Evidence Review 9

Innovation: R&D tax credits

October 2015

what works centre for
local economic growth

00

Contents

01

Preface

This report presents findings from a systematic review of evaluations of programmes that aim to support innovation – the development and diffusion of new products and processes – by providing tax credits for research and development activity (R&D). It is meant to sit alongside our similar review of grants, loans and subsidies for R&D activity.

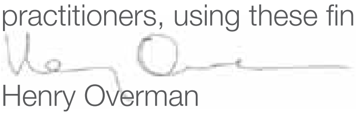
Together these reports comprise the ninth review produced by the What Works Centre for Local Economic Growth. The What Works Centre is a collaboration between the London School of Economics and Political Science, Centre for Cities and Arup and is funded by the Economic & Social Research Council, The Department for Communities and Local Government and The Department for Business Innovation & Skills.

These reviews consider a specific type of evidence – **impact evaluation** – that seeks to understand the causal effect of policy interventions and to establish their cost-effectiveness. To put it another way they ask 'did the policy work' and 'did it represent good value for money'? By looking at the details of the policies evaluated we can also assess what the evidence tells us about delivery issues – for example, is there any evidence that schemes with a particular sectoral focus do better than other schemes?

Evidence on impact and effectiveness is a crucial input to good policy making. Process evaluation – looking in detail at how programmes operate – provides a valuable complement to impact evaluation, but we do not focus on this. We recognise that may sometimes cause frustration for practitioners who are responsible for delivery.

However, we see these impact-focused reviews as an essential part of more effective policy making. We often simply do not know the answers to many of the questions that might reasonably be asked when implementing a new policy – not least, does it work? Figuring out what we do know allows us to better design policies and undertake further evaluations to start filling the gaps in our knowledge. This also helps us to have more informed discussions about process and delivery issues and to improve policymaking.

These reviews therefore represent a first step in improving our understanding of what works for local economic growth. In the months ahead, we will be working with local decision makers and practitioners, using these findings to help them generate better policy.



Henry Overman
Director, What Works Centre for Local Economic Growth

02

Executive Summary

This report presents findings from a systematic review of evaluations of tax credit schemes that aim to support innovation – by which we mean development and diffusion of new products and processes. A companion report looks at R&D grants, loans and subsidies. Other measures to support innovation will be considered in further work.

It is part of a wider set of reviews that consider alternative measures to support innovation. It is the 9th in a series of reviews produced by the What Works Centre for Local Economic Growth.

The review considered around **1,700** studies from the UK and other OECD countries (covering all aspects of support for innovation). This review considers the **21** impact evaluations that covered programmes offering R&D tax credits.

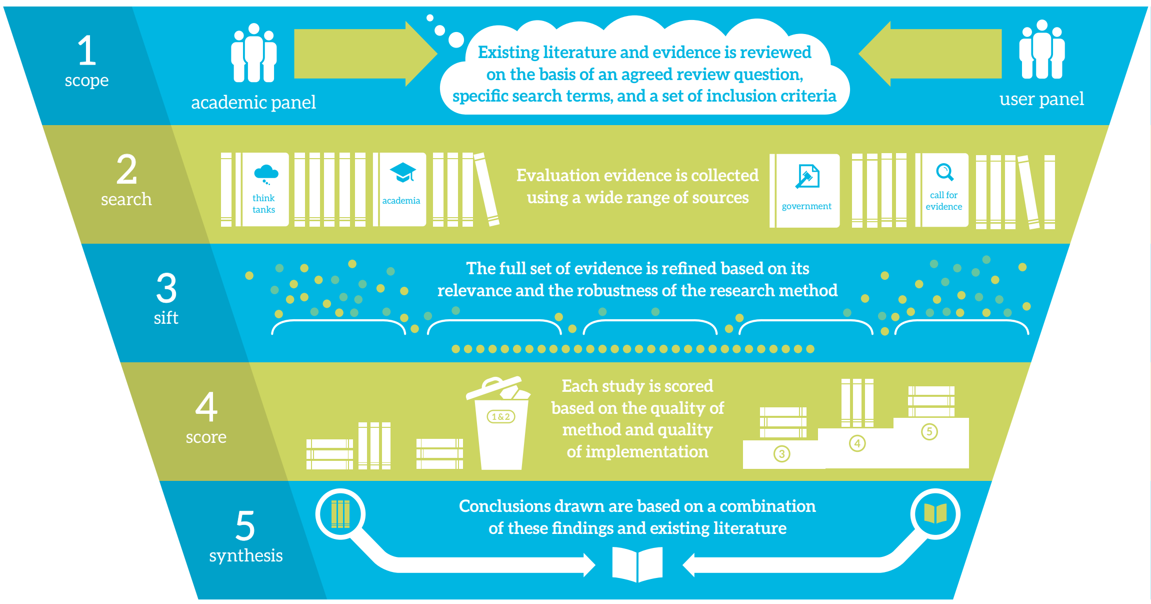
The 21 evaluations reviewed looked at one or more of three broad outcomes of interest: R&D expenditure, innovation and economic outcomes. Of these, 10 of 17 found positive programme impacts on R&D expenditure. All 3 studies that looked at innovation outcomes (patents or self-reported process or product innovation) found positive effects. Only 1 of the 3 studies looking at economic outcomes (productivity, employment of firm performance – profits, sales or turnover) found consistently positive effects.

Approach

The Centre seeks to establish causal impact – an estimate of the difference that can be expected between the outcome for firms in the programme and the average outcome they would have experienced without the programme (see Figure 1). Our methodology for producing our reviews is outlined in Figure 2.

Figure 1: Evaluating impact

Figure 2: Methodology



Findings

What the evidence shows

- R&D tax credits can positively impact R&D expenditure, although effects are not always positive.
- Impacts may depend on firm size with small firms slightly more likely to experience positive benefits. Smaller firms may face greater financial constraints, making them more responsive to changes in tax credits. However, smaller firms may also reclassify innovation-related spending as ‘formal’ R&D.

Where the evidence is inconclusive

- It is hard to reach any strong conclusions on differences between the different programme types in terms of effectiveness.

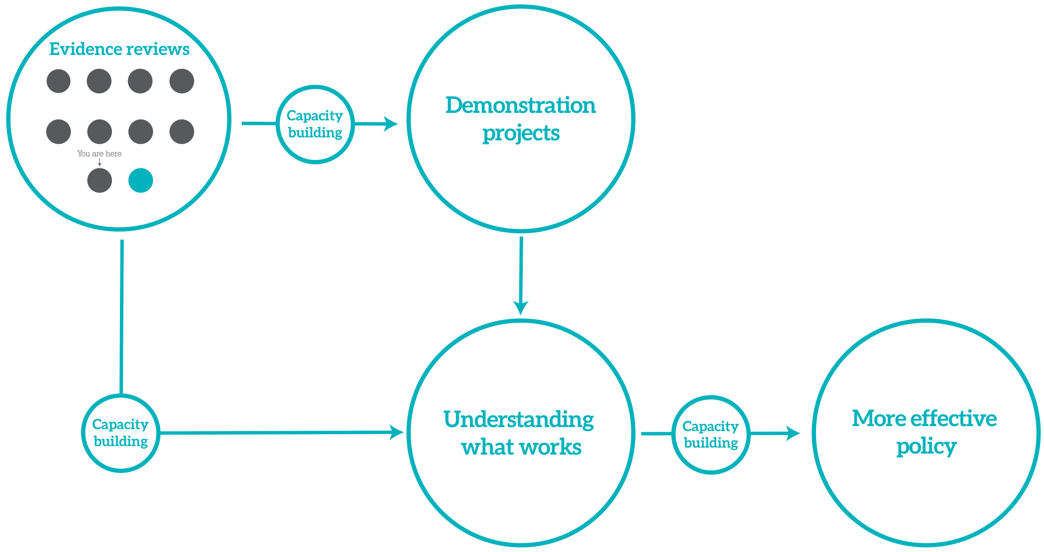
Where there is a lack of evidence

- Most shortlisted studies focus only on R&D effects of tax credits, and there is surprisingly little evidence on the impact of R&D tax credits on innovation (as measured by patents or self-reported innovative activity, for example). The available studies suggest that tax credits can have a positive impact on innovation, both at firm and area level.
- There is surprisingly little evidence on the effect of R&D tax credits on wider economic outcomes and it is hard to draw firm conclusions on the impact.
- Relatively few evaluations consider more than one element of the chain from increased R&D spend, through innovation, to improved firm performance. Results from these studies are generally positive.
- None of the shortlisted evaluations consider the timing of effects.

How to use these reviews

The Centre's reviews consider a specific type of evidence – impact evaluation – that seeks to understand the causal effect of policy interventions and to establish their cost-effectiveness. In the longer term, the Centre will produce a range of evidence reviews that will help local decision makers decide the broad policy areas on which to spend limited resources. Figure 3 illustrates how the reviews relate to the other work streams of the Centre.

Figure 3: What Works Centre work programme



Supporting and complementing local knowledge

This evidence review does not address the specifics of 'what works where' or 'what will work for a particular locality'. An accurate diagnosis of the specific local challenges policy seeks to address needs to be the first step in understanding how the overall evidence applies in any given situation.

However, while detailed local knowledge and context will be important in undertaking that analysis, as in most policy areas we have considered, the evidence presented here doesn't make the case for local over national delivery (or vice-versa).

The evidence urges some caution on the role that more localised innovation policy would play in driving local economic growth. Local decision makers need to think carefully about the desired objectives for local innovation policy. For example, our review shows that tax credits have a pretty good success rate in raising R&D spending (particularly for smaller / younger firms). But we know much less about whether, or how this increased R&D activity feeds through to greater innovation, better firm performance or longer term economic growth, particularly at the local level. These broader outcomes are the things most local economic decision makers ultimately care about. There are good reasons to think that many of these broader economic benefits are likely to 'spill over' so will be felt beyond the local area. This might still result in a net benefit for the place implementing the policy, but spillovers would need to be taken into account in evaluating impacts.

R&D tax credits could also make limited sense as a ***local*** policy if they caused firms to relocate across boundaries, triggering a race to the bottom as local policymakers offered larger and larger tax breaks regardless of their impact. Study 642 finds some evidence of firm relocation across US state borders in response to tax incentives. Any moves to devolve policy in the UK would need to carefully consider these issues.

Overall, then, it is important to remember that evaluation of the impact of innovation policy is still limited and this review raises as many questions as answers. The limited evidence base, particularly in terms of the impact on local economic outcomes, highlights the need for realism about the capacity and evidence challenges of delivering innovation policy at a more local level.

Helping to fill the evidence gaps

The review identifies a number of evidence gaps, specifically:

- 18 out of 21 studies score three on the Maryland Scale, the minimum criterion for inclusion. In these studies, unobservable factors may still explain the reported results. Given the prevalence of R&D tax credits it is important to think how we might generate further high quality impact evaluation evidence. Study 1208 provides one example for the UK. Government could help by releasing scheme performance data, including cost data, to researchers (to allow construction of treatment and control groups and calculations of cost-effectiveness).
- Very few studies look at economic effects of R&D tax credits beyond immediate impacts on R&D spend. Specifically, we found only three out of 21 studies looking at patents or reported innovation, and another three out of 21 studies looking at wider firm or area-level outcomes, such as productivity or concentrations of star scientists. If the ultimate aim of R&D incentives (especially at the local level) is to influence innovation and growth, it is crucial that we evaluate future policies against these objectives. To do this, policymakers have to ensure that researchers can link firm-level data on tax, financial assets, productivity, jobs and innovative activities.
- We need a much better sense of how R&D tax credits work alongside other elements of innovation policy. Better data on scheme reach and participants will help researchers to do this.
- Similarly, we need more evidence on whether regional or urban-level policy is appropriate.

> Innovative activity tends to cluster, and local 'ecosystems' often have unique characteristics. This implies that local policy could have a role to play. But as we discussed above, the benefits of innovation is not always spatially bounded, and traditional local cluster programmes have a very poor success rate.

The Centre's longer term objectives are to ensure that robust evidence is embedded in the development of policy, that these policies are effectively evaluated and that feedback is used to improve them. To achieve these objectives we want to:

- work with local decision makers to improve evaluation standards so that we can learn more about what policies work, where.
- set up a series of 'demonstration projects' to show how effective evaluation can work in practice.

Interested policymakers please get in touch.

03

Introduction

This review looks at the impact of tax credit schemes that aim to encourage firms to do research and development (R&D). It is a part of a wider set of reviews on aspects of innovation policy.

Innovation is usually defined as the ‘invention, diffusion and exploitation of new ideas’.[1] The innovation process is an important influence on long term economic development, and investment in research, development and new ideas is central to this. In particular, economists identify two key linkages from R&D to wider growth[2]:

- First, firms conduct R&D to find ways to cut costs; to develop smarter ways of working; and to develop new goods and services.[3] Those product and process innovations may, in turn, feed through to higher productivity, higher sales and profits for the firm. In turn, this helps recoup at least some of the cost of the original investment.
- Second, innovation in one firm may also spill over and benefit other individuals, firms or organisations. This means that the wider gains from R&D to society, which economists refer to as the ‘social returns’, may be greater than firms’ private returns.[4]

These knowledge spillovers occur because new ideas permeate outside the firm: as key staff take new jobs, or set up new companies; through imitation and reverse engineering by competitors; and because forms of intellectual property protection, like patents and trademarks, don’t offer complete and permanent coverage. This wider diffusion process is often disruptive, as in Schumpeter’s notion of ‘creative destruction’.[5]

The available evidence suggests that returns to private R&D are positive in most countries, and typically higher than regular capital investment. A 2010 survey suggests returns to R&D of 20-30% in more developed countries during the second half of the last century. Social returns are harder to estimate, but may be higher still: typically over 30% and in some cases even over 100% for studies over the same time period.[6]

1 Fagerberg (2005).
2 Two seminal endogenous growth contributions are Lucas (1988) and Romer (1990).
3 Hall et al. (2010).
4 Griliches (1992), Jaffe (1996), Hausmann et al. (2003), Rodrik (2004).
5 Schumpeter (1962).
6 Hall et al. (2010).

Public R&D activity is an important element in this mix. For example, a recent study of 15 OECD countries between 1980 and 1998 suggests that firms' response to public R&D spending is higher than for private sector spending.[7] In line with this, a 2013 study for the UK suggests substantial spillovers from academic research to private firms, while private sector R&D is almost wholly captured by the original investors.[8]

These numbers help explain why national governments directly and indirectly support R&D, as part of a broader portfolio of innovation policies. If the firm that makes the R&D investment bears the cost, but others across the economy benefit from the new knowledge, then society would invest far too little in new knowledge if R&D activity was left only to the market. What is more, research at the knowledge frontier has highly uncertain payoffs and often requires expensive investment by firms, for example in specialist staff and equipment: these factors may also lead to sub-optimal levels of R&D. Some R&D activities may also exhibit 'network spillovers' due to their cost and complexity, which create further disincentives for firms.

In practice, governments seek to generate both public R&D (through direct grants to universities and government labs) and private R&D (through grants, loans and subsidies to businesses, and through tax policy). We explore R&D grants, loans and subsidies in a companion review.

The spillover argument implies that governments should support investment in R&D – for example by funding R&D directly or by ***complementing*** private sector activities through subsidies or making parallel public investments.[9] For example, government can influence R&D activity by doing its own research; by encouraging collaboration between organisations, by funding universities and public research labs; or by funding private sector research through grants, loans and contracts. Our review of R&D grants, loans and subsidies evaluates the economic impacts of these interventions.

Government may also support R&D indirectly through tax credits or other incentives.[10] For example, the UK has operated an R&D tax credits scheme for small and medium-sized enterprises (SMEs) since 2000, with an extension to larger firms in 2002. The programme was made substantially more generous for SMEs in 2008; one of our studies evaluates the impact of these changes.

Part of the appeal of tax credits is practical: the delivery apparatus already exists through the business tax system. This makes them relatively easy to target on certain types of firm (such as SMEs) or to make them accessible to all firms. (That said, the detailed design of tax credit schemes can be extremely complex.)

Tax credits also fit with some policymakers' desire for a market-led, 'hands-off' approaches to innovation strategy: while grant programmes involve policymakers or experts selecting what they hope are the 'best' proposals, tax credits can reach a much larger number of businesses and avoid any suggestion of 'picking winners'.

Understanding whether R&D tax credits are effective should also be of interest to local and regional policymakers. Most tax credit programmes tend to be designed by national governments, but not all: in more fiscally devolved countries than the UK, there are also regional-level fiscal incentives for innovation. Just looking at the biotech industry, for example, at least eleven US states have their own fiscal incentives.[11]

Even in the absence of localised schemes, the fact that innovative activity is uneven and tends to cluster means that if R&D tax credits are effective, they are likely to have a local, as well as national, impact.[12] Although knowledge spillovers are often physically bounded, information can also spill over local boundaries, benefiting firms across the economy.[13] This may be good for national welfare, but

7 The elasticities of firm (total factor) productivity to R&D are 0.17 for public research and 0.13 for private research.
8 Guellec and Van Pottelsberghe de la Potterie (2004); Haskel, J. and G. Wallis (2013).
9 Rodrik (2004) and Harrison et al (2009).
10 Martin and Hughes (2012).
11 Study 526.
12 Jacobs (1962), Audretsch and Feldman (1996), Chatterji et al (2013).
13 Jaffe (1996) and Rodrik (2004).

will lessen the direct impact on local economic growth in a given area. For example, such spillovers are one important reason why R&D grants and subsidies are often devised by national government; even if some aspects of delivery take place locally.[14] Getting a sense of the likelihood, importance and scale of these policy impacts is therefore very important for those interested in local economic growth.

As this short introduction makes clear, innovation policy can involve a wide range of very different interventions. As we discuss below, it is also an area in which comprehensive evaluation is challenging.[15]

At the most basic level, innovation is not a linear process. Pathways from R&D tax credits to innovation can be iterative and unpredictable. More broadly, firms and public sector opportunities may be shaped by previous decisions and trends (processes known as 'path-dependence').[16] In turn, this can make identifying causal effects of interventions extremely difficult. In addition, although formal R&D is an important element of innovative activity, only a minority of firms are R&D-intensive: there are many other forms of innovation that governments can seek to support.

This has important implications for our evidence reviews, given their focus on impact evaluation. Preliminary sifts of the literature identified two areas for which there existed a sufficient number of impact evaluations to undertake a systematic review: 1) R&D grants, subsidies and loans, including collaboration/networking interventions associated with these policies and 2) tax credits and other fiscal incentives. This review considers the second of these, assessing the impact of R&D tax credits. We also found some evaluation evidence on 3) public venture capital policies and 4) collaboration / networking initiatives, although neither of these is large enough to merit a full review.

What can we expect tax credits to achieve? As with R&D as a whole, there are multiple impact channels which interact with, and feedback on, each other.[17] Tax credits should reduce the cost of research. More R&D should translate into 'innovation outcomes' like increased patenting, trademarks and new products or processes. In turn, that may feed through to higher productivity, higher sales/profits and increased employment in the investing firms – assuming they are able to effectively commercialise the knowledge. Spillovers should then help feed these benefits across the wider economy. These spillovers may, however, reduce the ability of individual firms to benefit from new R&D in terms of higher sales or profits (and related employment growth).

However, to initiate these effects, the tax credit has to offer a big enough cut in R&D costs for at least some firms to respond, something that is not easy to determine beforehand.[18] And unlike R&D grants, which are directed at specific activities that administrators deem have a high social return, firms will use tax credits to fund R&D projects with the highest return to that firm – which might not be the activities of most benefit to society.

There are also crucial aspects of these interventions which further complicate evaluation. In particular, R&D tax credits might also run the risk of crowding out private investments that firms would have made anyway, or of distorting efficient investment allocations.[19] This is an issue that especially relates to larger firms as they, amongst other things, face lower adjustment costs and, therefore, have a higher responsiveness to tax changes.[20]

In addition, governments tend to deploy a number of innovation policies at the same time. For example, a number of tax relief schemes reviewed in this report are offered at the same time of R&D grants and subsidies. There are also overlaps with other policy agendas, notably business support

14 Study 642.
15 For one recent attempt see NESTA's Compendium of Innovation Evidence, which comprises 19 evaluations, plus a synthesis report, combining case study, process and impact evaluation material.
16 David (1985) is the classic article. For a more recent review of the concept, see David (2007): http://www-siepr.stanford.edu/workp/swp06005.pdf
17 Hall and Van Reenen (2000) provide a review.
18 Bloom et al. (2002), Hall and Van Reenen (2000).
19 See for example Koehler et al (2012) for a review.
20 Study 1196.

and industrial policy.[21]

This complexity makes it harder to identify the causal impact of single programmes.[22] Compared to (say) public science programmes, which operate in a diffuse way, it should be simpler to trace the impacts of tax credits because they target firms directly.[23] However, researchers still need access to high quality firm-level data, and need to be able to track firms through time. As we shall see, relatively few of our evaluations are able to do this.

Figuring out the additional effect of R&D tax credits is particularly tough. Because tax credit programmes often require a qualifying level of existing R&D activity, it is possible that qualifying firms might have made further investments without the programme, or that non-qualifiers might have benefited more. Without a counterfactual, we will over or under-estimate the true programme impact. The knock-on effect of cheaper R&D on firms' innovative activity and economic performance is also conditional on 'absorptive capacity' – for instance, the presence of qualified staff, suitable equipment, connections to experts or previous organisational experience.[24] Again, we need to find ways to control for these hard-to-observe factors when evaluating impact.

In short, evaluating the impacts of R&D tax credits is extremely complex, even if the policy itself is relatively simple. The likely economic outcomes are hard to predict, hard to measure and evaluate, and may differ substantially at local and national level. This is reflected in our review: we find a number of impact evaluations that meet our minimum quality thresholds, but very few that can precisely identify the full range of policy effects (and none that can attribute this to specific aspects of programme design).

21 Nathan and Overman (2013); Chatterji et al (2013). NESTA's Compendium of Innovation Evidence, which comprises 19 evaluations, plus a synthesis report, combining case study, process and impact evaluation material.

22 Study 1205.

23 Cunningham et al. (2013).

24 Cohen and Levithal (1990) provide the classic analysis. Cunningham et al (2013) survey recent evidence.

04

Impact evaluation

Governments around the world increasingly have strong systems to monitor policy inputs (such as spending on an R&D tax credits programme) and outputs (such as the number of firms involved in that programme). However, they are often less good at identifying policy ***outcomes*** (such as the effect of tax credits on patenting or other forms of innovation, or on firms' productivity as a result of these innovations). In particular, many government-sponsored evaluations that look at outcomes do not use credible strategies to assess the **causal impact** of policy interventions.

By causal impact, the evaluation literature means an estimate of the difference that can be expected between the outcome for groups 'treated' in a programme, and the average outcome they would have experienced without it. Pinning down causality is a crucially important part of impact evaluation. **Estimates of the benefits of a programme are of limited use to policy makers unless those benefits can be attributed, with a reasonable degree of certainty, to that programme.**

The credibility with which evaluations establish causality is the criterion on which this review assesses the literature.

Using counterfactuals

Establishing causality requires the construction of a valid counterfactual – i.e. what would have happened to programme participants had they not been treated under the programme. That outcome is fundamentally unobservable, so researchers spend a great deal of time trying to rebuild it. The way in which this counterfactual is (re)constructed is the key element of impact evaluation design.

A standard approach is to create a counterfactual group of similar individuals not participating in the programme being evaluated. Changes in outcomes can then be compared between the 'treatment group' (those affected by the policy) and the 'control group' (similar individuals not exposed to the policy).

A key issue in creating the counterfactual group is dealing with the 'selection into treatment' problem. Selection into treatment occurs when participants in the programme differ from those who do not participate in the programme.

An example of this problem in R&D tax credits would be when the credit is set too low to induce any change in firm behaviour. Any R&D activity we observe would have happened anyway, but without a counterfactual, we would attribute this to the policy, overstating its true impact. Similarly, it might be that hard-to-observe factors such as management quality might determine whether cheaper R&D feeds through to innovative activity. Without a way to 'control' for this in an evaluation, we would again overstate the impact of the tax credit.

So the challenge for good programme evaluation is to deal with these issues, and to demonstrate that the control group is plausible. If the construction of plausible counterfactuals is central to good policy evaluation, then the crucial question becomes: **how do we design counterfactuals?** Box 1 provides some examples.

Box 1: Impact evaluation techniques

One way to identify causal impacts of a programme is to randomly assign participants to treatment and control groups. For researchers, such **Randomised Control Trials** (RCTs) are often considered the 'gold standard' of evaluation. Properly implemented, randomisation ensures that treatment and control groups are comparable both in terms of observed and unobserved attributes, thus identifying the causal impact of policy. However, **implementation of these 'real world' experiments is challenging and can be problematic.** RCTs may not always be feasible for local economic growth policies – for example, policy makers may be unwilling to randomise.[25] And small-scale trials may have limited wider applicability.

Where randomised control trials are not an option, **'quasi-experimental'** approaches of randomisation can help. These strategies can deal with selection on unobservables, by (say) exploiting institutional rules and processes that result in some firms quasi-randomly receiving treatment.

Even using these strategies, though, the treatment and control groups may not be fully comparable in terms of observables. Statistical techniques such as **Ordinary Least Squares** (OLS) and **matching** can be used to address this problem.

Note that higher quality impact evaluation first uses identification strategies to construct a control group and deal with selection on unobservables. Then it tries to control for remaining differences in observable characteristics. It is the combination that is particularly powerful: OLS or matching alone raise concerns about the extent to which unobservable characteristics determine both treatment and outcomes and thus bias the evaluation.

Evidence included in the review

We include any evaluation that compares outcomes for firms receiving treatment (the treated group) after an intervention with outcomes in the treated group before the intervention, relative to a comparison group used to provide a counterfactual of what would have happened to these outcomes in the absence of treatment.

This means we look at evaluations that do a reasonable job of estimating the impact of treatment using either randomised control trials, quasi-random variation or statistical techniques (such as OLS and matching) that help make treatment and control groups comparable. We view these evaluations as providing credible impact evaluation in the sense that they identify effects which can be attributed,

25 Gibbons, Nathan and Overman (2014).

with a reasonable degree of certainty, to the implementation of the programme in question. A full list of shortlisted studies is given in Appendix A.

Evidence excluded from the review

We exclude evaluations that provide a simple before and after comparison only for those receiving the treatment because we cannot be reasonably sure that changes for the treated group can be attributed to the effect of the programme.

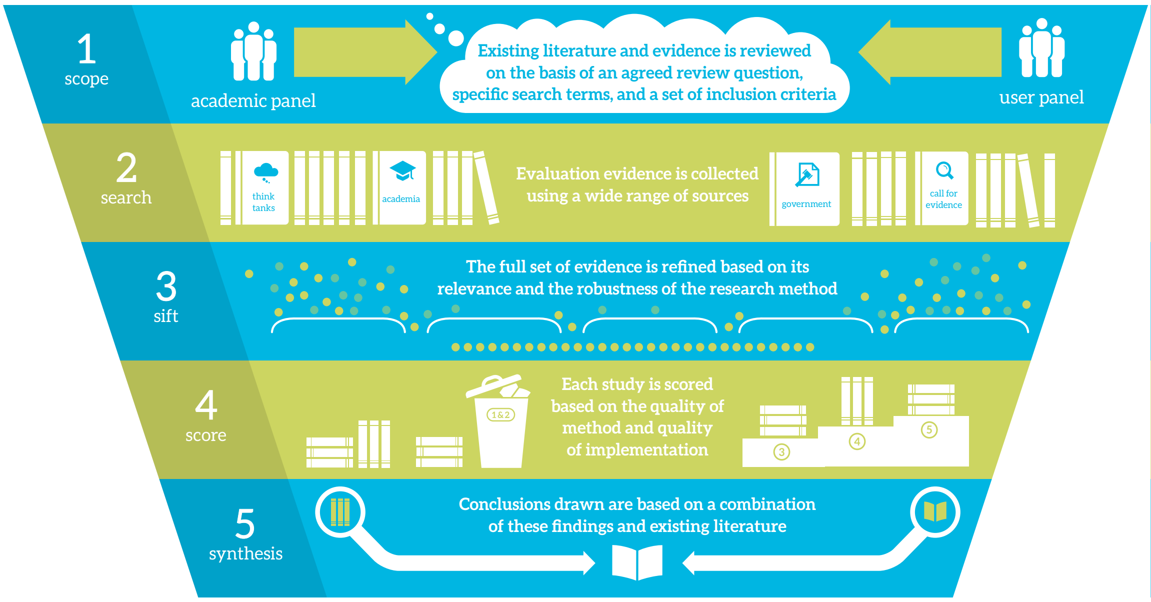
We also exclude case studies or evaluations that focus on process (how the policy is implemented) rather than impact (what was the effect of the policy). Such studies have a role to play in helping formulate better policy, forming an important complement to impact evaluations, but they are not the focus of our evidence reviews.

05

Methodology

To identify robust evaluation evidence on the causal impact of R&D tax credits, we conducted a systematic review of the evidence from the UK and across the world. Our reviews followed a five-stage process: scope, search, sift, score and synthesise.

Figure 1: Methodology



Stage 1: Scope of Review

Working with our User Panel and a member of our Academic Panel, we agreed the review question, key terms and inclusion criteria. We also used existing literature reviews and meta-analyses to inform our thinking.

Stage 2: Searching for Evaluations

We searched for evaluation evidence across a wide range of sources, from peer-reviewed academic research to government evaluations and think tank reports. Specifically, we looked at academic databases (such as EconLit, Web of Science and Google Scholar), specialist research institutes (such as CEPR and IZA), UK central and local government departments, and work done by think tanks (such as the OECD, ILO, ippr and Policy Exchange.) We also issued a call for evidence via our mailing list and social media. This search found close to 1700 books, articles and reports. The full list of search terms can be found online here: www.whatworksgrowth.org/policies/innovation/search-terms.

Stage 3: Sifting Evaluations

We screened our long-list on relevance, geography, language and methods, keeping impact evaluations from the UK and other OECD countries, with no time restrictions on when the evaluation was done. We focussed on English-language studies, but would consider key evidence if it was in other languages. We then screened the remaining evaluations on the robustness of their research methods, keeping only the more robust impact evaluations. We used the Maryland Scientific Methods Scale (SMS) to do this.[26] The SMS is a five-point scale ranging from 1, for evaluations based on simple cross sectional correlations, to 5 for randomised control trials (see Box 2). We shortlisted all those impact evaluations that could potentially score three or above on the SMS.[27] In this case we found 18 evaluations scoring three and three scoring four: for examples of evaluations that score three and four on the SMS scale, go to our website www.whatworksgrowth.org.

Stage 4: Scoring Evaluations

We conducted a full appraisal of each evaluation on the shortlist, collecting key results and using the SMS to give a final score for evaluations that reflected both the quality of methods chosen and quality of implementation (which can be lower than claimed by some authors). Scoring and shortlisting decisions were cross-checked with the academic panel member and the core team at LSE. The final list of included studies and their reference numbers (used in the rest of this report) can be found in Appendix B.

Stage 5: Synthesising Evaluations

We drew together our findings, combining material from our evaluations and the existing literature.

26 Sherman et al. (1998).
27 Sherman et al. (1998) also suggest that level 3 is the minimum level required for a reasonable accuracy of results.

Box 2: The Scientific Maryland Scale

Level 1: Correlation of outcomes with presence or intensity of treatment, cross-sectional comparisons of treated groups with untreated groups, or other cross-sectional methods in which there is no attempt to establish a counterfactual. No use of control variables in statistical analysis to adjust for differences between treated and untreated groups.

Level 2: Comparison of outcomes in treated group after an intervention, with outcomes in the treated group before the intervention ('before and after' study). No comparison group used to provide a counterfactual, or a comparator group is used but this is not chosen to be similar to the treatment group, nor demonstrated to be similar (e.g. national averages used as comparison for policy intervention in a specific area). No, or inappropriate, control variables used in statistical analysis to adjust for differences between treated and untreated groups.

Level 3: Comparison of outcomes in treated group after an intervention, with outcomes in the treated group before the intervention, and a comparison group used to provide a counterfactual (e.g. difference in difference). Some justification given to choice of comparator group that is potentially similar to the treatment group. Evidence presented on comparability of treatment and control groups but these groups are poorly balanced on pre-treatment characteristics. Control variables may be used to adjust for difference between treated and untreated groups, but there are likely to be important uncontrolled differences remaining.

Level 4: Comparison of outcomes in treated group after an intervention, with outcomes in the treated group before the intervention, and a comparison group used to provide a counterfactual (i.e. difference in difference). Careful and credible justification provided for choice of a comparator group that is closely matched to the treatment group. Treatment and control groups are balanced on pre-treatment characteristics and extensive evidence presented on this comparability, with only minor or irrelevant differences remaining. Control variables (e.g. OLS or matching) or other statistical techniques (e.g. instrumental variables, IV) may be used to adjust for potential differences between treated and untreated groups. Problems of attrition from sample and implications discussed but not necessarily corrected.

Level 5: Reserved for research designs that involve randomisation into treatment and control groups. Randomised control trials provide the definitive example, although other 'natural experiment' research designs that exploit plausibly random variation in treatment may fall in this category. Extensive evidence provided on comparability of treatment and control groups, showing no significant differences in terms of levels or trends. Control variables may be used to adjust for treatment and control group differences, but this adjustment should not have a large impact on the main results. Attention paid to problems of selective attrition from randomly assigned groups, which is shown to be of negligible importance.

06

Definition

By 'R&D', we mean investigative activity undertaken by the private sector (with or without academic participation), which has the objective of improving existing, or developing new, products or processes. Governments carefully define the scope of R&D inputs.[28] Programmes aimed at commercialising R&D aim to assist the generation, diffusion and exploitation of these products and processes.

In this review, we looked at evaluations of tax credit programmes designed to boost R&D. By construction, the primary goal of tax credits is to increase R&D spending by reducing its after tax-costs and thereby influencing wider economic outcomes as well.[29] In general, there are two main schemes for the roll out of tax credits:

- incremental-based, where a firm's eligibility for the credit depends on current R&D spending that exceed historic figures;
- volume-based, where the credit is only based on the current volume of R&D expenditures.

Other systematic reviews look at related areas of innovation policy, such as R&D grants, subsidies and loans; access to business finance, including public venture capital programmes; business advice; collaboration programmes, and fast internet.

Impact evaluation for R&D tax credits

As with other policy interventions, in an ideal world we would want to look at whether R&D tax credits generate a return to society that is at least equal to scheme costs. But identifying these social returns is very challenging.[30] For that reason, most evaluations tend to look at firm-level outcomes.

Impact evaluation for R&D tax credits presents some particularly tough challenges.[31] First, key to impact evaluation is high quality data for both a treated and a control group. Compared to network-building or public science programmes, such high quality data should be relatively easy to get for R&D tax credits,

28 For example, see https://www.gov.uk/guidance/corporation-tax-research-and-development-rd-relief#which-costs-qualify-for-rd-relief (accessed 25 September 2015).
29 Koehler et al. (2012).
30 Hall and Van Reenen (2000); Dechezleprêtre et al. (2015).
31 Cunningham and Gök (2013); Cunningham and Ramlogan (2013).

since target firms regularly have to provide public information through the tax system and through company reports. This data can be linked to other information from business surveys or patenting. In practice, however, getting access to such data is often challenging for researchers, and in many countries there are practical or legal constraints on data linkage and on tracking firms through time.

Second, even when high quality data is available, finding ways to robustly evaluate the *causal* impact of tax credits is hard because it is difficult to construct valid control groups (firms that are similar to those receiving tax credits but not participating in the programme). This is because tax credits are often open to all firms in the economy, or all firms in certain sectors (such as biotech) or of a certain type (such as SMEs).

Third, as noted in the introduction, it is difficult to identify additional effects of R&D tax credits. For example, schemes typically require some minimum level of R&D activity to qualify. Firms close to this level – but not achieving it – might be tempted to repackage routine activity as 'R&D' in order to qualify. Such 'gaming' can be very difficult or impossible to spot, but this means that true induced R&D from the credit may be lower than what is observed.

Fourth, the cost of R&D to firms will be affected by tax credits, and by number of other factors which also affect R&D spending, such as the real interest rate. Firms' current output and R&D activity is also likely to be affected by past activity, since businesses build up R&D and innovative capacity over time.[32]

The three most robust evaluations in our shortlist have all developed strategies to deal with these challenges. For example, study 605, which compares R&D tax credits in nine countries – including the UK – between 1979 and 1997, uses instrumental variables to proxy for the user cost of R&D and for firm output, as well as country level fixed effects. Study 1206, which looks at the US R&D tax credit between 1981 and 1991, also uses instruments. In this case, the author has access to firms' corporate tax returns as well as their R&D activity, and develops instruments based on changes in tax law to provide unbiased estimates of the effect of the tax credit.

Study 1208, which evaluates the UK R&D tax credits, exploits a major change in the policy implemented in 2008, which made the scheme substantially more generous for SMEs. The authors use this policy shock to examine changes in R&D spend for firms who just qualify for the new more generous treatment, versus changes for firms who just miss out (a so-called 'regression discontinuity' design).

Beyond these core issues, evaluators also face some other concerns. Cost calculations can be complicated if firms contract out R&D activity, or if firms' accounting data does not provide much detail. Similarly, very few evaluations have been able to connect credits either to innovative activity by firms (such as patenting) or to measures of firm economic performance (such as productivity or employment): study 1208 is one evaluation that is able to do this.

32 Hall and Van Reenen (2000); Bloom et al. (2002).

07

Findings

This section sets out the review's findings. We begin with a discussion of the evidence base, and then explore the overall pattern of positive and negative results. After this we consider specific programme features in more detail.

Quantity and quality of the evidence base

The review initially considered around 1,700 policy evaluations and evidence reviews from the UK and other OECD countries, identified during the initial keyword search.

Following a further high level review, nearly 1,500 were sifted out as not relevant (e.g. because they were theoretical rather than data-based; reviewed non-OECD countries; or because of subject relevance). From the remaining evaluations, we discarded around 130 further evaluations either because they turned out not to be relevant on more detailed review or because they did not meet our minimum standards. Of the remaining studies on innovation policy programmes, this review considers the 21 impact evaluations that covered programmes offering R&D tax credits.

This is a smaller evidence base than for our first review on innovation policy (R&D grants and loans) and most of our other reviews (on employment training, business advice and the impact of cultural sports projects), but roughly comparable to our reviews of business access to finance and estate renewal programmes. This may still be larger than the evidence base for many other local economic growth policies. However, it is a small base relative to that available for some other policy areas (e.g. medicine, aspects of international development, education and social policy).

Table 1: Studies ranked by SMS for implementation.

SMS score	Number	Reference number
3	18	499, 526, 604, 606, 610, 625, 626, 629, 630, 635, 640, 642, 643, 1196, 1198, 1201, 1204, 1205
4	3	605, 1206, 1208
Total	**21**	

Table 1 shows the distribution of studies ranked according to the SMS. We found only three studies (605, 1206 & 1208) that used credible quasi-random sources of variation (scoring 4 on the SMS). While one of these studies looks at the impact of tax credit schemes across countries (605), the two other evaluate the impacts of tax credits carried out in the US and the UK (1206 and 1208), respectively. Two of the evaluations exploit changes in the tax system (605 and 1206) in order to construct treatment and control groups (so called instrumental variables), whereas the study looking at the tax relief scheme in the UK (1208) uses eligibility criteria as cut-off points to compare outcomes for eligible and ineligible firms just around the cut-off (i.e. a 'regression discontinuity design').

All the other studies scored 3 on the SMS and use variations on difference-in-difference (occasionally combined with matching) or panel fixed effects methods. Since tax credits are usually open to all firms (or at least to all of a given type of firms – e.g. SMEs) with qualifying R&D expenditures in a given country, selection issues might be of an arguably smaller order than in the case of R&D grants. However, in the bulk of our 21 studies, unobservable factors have not been fully ruled out. This means our conclusions have to be used with some care.

Type and focus of programmes

As discussed above, tax credits can be broadly distinguished into two different types: volume- and incremental-based. In practice, however, policy programmes may combine different aspects of both types. Within these three broad categories (volume, incremental, mixed) we can further distinguish schemes depending on whether they are universal (i.e. participation is unconstrained and not limited to specific groups of firms), or targeted (i.e. participation is constrained to a specific group or more favourable for some groups of companies, such as SMEs). Of the 21 evaluations considered in this review:

- Six studies look at volume-based schemes.
  - Two of these six studies, evaluate programmes that are universally accessible. Study 630 evaluates the Wet Bevordering Speur en Ontwikkelingswerk[33] in the Netherlands and study 1201 considers an Italian tax credit scheme introduced in 2006.
  - The remaining four studies consider targeted tax credit schemes. Of these, two studies look at the UK tax credit relief scheme.[34] This programme was introduced in 2000 and initially only open to SMEs. In 2002, the scheme was extended to large companies. Study 606 looks at the SkatteFUN scheme in Norway which was introduced for SMEs in 2002 but expanded to large companies in 2003. The last study looks at the Canadian Scientific Research and Experimental Development tax programme.[35]
- Three studies consider incremental-based schemes.
  - All of these three studies look at programmes that are universally accessible. Two studies consider the effects of the Economic Recovery Tax Act introduced in the US in 1981.[36] Study 629 looks at a tax credit scheme in Japan that operated between 1967 and 1999.
- Three further studies look at policy programmes that combine different aspects of volume- and incremental based approaches:

33 "Law for lowering wage taxes and social security contributions related to R&D activities" (see, for example, de Jong and Verhoeven (2007)). Study 630 describes this programme as targeted at SMEs (see the discussion on p. 825) but does not outline any policy detail (coverage, degree of support, etc.) that depends on firm size. Given this, we treat it as a universally accessible scheme.

34 Studies 499 & 1208.

35 Study 1196.

36 Studies 604 & 1206.

    - All three of these studies consider tax credit schemes that are universally accessible, but provide favourable conditions for SMEs. Study 640 evaluates the impact of the Australian tax concession scheme. As a part of this programme, a small business tax offset scheme that especially benefited small technology start-ups was introduced in 2002.[37] The remaining two studies look at the tax credit programme in Spain[38] which grants more generous conditions to SMEs.

- The remaining nine studies look at multiple tax credit schemes at once and do not distinguish specific aspects of these programmes.
    - One these nine studies[39] considers international differences and looks at the effects of tax credit schemes in nine different OECD countries.
    - Four studies consider legislation implemented at the national level. Of these, two look at US programmes.[40] The first focusses on the effect of US tax credit programmes in the 1980s on multinational firms, while the second looks at the heterogeneous effects of federal policy changes on the state level. Study 610 evaluates the effect of various state and national level tax credit schemes in Canada. The fourth study looks at Japan's tax credit reform in 2003 when it moved from an incremental- to a volume-based scheme.
    - The remaining four studies investigate the impacts of various tax credit schemes operating at US state level.[41] Studies 526 and 642 consider the policy effects for the 32 US states that had implemented tax credit schemes by 2006.[42] Study 643 also looks at US states focussing on the 13 states for which R&D data was available by 2005.[43] Finally, study 635 compares the Californian and Massachusetts tax credit schemes.

When considering the effects of programmes we adopt the same approach as we did when looking at the impact of R&D grants and loans programmes. That is, we distinguish between evaluations that consider:[44]

- the effect on R&D spending (i.e. on inputs in to the innovation process);
- the (direct) impact on innovative activities (such as patenting and reported product/process innovations);
- the (indirect) impact on economic outcomes (productivity, employment and so on).

Results for each of these three categories are reported in Table 2 and explained further below. Table A1 in the appendix reports results for individual outcomes.

We use this breakdown for a number of reasons. First, it is important to check that R&D grants have the expected positive effect on R&D itself, especially when this is a scheme objective. Second, we want to know whether increased R&D spend feeds through to measures of innovation. As set out in section 1, to the extent that these programmes do not crowd out private sector R&D, we might

37 See, for example, Study 640, p. 262. However, due to data restrictions this evaluation can only look at the effect on large companies. We discuss further below.
38 Studies 1204 & 1205. See for example Study 1204, p. 10.
39 Study 605.
40 Studies 625 & 1198.
41 Most US state level tax credits are similar to the Economic Recovery Tax Act (see e.g. Study 643, p. 788) and can be described as incremental-based schemes. However, due to the lack of information on specific programmes and the consideration of multiple states, they were included in this section.
42 See Study 642, p. 431.
43 Alabama, Arizona, California, Colorado, Connecticut, Florida, Illinois, Massachusetts, New Jersey, New York, Ohio, Pennsylvania and Virginia.
44 Note that some of the evaluations cover more than one outcome, so category counts do not sum to the total count.

reasonably expect the direct effects of these programmes to be felt on innovation outcomes. Third, when it comes to *local* economic growth, we also want to know if changes in innovative activity feed through to broader economic outcomes such as firm productivity and employment.[45]

In terms of understanding whether there is a link from programme to firm performance, we should have most confidence in evaluations that consider the link from increased R&D spend, through innovation, to improved firm performance. Unfortunately, none of the evaluations do this. Similarly, there are no studies looking at R&D spend and firm performance (but not innovation). There is one evaluation that considers both innovation and firm performance measures (but not R&D).[46]

Table 2. Overall findings for broad outcome categories

Outcome category	Works	May help	Mixed results	Doesn't work	Harmful	Share of positive
R&D expenditure	10	0	5	2	0	10/17
Innovation outcomes	3	0	0	0	0	3/3
Firm performance	1	0	2	0	0	1/3

Effects on R&D

R&D tax credits can positively impact R&D expenditure, although effects are not always positive.

There are 17 evaluations that consider the effect of programmes on total R&D spending. Ten of these find a positive effect on R&D spending, while for another five the evidence is more mixed. Two evaluations find zero effects.

Additionally, four studies look at particular aspects of R&D spending in terms of R&D wages,[47] supplies[48] or contracts.[49] All three studies that consider R&D wages find consistently positive effects. Two of these consider the total R&D wage bill meaning that the increase could come from either higher employment or higher wages. The third study shows an increase in wages which may partially offset the positive effect on the amount of R&D undertaken.[50] In contrast, the results for contracted R&D work are more mixed (one study finds a positive effect, one mixed and one no effects). One possible explanation for these mixed findings is that contracted R&D might be substituted with in-house research (or vice versa). Therefore, specific aspects of the programme design can matter a lot. Finally, the one study that also considers R&D supplies finds positive effects.

45 Given the difficulties in measuring innovation outcomes, it is possible that studies that consider both could find positive effects on employment with no matching effect on innovation outcomes. In practice, this is not an issue for the evaluations that we consider in this review.
46 Study 526.
47 Studies 630, 1196 & 1206. Study 630 looks at R&D wages only but not at aggregate R&D spending. It was therefore not included in the 17 studies listed above.
48 Study 1206.
49 Studies 635, 1196 and 1206.
50 Although these higher wages may retain higher skilled researchers with implications for innovation both now and in the future.

Overall this is, arguably, encouraging. However, raising R&D is a specified programme objective in at least 17 of these programmes.[51] So it is of some concern that success rates are not even higher than this.

Taking these results at face value, the existing literature suggests three reasons why around a third of studies find mixed or (in two cases) zero effects. One explanation is that in these specific schemes tax credits are not large enough to affect firm behaviour very much or at all; any responses may not be large enough to be picked up by the evaluations.

An alternative is that these seven studies are not able to pick up positive R&D effects because of shortcomings in their methods. All seven studies score three on the Maryland Scale, meaning that they do not control for time-varying unobservable factors that may influence firm behaviour. By contrast all three studies that do control for these factors – scoring SMS4 – do find positive effects of tax credits on R&D. Of course, seven studies that find positive R&D impacts also score SMS3, so this explanation may not hold: the evaluations may truly be capturing a failure to increase R&D for the reason outlined above.

A third possible explanation is considered in study 604. The positive effect found in this study is reduced by price increases that results from a higher competition for R&D inputs induced by the tax credit. More work would be needed to understand if these price effects generalise.

The only two evaluations to find zero effects of R&D tax credits are studies 610 and 640. Study 610 covers national programmes in Canada between 1975 and 1992. For a panel of 434 firms, the authors find no effect of tax credits on firms' R&D stock.[52] They also find no increases in the number of firms conducting R&D (specifically, no change in firms moving from doing no R&D to doing some R&D). These results should be treated with some caution: apart from the historic study period, the authors express some concerns about whether the sample of firms is representative of Canadian industry as a whole. Study 640 looks at the effect of R&D Tax Concession on Australian firms' R&D stock, using changes in policy rules to explore impacts. Given data restrictions, this evaluation can only consider the 2000 largest Australian firms and does not find that R&D tax credits increase total R&D expenditure. We will revisit this finding below when we discuss the effects of tax incentives across different firm sizes.

Effects on Innovation

There is surprisingly little evidence on the impact of R&D tax credits on innovation measures (as proxied by patents or self-reported innovation activity, for example). However, the available studies suggest that tax credits can have a positive impact on innovation, both at firm and area level.

Only three of the 21 studies look at 'innovation' outcomes: of these, two (studies 526 and 1208) look at patenting at area level and firm level, respectively, and one (study 499) looks at product or process innovations reported by firms. In addition to patents, study 526 also looks at the number of 'star' scientists in a given area. We start by looking at the three studies covering patents or reported innovation by firms, then move on to look at the single study covering a less standard measure.

51 For those evaluations where programme objectives are described. 'Increased R&D' is a stated programme outcome in other case, but is not covered in the evaluation. In practice, it is likely that increasing R&D is a stated objective for all 21 shortlisted evaluations.

52 The authors look at accumulated R&D activity (wages, equipment, contracts). They estimate an initial stock for each firm and assume it increases at the same average rate of gross production.

Effect on patents, product or process innovation

Study 1208 evaluates the UK R&D tax credit, focusing on the effect of a major change to the scheme in 2008, which made it much more generous to small and medium size firms (SMEs). The authors look at changes in patenting for firms who just qualify for the more generous treatment, compared to those who just miss out because of eligibility. They find that for each £1m of R&D credit spend between 2009 and 2011, an additional 5.8 patents are generated.

If innovative activity in a sector is physically clustered, patenting by researchers and firms should show up at area level. Study 526 explores this issue by looking at the US biotech sector across US states. The study considers a range of measures, including tax credits, using variation in national and state-level policy to identify impact across locations.[53] The authors find that R&D tax credits (but not grants) have a positive effect on area-level biotech patenting.

Patents are the most objectively measured innovation outcome. However, as discussed extensively in the academic literature, patents only capture one aspect of the innovation process. As recent research shows, only a minority of UK firms patent, so some patents may not be using an appropriate success measure.[54] Self-reported innovation measures have the great advantage of capturing other aspects of innovative activity - new ways of working, as well as new products and services - that do not result in patents or other formal kinds of IP protection. On the other hand, some self-reported innovations may turn out to be trivial, and as discussed earlier, it is possible that firms with something to report may be more likely to respond to the survey.

Study 499, which also covers the UK, looks at both R&D grants and R&D tax credits on firms' self-reported innovative activity between 2002-2004. Results for R&D grants and credits are both positive, with no significant difference found between grants and credits in their effect on reported product and process innovation. Tax credits appear to be particularly effective for SMEs, a point we return to below.

Effect on other innovation outcomes

Study 526 also looks at other aspects of area-level clustering in the biotech industry, such as the number of 'star' scientists (publishing seminal / highly cited research) in a given state. Here, the authors find that R&D tax credits help raise the number of star scientists in states with more generous tax credit policies. The implication is that tax credits may play a role in shaping scientists' and/or employers' location choices.

Effects on Economic Outcomes

There is surprisingly little evidence on the effect of R&D tax credits on wider economic outcomes and it is hard to draw firm conclusions on the impact.

Three studies look at various economic outcomes, two of which look at firms (studies 604 and 606) and one of which (study 526) looks at area-level outcomes. Overall, the reported impacts of tax credits on these wider outcomes is quite mixed, with only one study showing positive effects. However, the diversity of outcomes reported makes it difficult to draw any firm conclusions.

53 Specifically, the authors compare a) non-targeted state-level R&D tax credits with b) state-level biotech-specific measures. The latter include tax credits, tax exemptions, low-cost loans and grants. We report results for a) R&D tax credits, plus b) biotech-specific tax incentives where this is provided in the paper.

54 Hall et al (2010).

Study 604 looks at effect of the US Research and Experimentation tax credit, introduced in 1982, using a panel of firms between 1975 and 1989. The authors find that for firms benefitting from the tax credit, the market value of equity rose by 1.99% between 1982 and 1989. Study 606 evaluates the Norwegian SkatteFUN programme between 1995 and 2004; the tax break is available at various levels, and the authors use this variation to back out the effect of the policy. The authors find a weakly significant effect of the programme on participating firms' productivity growth.

Study 526, for the US, looks at a range of wider economic outcomes at State level. It finds mixed results for the impact of R&D tax credits on employment in biotech-related sectors: there are positive impacts on pharmaceutical and medicine manufacturing, but only weakly significant impacts on the pharmaceutical preparation manufacturing sub-sector, and on R&D in physical, engineering and life sciences more broadly. Tax credits also have a small, mixed effect on wages, which is significant for pharmaceutical and medicine manufacturing, but close to zero for the pharma preparation subsector, and for R&D employment generally. By contrast, tax credits have a significant, positive impact on the number of new firms doing R&D in physical, engineering or life sciences.

Linked analysis on R&D, Innovation and Economic Outcomes

Relatively few evaluations consider more than one element of the chain from increased R&D spend, through innovation, to improved firm performance. Results from these studies are generally positive.

Only three studies consider more than one element of the chain from increased R&D spend, through innovation, to improved firm performance. Study 604 looks at the impact of the US Research and Experimentation tax credit on both firms R&D spend and on their later market value, finding positive results in both cases. Study 1208, on the UK R&D tax credit, finds changes to the policy, making it more generous, induced both additional R&D spending (around £150k per firm per year) and additional patents by treated firms (0.07 patents per firm per year).[55]

In contrast, study 526 looks at area-level changes to innovation outcomes in the biotech industry (patenting, presence of star scientists) and economic shifts in the industry (employment, wages and establishments). It finds positive effects of R&D tax credits on patenting and star scientist counts, and positive effects on the number of new R&D-intensive firms, but mixed results on wages and employment.

Differences across firms: SMEs vs. larger firms

Impacts may depend on firm size with small firms slightly more likely to experience positive benefits.

The effects presented above can mask considerable heterogeneity across different types of firms. Such heterogeneity is obviously of interest to policy makers deciding whether to target scarce funds at particular types of firms.

The most frequently studied heterogeneity relates to firm size. Twelve evaluations report findings that allow us to consider whether results differ on this dimension. Of these, six studies consider one

55 Study 1208 uses linked firm-level data which will also allow for analysis of productivity and employment effects in future research.

specific firm size only: four studies use data for large firms[56]; one for SMEs[57] and one for small firms.[58] The remaining six studies directly compare differences across firms according to size: three studies look at SMEs vs large companies[59], one looks at small vs medium sized firms[60], one at small vs large firms[61] and one at medium sized vs large firms.[62] It is important to note that the focus on a particular firm size, or a particular comparison across sizes, may be driven purely be data availability rather than any aspect of the programme design.[63]

Of the three studies that compare SMEs and large firms directly, two find that tax credits had a greater impact on R&D spending for smaller firms, while the third finds that only large firms benefit. (The one study that looks within the SME category, and distinguishes small and medium sized firms, finds that the latter benefit more from tax credits.)

Overall, this set of results is consistent with the two studies that look only at small firms or SMEs and also find strong effects on total R&D spending. Study 626 offers a possible explanation: smaller firms that also face greater financial constraints are more responsive to changes in tax credits. As with R&D grants, however, smaller firms may also reclassify innovation-related spending as 'formal' R&D in response to a policy, so that the net effect may be smaller than evaluations suggest.

Of the four studies that only consider large firms, two find no effects on total R&D spending. Of the remaining two studies in this group, one finds mixed results[64] and only one shows positive effects.[65] At least for the specific structure in Japan, study 629 finds that only large firms increased their R&D spending because of tax credits whereas medium sized companies did not. As with R&D grants, though, it is also possible that public support for R&D through tax credits may have positive effects in larger firms, but that these are too small to generate statistically significant impacts in available data.

On the face of it, this analysis shows suggestive evidence that, at least in the Western hemisphere, smaller companies might be more likely to increase R&D spending due to tax credits. But the caveats above should be borne in mind when developing policy.

Differences across programme types

It is hard to reach any strong conclusions on differences between the different programme types in terms of effectiveness.

As discussed above we can identify three broad programme types (volume, incremental and mixed) covered by the evaluations. On the basis of the relatively small number of studies available it is hard to reach any strong conclusions on differences between the different programme types in terms of effectiveness.

56 Studies 604, 610, 625 & 640.
57 Study 1208.
58 Study 1196.
59 Studies 1204, 1205 & 1206.
60 Study 499.
61 Study 626,
62 Study 629.
63 For example, the policy scheme evaluated in study 640 has some aspects that particularly benefit small technology start-ups but data restrictions limit the evaluation of this policy scheme to large companies only.
64 Study 625 finds positive effects for R&D stock and mixed effects for flows.
65 Of these four studies, three (604, 610 & 625) consider Compustat data during the 1980s. As the authors acknowledge, this might have led to highly selective samples. See, for example, the discussion on p. 27 of study 625.

In total, nine studies consider R&D spending for single programmes that can be classified as either a volume- or incremental-based scheme or a combination of the two. All three studies of volume based schemes that consider total R&D spending find consistently positive effects. Two of the three evaluations looking at incremental-based schemes also find positive effects on R&D spend, with a third finding mixed results.[66] The three studies that considered mixed schemes and their effect on total R&D spending show more mixed results with effects depending on the size of the company (an issue we discussed further above). Overall, as already noted, this analysis does not point to big difference between volume- and incremental-based schemes in terms of the effect on R&D spending.

Unfortunately, for innovation outcomes we only have two evaluations where scheme type is identified – both for volume-based schemes. Those studies show a positive effect on self-reported process or product innovations (study 499) and patents (1208).

Similarly, there is little evidence on differences in effects on economic outcomes. Drawing conclusions for economic outcomes is further complicated by the fact that two of the three studies in this subcategory look at “other” outcomes that are not commonly evaluated.[67]

The situation is similar when we turn to differences between schemes depending on whether they are universally accessible or instead targeted at specific groups of firms. Again, most evidence is provided for R&D spending. Three out of four universally accessible programmes foster total R&D spending (i.e. they work or at least may help) while only two out of five targeted programmes achieve consistently / predominantly positive impacts. This comparison, however, masks that the three studies that find mixed or no effects for targeted R&D tax credits obtain heterogeneous effects for different firm sizes. Interestingly, two of these studies look at Spain and come to different conclusions: while study 1204 finds that smaller firms benefit more from these incentives, study 1205 finds the opposite.

Unfortunately, for innovation outcomes, we once again only have results for one kind of scheme involving targeted programmes. Both papers that look at the effect on self-report product or process innovations and patents find consistently positive results. Once again, the limited number of studies prevents us reaching any conclusion on wider economic outcomes.

In summary, what evidence is available points to little differences between types and focus of schemes in terms of impacts on R&D spending. There is too little evidence regarding innovation or economic outcomes to allow for sensible comparisons of tax credit programmes by their type and focus.

Cost-effectiveness

Only three of the 21 studies provide cost-effectiveness calculations, and only two break this down for tax credits specifically – making it hard to provide much concrete evidence.

Study 1208, which looks at the current UK R&D tax credit, uses high quality microdata and finds clear evidence that the programme is cost-effective. Specifically, extensions to the programme for SMEs generated additional R&D of £150k per firm per year, at a cost to government of £13k per firm per year.

Similarly, study 604, on the US Research and Experimentation tax credit, suggests that during the period 1982-5 – the first four years of the policy – the credit induced $1.74 of additional spending per revenue dollar foregone.

66 Effects differ by firm size. See discussion above.

67 Study 604 finds that tax credits create implicit taxes and study 526 considers wages and establishment rates at the state rather than the firm level.

Study 499, which covers UK during the period 2002-4, looks at innovation policy as a whole, but does not provide a separate estimate for tax credits. The authors bases their results on a) national scheme cost data b) national GDP figures c) firms' reported share of turnover due to new innovations. The modelling suggests that for SMEs, innovation policy support as a whole generates about £100m net value added on a budget of £320m (including knowledge transfer activities, business link and R&D tax credits).

Another five studies (1196, 1198, 1201, 1204 and 1206) present cost data but do not make cost-effectiveness calculations.

08

Summary of findings

What the evidence shows

- R&D tax credits can positively impact R&D expenditure, although effects are not always positive.
- Impacts may depend on firm size with small firms slightly more likely to experience positive benefits. Smaller firms may face greater financial constraints, making them more responsive to changes in tax credits. However, smaller firms may also reclassify innovation-related spending as 'formal' R&D.

Where the evidence is inconclusive

- It is hard to reach any strong conclusions on differences between the different programme types in terms of effectiveness.

Where there is a lack of evidence

- Most shortlisted studies focus only on R&D effects of tax credits, and there is surprisingly little evidence on the impact of R&D tax credits on innovation (as measured by patents or self-reported innovative activity, for example). The available studies suggest that tax credits can have a positive impact on innovation, both at firm and area level.
- There is surprisingly little evidence on the effect of R&D tax credits on wider economic outcomes and it is hard to draw firm conclusions on the impact.
- Relatively few evaluations consider more than one element of the chain from increased R&D spend, through innovation, to improved firm performance. Results from these studies are generally positive.
- None of the shortlisted evaluations consider the timing of effects.

How to use this review

This review considers a specific type of evidence – impact evaluation. This type of evidence seeks to identify and understand the causal effect of policy interventions and to establish their cost-effectiveness. To put it another way they ask 'did the policy work' and 'did it represent good value for money'?

The focus on impact reflects the fact that we often do not know the answers to these and other basic questions that might reasonably be asked when designing a new policy. Being clearer about what is known will enable policy-makers to better design policies and undertake further evaluations to start filling the gaps in knowledge.

Supporting and complementing local knowledge

This evidence review does not address the specifics of 'what works where' or 'what will work for a particular locality'. An accurate diagnosis of the specific local challenges policy seeks to address needs to be the first step in understanding how the overall evidence applies in any given situation.

However, while detailed local knowledge and context will be important in undertaking that analysis, as in most policy areas we have considered, the evidence presented here doesn't make the case for local over national delivery (or vice-versa).

The evidence urges some caution on the role that more localised innovation policy would play in driving local economic growth. Local decision makers need to think carefully about the desired objectives for local innovation policy. For example, our review shows that tax credits have a pretty good success rate in raising R&D spending (particularly for smaller / younger firms). But we know much less about whether, or how this increased R&D activity feeds through to greater innovation, better firm performance or longer term economic growth, particularly at the local level. These broader outcomes are the things most local economic decision makers ultimately care about. There are good reasons to think that many of these broader economic benefits are likely to 'spill over' so will be felt beyond the local area. This might still result in a net benefit for the place implementing the policy, but spillovers would need to be taken into account in evaluating impacts.

R&D tax credits could also make limited sense as a ***local*** policy if they caused firms to relocate across boundaries, triggering a race to the bottom as local policymakers offered larger and larger tax breaks regardless of their impact. Study 642 finds some evidence of firm relocation across US state borders in response to tax incentives. Any moves to devolve policy in the UK would need to test for these issues.

Overall, then, it is important to remember that evaluation of the impact of innovation policy is still limited and this review raises as many questions as answers. The limited evidence base, particularly in terms of the impact on local economic outcomes, highlights the need for realism about the capacity and evidence challenges of delivering innovation policy at a more local level.

Helping to fill the evidence gaps

Given the importance of R&D support programmes in the innovation policy mix – and in wider policy agendas such as industrial strategy – it is important to think how we might generate further high quality impact evaluation evidence. Study 1208, which evaluates the UK R&D tax credit, is one example of best practice, which combines detailed administrative data (from HMRC) with scheme performance data, and exploits a change in scheme design to evaluate impact.

Government could help evaluate other policies by releasing similar datasets, including cost data, to researchers (to allow construction of treatment and control groups and calculations of cost-effectiveness). Policymakers should also think about how to implement policies in ways that facilitate evaluation – for example, through competitive application processes, or by staggering programme rollout across locations and/or time.

Very few studies look at economic effects of R&D support beyond immediate impacts on R&D spend, to consider patents or reported innovation, or wider firm or area-level outcomes, such as productivity or concentrations of star scientists. If the ultimate aim of R&D support policies (especially at the local level) is to influence innovation and growth, it is crucial that we evaluate future policies against these wider objectives. To do this, policymakers have to ensure that researchers can link firm-level data on tax, financial assets, productivity, jobs and innovative activities.

We need a much better sense of how different forms of R&D support perform against each other (grants / subsidies / loans vs tax credits), and against other aspects of innovation policy (such as those covered in NESTA's Compendium of Evidence on Innovation Policy). Better data on scheme reach and participants will help researchers to do this.

Similarly, we need more evidence on the appropriate policy mix, including whether regional or urban-level policy is appropriate. Innovative activity tends to cluster, and local 'ecosystems' often have unique characteristics. This implies that local policy could have a role to play. But as we discussed above, the benefits of innovation is not always spatially bounded, and traditional local cluster programmes have a very poor success rate.

The Centre's longer term objectives are to ensure that robust evidence is embedded in the development of policy, that these policies are effectively evaluated and that feedback is used to improve them. To achieve these objectives we want to:

- work with local decision makers to improve evaluation standards so that we can learn more about what policies work, where.
- set up a series of 'demonstration projects' to show how effective evaluation can work in practice.

Interested policymakers please get in touch.

09

References

Aghion, P., Dewatripont, M., Du, L., Harrison, A., Legros, P., 2012. Industrial Policy and Competition, NBER Working Paper 18048. NBER, Cambridge, Mass.

Chesborough, H., 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press, Cambridge, MA.

Cohen, W.M., Levinthal, D.A., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly 35, 128-152.

Cunningham, P., Gök, A., 2013. The Impact and Effectiveness of Policies to Support Collaboration for R&D and Innovation, Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Report 6. NESTA, London.

Cunningham, P., Ramlogan, R., 2013. The Effects of Innovation Network Policies, Compendium of Evidence on the Effectiveness of Innovation Policy Intervention Report 7, London, NESTA.

Edler, J., Cunningham, J., Gök, A., Shapira, P., 2013. Impacts of Innovation Policy: Synthesis and Conclusion, Nesta Working Paper No.13/21. NESTA, London.

Fagerberg, J., 2005. Innovation: A guide to the literature, in: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), The Oxford Handbook of Innovation. OUP, Oxford, pp. 1-27.

Foray, D., Mowery, D.C., Nelson, R.R., 2012. Public R&D and social challenges: What lessons from mission R&D programs? Research Policy 41, 1697–1702.

Freeman, C., 1991. Networks of innovators: A synthesis of research issues. Research Policy 20, 499-514.

García-Quevedo, J., 2004. Do Public Subsidies Complement Business R&D? A Meta-Analysis of the Econometric Evidence. Kyklos 57, 87-102.

Gibbons, S., Nathan, M., Overman, H., 2014. Evaluating spatial policies, SERC Policy Paper SERCPP12. LSE, London.

Guellec, D., Van Pottelsberghe De La Potterie, B., 2003. The impact of public R&D expenditure on business R&D*. Economics of Innovation and New Technology 12, 225-243.

Hall, B.H., Helmers, C., Rogers, M., Sena, V., 2013. The Importance (or not) of Patents to UK Firms, National Bureau of Economic Research Working Paper 19089. NBER, Cambridge, MA.

Hausmann, R., Pritchett, L., Rodrik, D., 2005. Growth Accelerations. Journal of Economic Growth 10, 303-329.

Iammarino, S., McCann, P., 2013. Multinationals And Economic Geography: Location, Technology and Innovation. Edward Elgar, Cheltenham.

Jaffe, A., 1996. Economic analysis of research spillovers: Implications for the Advanced Technology Program. Economic Analysis, 1-14.

Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. The Quarterly Journal of Economics 108, 577-598

Lerner, J., 2009. Boulevard of Broken Dreams. Princeton University Press, Princeton.

Lerner 2002 to do

Lucas, R., 1988. On the Mechanics of Economic Growth. Journal of Monetary Economics 22, 3-42

Lundvall, B.-Å., Borrás, S., 2006. Science, Technology, and Innovation Policy in: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), The Oxford Handbook of Innovation. OUP, Oxford.

Malerba, F., 2002. Sectoral systems of innovation and production. Research Policy 31, 247-264

Mazzucato, M., 2011. The Entrepreneurial State. Demos, London.

Nathan, M., Overman, H., 2013. Agglomeration, clusters, and industrial policy. Oxford Review of Economic Policy 29, 383-404.

Powell, W.W., Grodal, S., 2006. Networks of Innovators, in: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), The Oxford Handbook of Innovation. OUP, Oxford

Rodrik, D., 2004. Industrial Policy for the Twenty-First Century, CEPR Discussion Paper 4767. Centre for Economic Policy Research, London.

Romer, P., 1990. Endogenous Technological Change. Journal of Political Economy 98, 71-102.

Schumpeter, J., 1962. The Theory of Economic Development. Springer, Berlin

Sherman, L. W., Gottfredson, D. C., MacKenzie, D. L., Eck, J., Reuter, P., & Bushway, S. D. (1998). Preventing Crime: What Works, What Doesn't, What's Promising. Washington DC: US Department of Justice.

Smith, K., 2005. Measuring innovation, in: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford, pp. 148-177.

von Hippel, E., 1986. Lead Users: A Source of Novel Product Concepts. Management Science 32, 791-805.

Appendix A: Findings by outcome

Table A1. Programme effects by outcome and objective

Outcome	Evaluations	Total assessed	Positive	Mixed	Zero	Negative	Share of positive
Increase R&D spend	604, 605, 610, 625, 626, 629, 635, 640, 642, 643, 1196, 1198, 1201, 1204, 1205, 1206, 1208	17	604, 605, 635, 642, 643, 1196, 1198, 1201, 1206, 1208	625, 626, 629, 1204, 1205	610, 640		10/17
Of which R&D wages	630, 1196, 1206	3	630, 1196, 1206				3/3
Of which R&D contracts	635, 1196, 1206	3	1206		635, 1196		1/3
Of which R&D supplies	1206	1	1206				1/1
Innovation outcomes							
Patents	526, 1208	2	526, 1208				2/2
Product or process innovation	499	1	499				1/1
Other	526	1	526				1/1
Economic outcomes							
Productivity	606	1		606			0/1
Sales, Turnover or Profit		0					0/0
Employment	526	1		526			1/1
Other	526, 604	2	604	526			1/2

Appendix B: Evidence Reviewed

Ref no.	Reference
499	Foreman-Peck, J. (2013). Effectiveness and Efficiency of SME Innovation Policy. *Cardiff Economics Working Papers E2012/4*, Cardiff: Cardiff Business School.
526	Moretti, Enrico; Wilson, Daniel J. 2013 State Incentives for Innovation, Star Scientists and Jobs: Evidence from Biotech. *Federal Reserve Bank of San Francisco Working Paper 2013-17*, San Francisco: FRBSF.
604	Berger, P.G. (1993). Explicit and Implicit Tax Effects of the R&D Tax Credit. *Journal of Accounting Research* 31(2), 131-171.
605	Bloom, N., Griffith, R. and Van Reenen, J. (2002). Do R&D tax credits work? Evidence from a panel of countries 1979-1997. *Journal of Public Economics* 85, 1-31.
606	Cappelen, A., Raknerud, A. and Rybalka, M. (2007). The effect of R&D tax credits on firm performance. *Statistics Norway Reports 2007/22*, Oslo: Statistics Norway.
610	Dagenais, M., Mohnen, P. and Therrien, P. (1997). Do Canadian Firms Respond to Fiscal Incentives to Research and Development? Scientific Series October 1997, Montréal: CIRANO
625	Hines, J.R. (1991) On the sensitivity of R&D to delicate tax changes, *NBER Working Paper 3930*, Cambridge, MA: NBER.
626	Kasahara, H., Shimotsu K., Suzuki, M. (2014) Does an R&D tax credit affect R&D expenditure? The Japanese R&D tax credit reform in 2003, *J. Japanese Int. Economies* 31 (2014) 72–97
629	Koga T. (2003) Firm size and R&D tax incentives, *Technovation* 23 (2003) 643–648
630	Lokshin B. and Mohnen P. (2013), Do R&D tax incentives lead to higher wages for R&D workers? Evidence from The Netherlands, *Research Policy* 42, 823– 830.
635	Paff L. (2005) State-Level R&D Tax Credits: A Firm-Level Analysis, *Topics in Economic Analysis & Policy* 5:1, 1-25.
640	Thomson, R. (2010) Tax Policy and R&D Investment by Australian Firms, *The Economic Record* Vol. 86 (273), 260–280
642	Wilson D. (2007) Beggar thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits, *Federal Reserve Bank Of San Francisco Working Paper 2005-08*, San Francisco: FRBSF.
643	Wu, Y (2005) The Effects of State R&D Tax Credits in Stimulating Private R&D Expenditure: A Cross-state Empirical Analysis, *Journal of Policy Analysis and Management*, 24 (4), 785–802.
1196	Agrawal, A., Rosell, C. and Simcoe, T. (2014) Do Tax Credits Affect R&D Expenditures by Small Firms? Evidence from Canada, *NBER Working Paper 20615*, Cambridge, MA: NBER.
1198	Chang, A. (2014) Tax Policy Endogeneity: Evidence from R&D Tax Credits, *FEDS Working Paper 2014-101*, Washington DC: Federal Reserve Board.

Ref no.	Reference
1201	Cantabene, C. and Nascia, L. (2014) The race for R&D subsidies: evaluating the effectiveness of tax credits in Italy, *Econmia E Politica Industriale* 3, 133-158.
1204	Labeaga Azcona, J., Martinez-Ros, E. and Mohnen, P. (2014), Tax incentives and firm size: effects on private R&D investment in Spain, *UNU-MERIT Working Paper 2014-081*, Brussels: UNU-MERIT.
1205	Romero-Jordan, D., Delgado-Rodriguez, M., Alvarez-Ayuso, I. and Lucas-Santos, S. (2014) Assessment of the public tools used to promote R&D investment in Spanish SMEs, *Small Business Economics*, 43,959-976.
1206	Rao, N (2015), Do Tax Credits Stimulate R&D spending? The effect of the R&D tax credit in its first decade, *NYU Wagner Research Paper 2272174*, New York: NYU.
1208	Dechezlepretre, A., Einio, E., Martin, R., Nguyen, K-T. and Van Reenen, J. (2015) Can tax reductions cause innovation? An RDD for R&D, Monograph, London: LSE.

Find the full list of search terms we used to search for evaluations on our website here:
whatworksgrowth.org/policies/innovation/search-terms

The What Works Centre for Local Economic Growth is a collaboration between the London School of Economics and Political Science (LSE), Centre for Cities and Arup.

www.whatworksgrowth.org

THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

centreforcities

ARUP

what works centre for
local economic growth

This work is published by the What Works Centre for Local Economic Growth, which is funded by a grant from the Economic and Social Research Council, the Department for Business, Innovation and Skills and the Department of Communities and Local Government. The support of the Funders is acknowledged. The views expressed are those of the Centre and do not represent the views of the Funders.

HM Government

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

October 2015

What Works Centre for Local Economic Growth

info@whatworksgrowth.org
@whatworksgrowth

www.whatworksgrowth.org