate values very close to those of our model 2. They find that the maximum multiplier is 1.21 for consumption after five years and 2.12 for investment after half a year. When these authors compare defence and non-defence spending, they estimate that the maximum multiplier is virtually the same, that is 1.16 after three quarters and 1.17 respectively after nine quarters.

In summary, this analysis represents the first systemic analysis of the effect of government spending on R&D. By separating out directed, innovation-oriented spending from the rest of the government spending, we discover that this class of public expenditure has a far greater performance in terms of stimulating aggregate demand, with a contemporaneous multiplier of almost 9 on GDP and 0.50 on private R&D.

[8] Here we are interested in the linear model estimated in Auerbach and Gorodnichenko (2012), but we stress that the main contribution of these authors is the ability to distinguish multipliers during recessions and booms, which is obtained using a regime-switching framework.

5. Conclusion and questions for further research

The sluggish growth endured by advanced economies in the post-financial crisis period has seen the UK Government and others around the world begin to reconsider important aspects of economic policy, including fiscal, industrial and innovation policy. In this report, we introduce a new theoretical framework for understanding the links between fiscal policy and innovation, arguing that 'mission-oriented' innovation policy, which focuses upon on concrete societal problems that can only be solved by multiple sectors interacting in new ways, can generate very large economic returns—so called 'supermultiplier' impacts.

The supermultiplier accounts for both multiplier and accelerator effects. This approach contrasts with standard economic theory where fiscal policy can only have short-run demand-side effects. Instead, we argue that private investment is determined by demand, expectations of future growth and technical progress, and that innovation can be stimulated by targeted public policies that positively stimulate private R&D (crowding in rather than crowding out). Finally, expansionary fiscal policies generate positive effects on output, effects which can have long-run impacts when they are driven by persistent and systemic policies geared towards structural transformation.

To test this theory, we examined several alternative fiscal policies in terms of their impact on GDP growth and private investment. These included: (i) tax cuts; (ii) investment in 'shovel-ready' projects and infrastructure; and (iii) directed spending aimed at structural transformation through innovation across multiple sectors. We used two approaches for the analysis: a stock-flow consistent numerical simulation—the results of which are reported in Appendix 4—and the first ever empirical analysis of different forms of innovation-spending based upon US data.

The two analyses produced complementary results that can be summarised as follows:

1. The macroeconomic effects of different types of public investment are very different, with government investment having a higher economic return than consumption spending.
2. Mission-oriented innovation policy, proxied by government defence spending in our empirical study, generates the largest economic returns (measured in terms of GDP growth) over the longest time period and the highest level of private innovation spending.

The findings of this report have important policy implications. Firstly, they suggest that fiscal policy should be considered an important tool for supporting the long-run capacity and capital development of the economy, rather than it being assumed it can only have short-run effects. But not all fiscal policies are equal. While it is increasingly accepted that investment can have stronger longer-term impacts on productivity than government consumption spending, our findings also suggest that certain types of investment spending—mission-oriented innovation spending—can have significantly larger and longer term economic impacts than standard capital investment (e.g. on infrastructure). In addition, such policies could have major economic benefits anywhere in the economic cycle and not just during recessions as counter-cyclical measures. This implies there is a case for closer coordination between fiscal policy and industrial policy, and the departments in charge of these policies (in the UK those being HM Treasury and BEIS).

Secondly, these findings suggest a new approach to economic appraisal and evaluation of government policy. The 'market-failure' framework, with its focus on marginal improvements inherent in CBA and net-present value approaches, is excessively static and fails to capture the potential of mission-oriented policies to effectively co-create and shape new markets by crowding in private R&D, and generate large and long-lasting multiplier effects. Further work is needed to develop a more rigorous approach to the measurement of value generated by systemic government policies which can produce large spillovers across multiple sectors by creating structural change in the economy (Kattel et al. 2019).

Thirdly, our review of the data on R&D spending in advanced economics surprisingly found that only the US collects quarterly data on this variable. We suggest the UK and European statistics agencies should rectify this and begin collecting quarterly data that would enable the use of a wide range of standard time series econometric methods to analyse the dynamics of innovation spending.

While this analysis has provided unquestionable evidence on the distinctive effect of a specific class of government spending—R&D investments—there are several questions that remain open and that are worth exploring further.

First, it would be interesting to produce a historical account of how different types of spending, and the innovation type in particular, have contributed to the movements in consumption, investment and R&D in different periods. While we assumed constant-parameters in our econometric analysis, the historical idiosyncrasies of US history may mean that the multiplier of innovation spending has changed over time. This can be considered by estimating a time-varying model to identify the extent and the timing with which the effectiveness of this type of macroeconomic policy has changed.

Secondly, it is important to find ways to capture the inter-sectoral spillovers generated from mission-oriented policies (Mazzucato, 2018). To do so it would be useful to use dynamic input-output analysis, which can look at how investments in one part of the economy cause cross-sectoral interactions and the effects this has on macroeconomic growth (Pasinetti 1983; Carter 1970).

Thirdly, we could build on our finding that the innovation expenditure has a direct contemporaneous impact on private R&D. While this suggests an expectations-based channel through which the public stimulus of aggregate demand operates, this should be subject to a deeper investigation that aims at explaining in more detail which mechanisms lie behind the large values of the multiplier in the case of R&D activities.

Finally, this report uses aggregated measures of innovation spending, using defence-related spending as a proxy for mission-oriented public intervention. Whilst this enables the examination of a long-time series of data, it is less useful in terms of understanding how individual policies and projects put in place in different years impact on the rest of the economy. This kind of analysis can be performed only by adopting a narrative approach, which implies a detailed study of policy developments in public R&D and related mission-oriented innovation projects for different sectors. It would be useful to conduct such a project for the UK as well as other countries. However, this assumes the availability of quarterly data for government R&D spending which, as discussed above, is currently the main limitation on our ability to address the UK context.

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Appendix 1. Model diagnostics

A1.1. Unit root testing and cointegration

We undertake two unit root tests to ascertain the order of integration of our variables: the Augmented Dickey-Fuller test and the Phillips-Perron test. The specification chosen for the test is based on observation of the plot, while the lag length considers the suggestions from four alternative criteria (the BIC and MAIC information criteria, a sequential t-test on the last lagged term and a sequential Ljung-Box test for autocorrelation in the residuals). As can be seen in Table A1.2, the indications of the two tests are mixed, even though slightly favouring the I(1) hypothesis, but because Y is undoubtedly characterised by a unit root, we decide to treat the whole set of our variables as generated by I(1) processes. As a consequence, the variables enter the VAR model in 1st differences after taking the logarithm of their value. Because we do not have strong beliefs on the existence of a long-run cointegrating relationships among our variables, we skip the test for cointegration. [9]

Table A1.1. Unit root tests

	levels		1st differences	
variable	ADF	PP	ADF	PP
Y	0.65	0.96	0.00	0.00
G	0.00 - 0.02	0.37	0.00	0.00
R_D	0.00 - 0.12	0.83	0.00	0.00
T	0.01 - 0.32	0.24	0.00	0.00
G_I	0.01 - 0.35	0.03	0.03 - 0.18	0.00
G_R	0.00 - 0.02	0.41	0.00	0.00
G_ID	0.00 - 0.04	0.61	0.00 - 0.29	0.00
G_IND	0.81 - 0.92	0.00	0.00	0.00
G_INV	0.00 - 0.02	0.00	0.00	0.00
G_C	0.04 - 0.48	0.92	0.00	0.00

Entries are p-values of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Under ADF we show the range of p-values across all selected lag lengths.

Table A1.2. LM test for serial correlation: model 1

	system		individual eq			
h	stat	pv	G	R_D	T	Y
1	1.4033	0.13305	0.59392	0.091124	0.97713	0.98228
2	1.5607	0.025563	0.10232	0.026952	0.78168	0.40455
3	1.5161	0.014866	0.15857	0.057166	0.90857	0.2705
4	1.7883	0.00023	0.26855	0.1033	0.04852	0.10437

Stat is the F statistic of Doornik (1996), pv is the correspond Stat is the F

[9] See Blanchard and Perotti (2002) for a discussion about a possible long-run relationship among levels.

Table A1.3. LM test for serial correlation: model 2

	system		individual eq				
h	stat	pv	GovI	GovC	R_D	T	Y
1	0.92316	0.57302	0.2867	0.94391	0.9085	0.51272	0.40135
2	1.3988	0.037252	0.43654	0.003758	0.14196	0.76296	0.26763
3	1.3977	0.016794	0.201	0.003708	0.041058	0.85705	0.36598
4	1.4664	0.002874	0.20818	0.008237	0.065428	0.011604	0.37745

Stat is the F statistic of Doornik (1996), pv is the corresponding p-value.

Table A1.4. LM test for serial correlation: model 3

	system		individual eq				
h	stat	pv	G_I	G_R	R_D	T	Y
1	2.0317	0.002143	0.11935	0.75726	0.006224	0.34134	0.1634
2	1.8584	0.000355	0.28121	0.85503	0.000783	0.47012	0.15753
3	2.2229	4.33E-08	0.029655	0.77178	0.002419	0.67664	0.12195
4	2.1753	2.15E-09	0.061698	0.66696	0.005593	0.20125	0.096526

Stat is the F statistic of Doornik (1996), pv is the corresponding p-value.

Table A1.5. LM test for serial correlation: model 4

	system		individual eq					
h	stat	pv	G_ID	G_IND	G_R	R_D	T	Y
1	1.1517	0.25048	0.5638	0.78826	0.63179	0.16448	0.81966	0.20791
2	1.2407	0.091913	0.61995	0.95121	0.85702	0.001847	0.79726	0.3059
3	1.4036	0.006473	0.007742	0.99174	0.93365	0.005019	0.79785	0.20326
4	1.5159	0.000286	0.017249	0.98002	0.74331	0.011525	0.36579	0.2315

Stat is the F statistic of Doornik (1996), pv is the corresponding p-value.

Table A1.6. LM test for residual ARCH heteroskedasticity: model 4

	individual eq					
h	G_ID	G_IND	G_R	R_D	T	Y
1	0.011982	0.006305	1.49E-07	0.001724	1.61E-06	0.70609
2	0.011807	0.008412	2.92E-07	0.000217	9.86E-06	0.009056
3	0.014996	0.000764	1.30E-06	0.000487	2.07E-05	0.021983
4	0.025555	1.37E-06	2.59E-06	0.000986	6.19E-05	0.019023

Entries are the p-values of the LM statistic.

Appendix 2. SVAR modelling

Following standard estimation procedure for SVARs, we start by estimating a reduced-form VAR(p) model (equation 1)

$$y_t = c + \sum_{i=1}^{p} A_i \, y_{t-p} + u_t, (1)$$

where y_t is a k x 1 vector of variables in log first differences, c is a constant, A_i are the k x k matrices of reduced-form coefficients and u_t is the error term. The lag length *p* of this VAR is chosen with the main objective of removing any substantial residual autocorrelation, as indicated by the Breusch-Godfrey LM test. We find that starting from a VAR with 0 lags and increasing the order one at a time, 8 lags are needed to remove almost all evidence of serial autocorrelation (see Appendix 1, Table A1.2 – A1.5), while significant heteroskedasticity remains in the residuals (see Appendix 1, Table A1.6), but this is expected considering the long span of time and the wide range of historical circumstances included in our sample.

In order to study the effects of changes in government spending on GDP and the other macroeconomic aggregates, we need to isolate the exogenous variation in the relevant variables. This is obtained via an identification strategy that allows us to recover the structural model that generated the data represented in equation (2). More formally, we assume that our data is generated by a SVAR(p)

$$B_0 y_t = c + \sum_{i=1}^{p} B_i \, y_{t-p} + w_t, (2)$$

where w_t is the vector of structural shocks, with $\mathbb{E}(\mathrm{w_t w_t'}) = \mathrm{I_K}$, B_i are k x k matrices of structural parameters, and, in particular, $\mathrm{B_0}$ is the matrix containing the contemporaneous correlations between the k endogenous variables in y_t. Identification of the structural model (2) requires to impose at least $(k^2 - k)/2$ extra restrictions on $\mathrm{B_0}$ using *a priori* assumptions on the contemporaneous relationship between variables, typically based on intuitions drawn from economic theory. Our identification scheme is based on the following assumptions. We assume that decisions on government spending is predetermined with respect to GDP within the quarter, that it does not respond to contemporaneous private R&D investments, and that the decision to spend precedes that about taxes. R&D investments is assumed to be influenced by GDP within the quarter, but not by the volume of government spending or taxes. Taxes are a function of contemporaneous GDP and government spending, but is independent of contemporaneous private R&D. Finally, GDP can be potentially affected by all the other three variables within the quarter. The other three models incorporate this same core identification scheme, plus the assumption that the different types of government spending reflect decisions that are autonomous, so they are independent of each other within the quarter. Notice that this identification scheme is both quite general in the sense that no restrictive assumptions are imposed on the relationship between G, T and Y, except that G precedes the decision on T. Moreover, we highlight how the multipliers of G are not affected by the specific assumptions used to identify the other three shocks. Estimation of the $\mathrm{B_0}$ matrix is implemented via maximum likelihood.

Once we have estimated B_0, we calculate the impulse response function (IRF) from the moving average representation of the SVAR (equation 3)

$$y_t = \mu + \sum_{i=0}^{\infty} \Theta_i w_{t-i}\,, (3)$$

where Θ_m represents the response of the variables in y_t to a dollar increase in one of the shocks contained in w_t after m quarters have passed. Notice that because our variables are expressed in log-difference, we rescale the original IRFs by the sample mean of the corresponding ratio to convert the estimated elasticities in derivatives so that, for instance, the element in the fourth row, first column of Θ_m, represents the response of GDP to a one-dollar increase in government spending. To measure the uncertainty about the estimated IRFs we calculate the 68% confidence interval using the quantile of the normal distribution and a bootstrap of 500 replications to estimate the standard deviations.

Appendix 3. Dynamic responses

Table 3.1. IRFs, model 1

response of	Y		R_D	
	shocks			
t	G	T	G	T
0	0.806	-0.992	0.004	-0.005
1	0.954	-1.202	0.001	-0.012
2	1.339	-1.355	0.022	-0.010
3	1.192	-1.501	0.033	-0.014
4	1.036	-1.443	0.052	-0.012
5	1.039	-1.308	0.070	-0.011
6	1.443	-1.305	0.087	-0.013
7	1.706	-1.296	0.101	-0.013
8	1.836	-1.351	0.105	-0.013
9	1.716	-1.396	0.101	-0.014
10	1.669	-1.459	0.102	-0.013
11	1.418	-1.498	0.103	-0.013
12	1.151	-1.522	0.104	-0.014
13	0.961	-1.510	0.108	-0.014
14	0.873	-1.517	0.109	-0.015
15	0.870	-1.509	0.108	-0.016
16	0.959	-1.503	0.106	-0.015
17	1.020	-1.518	0.103	-0.016
18	1.057	-1.528	0.099	-0.016
19	1.029	-1.528	0.097	-0.015
20	0.972	-1.527	0.096	-0.015
21	0.924	-1.521	0.096	-0.016
22	0.912	-1.515	0.096	-0.016
23	0.928	-1.514	0.096	-0.016
24	0.979	-1.515	0.096	-0.016

Table 3.2. IRFs, model 2

response of	Y			R_D		
	shocks					
t	G_INV	G_C	T	G_INV	G_C	T
0	**1.969**	**0.432**	-0.315	0.000	-0.001	0.001
1	**2.706**	**0.576**	-0.187	0.008	**-0.011**	-0.003
2	**3.157**	**1.151**	-0.063	**0.027**	0.009	-0.001
3	**2.908**	**1.207**	-0.182	0.027	**0.024**	-0.002
4	**3.641**	0.723	-0.088	**0.062**	**0.036**	0.003
5	**3.624**	0.736	0.001	**0.094**	**0.045**	0.008
6	**4.562**	0.883	-0.136	**0.129**	**0.054**	0.010
7	**4.276**	**1.418**	-0.239	**0.163**	**0.056**	0.011
8	**3.835**	**1.828**	-0.443	**0.165**	**0.062**	0.011
9	**3.612**	**1.904**	-0.544	**0.173**	**0.052**	0.007
10	**3.568**	**1.868**	-0.601	**0.186**	**0.050**	0.007
11	**3.284**	**1.653**	-0.622	**0.199**	**0.045**	0.006
12	**2.930**	**1.404**	-0.631	**0.209**	**0.043**	0.005
13	**2.622**	**1.288**	-0.640	**0.218**	**0.043**	0.005
14	**2.260**	**1.340**	-0.664	**0.222**	**0.044**	0.004
15	2.242	**1.377**	-0.632	**0.224**	0.039	0.003
16	2.213	**1.519**	-0.605	**0.228**	0.035	0.003
17	2.196	**1.659**	-0.609	**0.226**	0.029	0.002
18	2.013	**1.824**	-0.604	**0.222**	0.025	0.001
19	1.819	**1.869**	-0.606	**0.217**	0.024	0.000
20	1.682	**1.848**	-0.604	**0.214**	0.022	-0.001
21	1.625	**1.813**	-0.599	**0.211**	0.022	-0.001
22	1.600	**1.816**	-0.589	**0.210**	0.022	-0.001
23	1.572	**1.878**	-0.587	**0.208**	0.021	-0.001
24	1.571	**1.990**	-0.582	**0.205**	0.021	-0.001

Significant estimates are indicated in bold.

Table 3.3. IRFs, model 3

response of	Y			R_D		
	shocks					
t	G_I	G_R	T	G_I	G_R	T
0	**8.855**	**0.815**	**-0.900**	**0.527**	0.004	**-0.004**
1	**20.283**	**0.972**	**-1.094**	**0.938**	0.000	**-0.009**
2	**20.007**	**1.304**	**-1.239**	**1.167**	**0.020**	**-0.007**
3	**28.768**	**1.126**	**-1.354**	**1.492**	**0.030**	**-0.010**
4	**24.654**	**0.990**	**-1.338**	**1.734**	**0.048**	-0.009
5	**20.587**	**1.016**	**-1.232**	**1.727**	**0.066**	-0.007
6	13.561	**1.435**	**-1.228**	**1.683**	**0.083**	-0.010
7	9.712	**1.680**	**-1.206**	**1.771**	**0.096**	-0.010
8	9.236	**1.698**	**-1.230**	**1.844**	**0.099**	-0.009
9	9.049	**1.517**	**-1.237**	**1.871**	**0.093**	-0.010
10	9.793	**1.439**	**-1.278**	**2.022**	**0.091**	-0.009
11	13.593	**1.259**	**-1.274**	**2.100**	**0.093**	-0.008
12	16.152	**1.073**	**-1.278**	**2.143**	**0.095**	-0.009
13	19.213	**0.947**	**-1.261**	**2.275**	**0.098**	-0.009
14	**22.136**	**0.880**	**-1.282**	**2.355**	**0.100**	-0.009
15	**23.866**	**0.915**	**-1.294**	**2.404**	**0.100**	-0.010
16	**24.878**	**1.015**	**-1.314**	**2.526**	**0.099**	-0.010
17	**25.778**	**1.075**	**-1.338**	**2.596**	**0.097**	-0.010
18	**26.102**	**1.098**	**-1.354**	**2.674**	**0.094**	-0.011
19	**26.952**	**1.062**	**-1.353**	**2.772**	**0.092**	-0.011
20	**27.320**	**1.017**	**-1.352**	**2.844**	**0.091**	-0.011
21	**27.871**	**0.988**	**-1.344**	**2.900**	**0.092**	-0.011
22	**28.146**	**0.992**	**-1.338**	**2.969**	**0.093**	-0.011
23	**28.291**	**1.026**	**-1.337**	**3.008**	**0.094**	-0.012
24	**28.455**	**1.077**	**-1.339**	**3.054**	**0.095**	-0.012

Significant estimates are indicated in bold.

Table 3.4. IRFs, model 4

response of	Y				R_D			
	Shocks							
t	G_ID	G_IND	G_R	T	G_ID	G_IND	G_R	T
0	5.405	**7.110**	**0.813**	**-0.794**	**0.501**	**0.247**	0.002	-0.002
1	**23.623**	**12.909**	**0.990**	-0.894	**1.038**	**0.390**	-0.002	-0.008
2	**34.005**	**10.225**	**1.300**	-0.992	**1.578**	**0.415**	**0.015**	-0.006
3	**40.530**	**14.381**	**1.006**	-1.168	**1.916**	**0.497**	**0.022**	-0.009
4	**45.009**	9.192	**0.824**	-1.125	**2.788**	**0.558**	**0.039**	-0.007
5	**36.802**	4.569	**0.796**	-1.055	**2.742**	**0.621**	**0.059**	-0.004
6	18.495	4.013	**1.248**	-1.091	**2.451**	**0.673**	**0.078**	-0.005
7	17.510	0.755	**1.476**	**-1.119**	**2.441**	**0.843**	**0.093**	-0.003
8	16.597	5.470	**1.556**	**-1.219**	**2.537**	**0.971**	**0.098**	-0.002
9	13.117	6.441	**1.376**	**-1.236**	**2.275**	**0.990**	**0.092**	-0.003
10	8.932	6.882	**1.255**	**-1.251**	**2.459**	**1.073**	**0.087**	-0.001
11	14.930	9.984	**1.019**	**-1.251**	**2.850**	**1.061**	**0.085**	-0.001
12	15.437	11.077	0.828	**-1.277**	**3.048**	**1.059**	**0.088**	-0.003
13	13.109	11.904	0.694	**-1.264**	**3.312**	**1.161**	**0.090**	-0.002
14	17.166	13.179	0.501	**-1.320**	**3.568**	**1.223**	**0.092**	-0.004
15	22.718	12.166	0.512	**-1.348**	**3.701**	**1.274**	**0.093**	-0.006
16	23.955	12.453	0.548	**-1.377**	**3.785**	**1.377**	**0.092**	-0.007
17	24.819	12.595	0.529	**-1.434**	**3.837**	**1.387**	**0.088**	-0.009
18	26.499	12.739	0.540	**-1.454**	**3.911**	**1.422**	**0.085**	-0.010
19	26.567	13.634	0.517	**-1.467**	**4.073**	**1.438**	**0.081**	-0.011
20	24.951	13.043	0.465	**-1.488**	**4.198**	**1.414**	**0.080**	-0.012
21	24.360	13.125	0.430	**-1.486**	**4.360**	**1.421**	**0.079**	-0.013
22	25.347	12.907	0.412	**-1.488**	**4.566**	**1.432**	**0.080**	-0.014
23	25.636	12.046	0.437	**-1.487**	**4.672**	**1.434**	**0.081**	-0.015
24	25.848	12.237	0.485	**-1.481**	**4.768**	**1.462**	**0.081**	-0.015

Significant estimates are indicated in bold.

Appendix 4: Simulation using stock-flow consistent 'supermultiplier model'

In addition to our empirical study of the supermultiplier, we have also undertaken numerical simulation using the stock-flow consistent (SFC) macroeconomic model developed in Deleidi et al. (2019b) and based on the supermultiplier model developed in Deleidi and Mazzucato (2018). [10]

SFC models provide several advantages compared to standard dynamic-stochastic-general-equilibrium (DSGE) models employed by mainstream economists: (i) they provide a rigorous accounting framework following the system of national accounts used by most governments, which allows the identification of relationships between sectoral transactions in the short and long run, and allows us to confidently examine how the economy might react differently when policies such as fiscal expansion are imposed slowly or quickly; ii) they consider the mutual influence between financial asset positions and the real economy; (iii) they include the fundamental role played by finance, money, credit and banks; and (iv) they assume more realistic hypothesis in terms of expectations, the behaviour of economic agents, and heterogeneity than conventional macroeconomic models (Burgess et al. 2016, p.3).

Four shocks or alternative policy scenarios have been considered:

- A permanent increase in the absolute level of mission-oriented innovation spending undertaken by the government (equal to 1% of output in 2018);
- A permanent increase in the absolute level of routine (non-innovation focused) government spending (equal to 1% of output in 2018);
- A permanent cut in the absolute level of taxes on workers' income (equal to 1% of output in 2018); and
- A permanent cut in the absolute level of taxes on capitalists' income (equal to 1% of output in 2018);

Scenarios (1) to (4) are displayed in Figure 1 and Figure 2. Each series is expressed as a ratio to (or difference with) its own baseline value.[11] The policies considered all have a positive impact on output (GDP), consumption and investment. We find that mission-oriented innovation spending is the policy with the highest multiplier effect on output (Figure 1a), followed by routine spending (e.g. public investment in 'shovel-ready' projects and government consumption expenditure) (Figure 1b). A tax cut also has a positive impact on output and its components, mainly through an increase in consumption levels. However, the effect is far below that of an increase in government spending, due to household saving 'leakages', i.e. households do not exploit the additional purchasing power they

[10] With thanks to Marco Veronese Passarella and Riccardo Pariboni for SFC model estimations. Our approach is based upon the methodology outlined by Godley and Lavoie (2016). See also Nikiforos and Zezza (2017) for a detailed survey of stock-flow consistent models.

[11] That is, value under scenario *x* divided by (or minus) the baseline value. While results are displayed in a quarterly series, this is just a numerical simulation exercise. In other words, our findings are purely qualitative. No specific meaning should be attributed to absolute values of series or their timing.

enjoy from the tax cut but instead save it. A tax cut offered to workers is (slightly) more effective because they have a lower propensity to save income compared to capitalist households.

Figure 3 summarises our findings with respect to output reaction to shocks (Figure 3a). It shows that one of the channels through which government spending affects output (in the short run) is the change in the utilisation rate of manufacturing plants (Figure 3b). Mission-oriented innovation policy generates the largest positive effect on the degree of capacity utilisation.

The impact of an expansionary fiscal policy on the government deficit and the stock of debt has become a major concern for policymakers in recent decades. Figure 4a shows that the effect on the deficit-to-GDP ratio is just temporary for all four policies. Again, mission-oriented innovation spending turns out to be the best option, as it is characterised by the smallest peak in the deficit-to-GDP ratio following the shock. The ratio then falls sharply and stabilises below the baseline level (that is, the difference with the baseline value remains negative).

Routine spending is the second-best option, while the tax cut has a stronger impact on the deficit and can take more time to be reabsorbed (especially a tax cut on capitalists' income). The same goes for the stock of debt-to-GDP ratio (Figure 4b). An increase in mission-oriented innovation spending by the government entails a lower debt peak compared to other options and allows for a permanent reduction in the debt-to-GDP ratio. Notice that other expansionary fiscal policies also enable cutting the debt-to-GDP ratio in the long run, but at a much slower pace.

The simulations suggest that mission-oriented innovation investment crowds in the private sector, thereby increasing the growth rate of output more than other types of fiscal policy. In fact, a shock to mission-oriented innovation policy generates a positive and persistent effect on private R&D expenditure (figure 5b). Other expansionary policies also have a positive impact on output grow rate, but their effects are lower than mission-oriented policies (Figure 5a). These results support and complement the findings from our econometric estimations reported in section 4.

Figure 1. Reaction of output (GDP), total consumption and investment following a positive shock to innovative (a) and routine (b) government spending, respectively

(a) Shock to mission-oriented innovation expenditure (2018 = +0.1% GDP [2018])

(b) Shock to routine gov. spending (2018 = +0.1% GDP [2018])

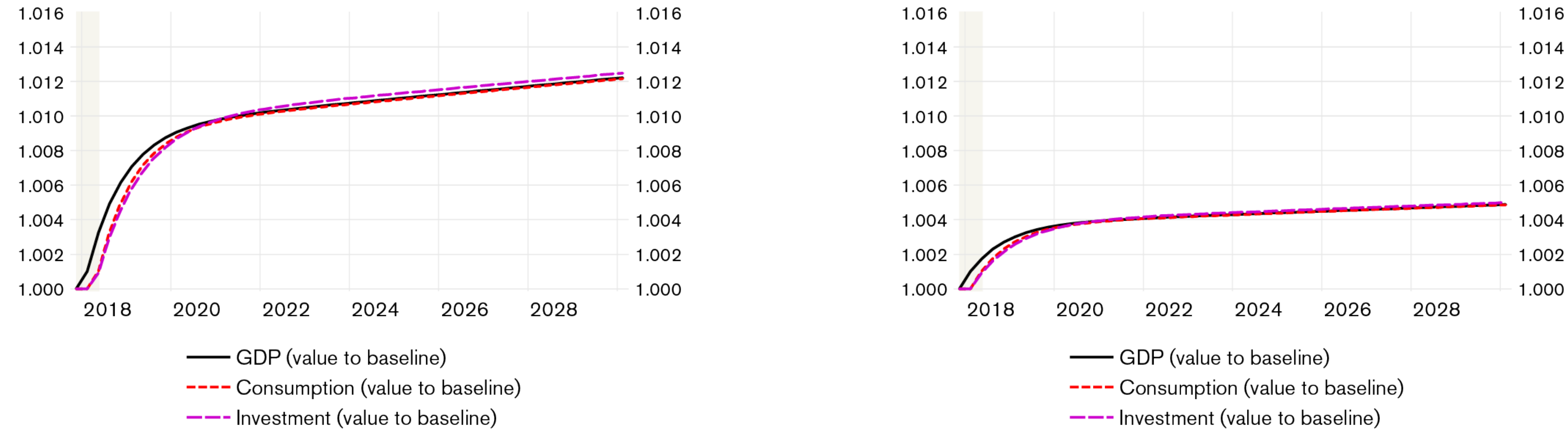


Figure 2. Reaction of output (GDP), total consumption and investment following a negative shock to taxes paid by workers (a) and capitalists (b)

(a) Cut in taxes by workers (2018 = -0.1% GDP [2018])

(b) Cut in taxes paid by capitalists (2018 = -0.1% GDP [2018])

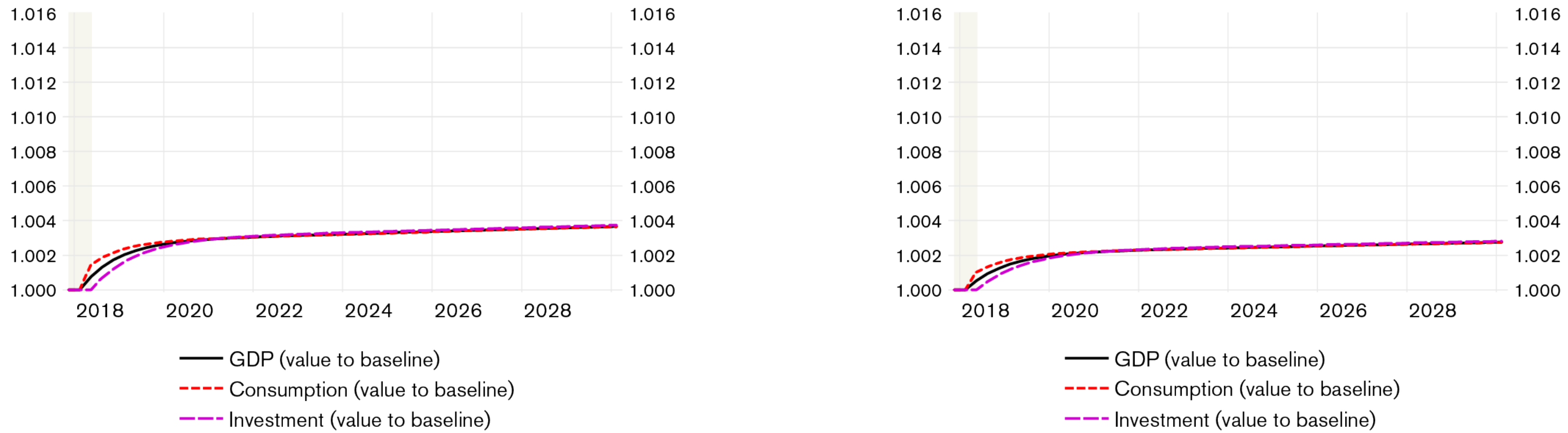


Figure 3. Reaction of output (a) and capacity utilisation (b) following different fiscal shocks

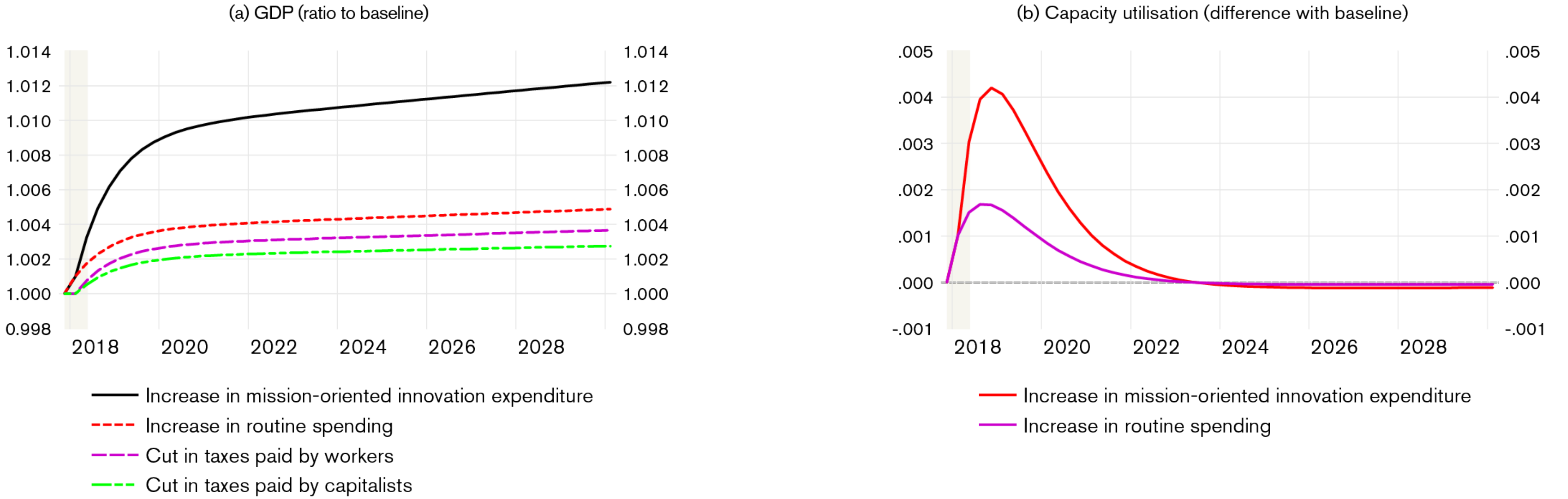


Figure 4. Reaction of government deficit (a) and debt (b) to GDP ratios following different fiscal shocks

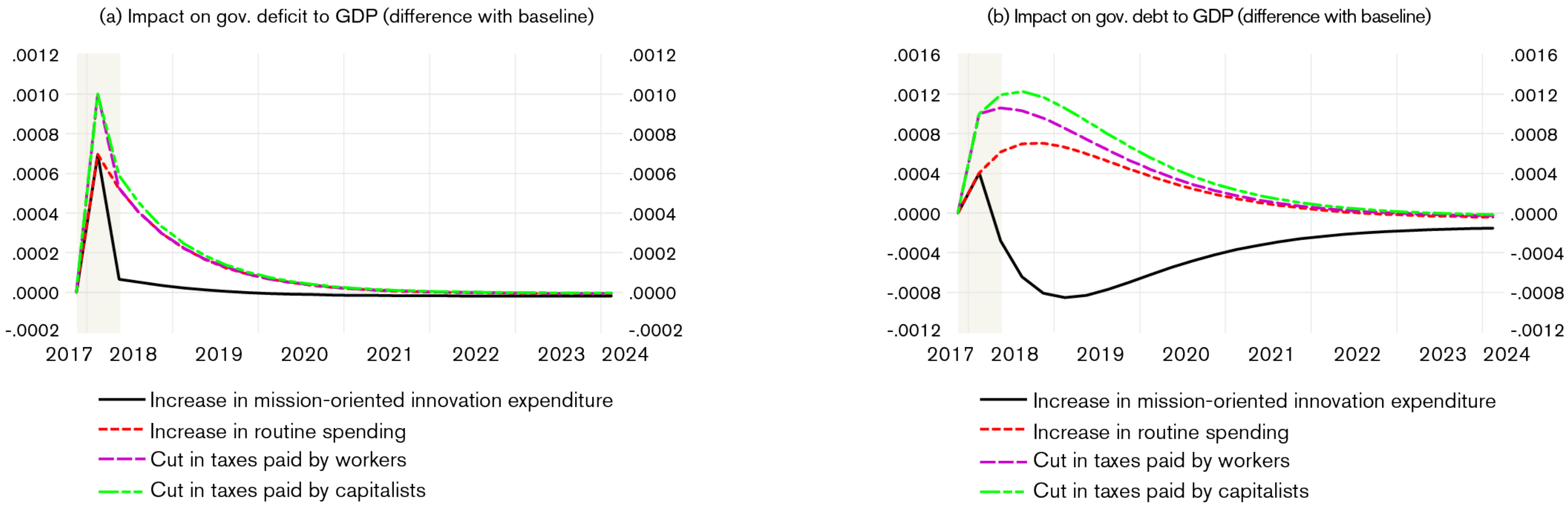
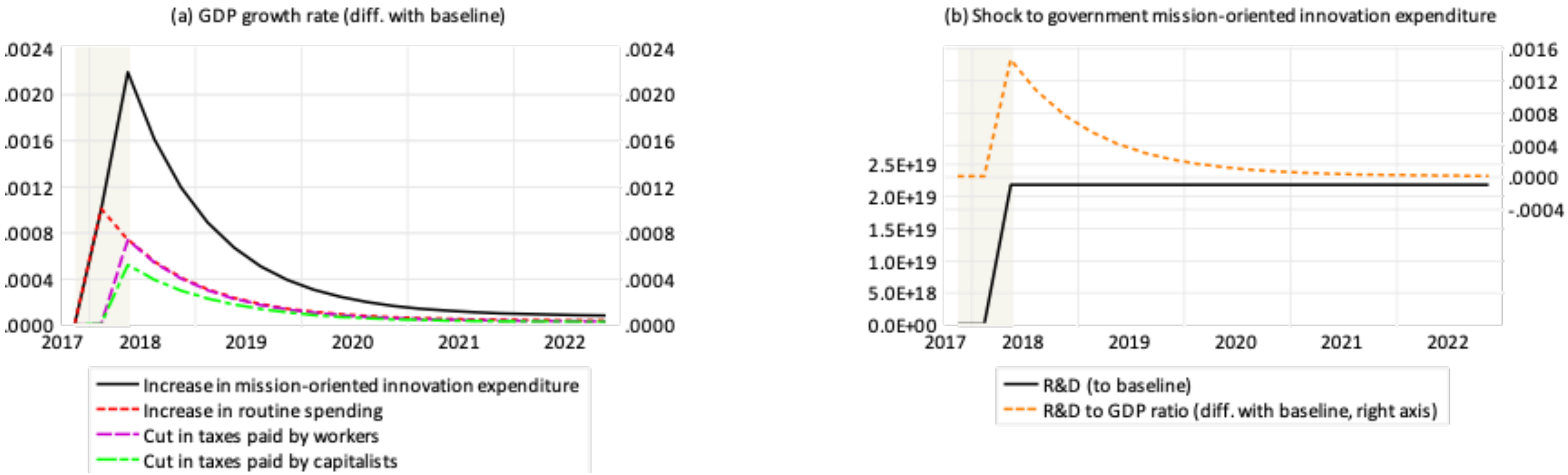


Figure 5. Reaction of output growth rate following different shocks (a) and private R&D expenditure following a positive shock to innovative government spending (b).



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