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Evaluation of Research and Development Tax Credit

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1. Summary

This report summarises the take-up and use of the Research and Development (R&D) tax credit and assesses the impact of the relief on R&D investment in the UK using econometric techniques.

HMRC publishes National Statistics on R&D tax credits annually including figures on take up, costs and the characteristics of the companies claiming them. The latest statistics were released in August 2014. This report includes additional analysis of the data aimed at providing more detailed insights.

The econometric evaluation assesses the cost effectiveness of the tax credits in increasing the investment in R&D. This is done by estimating a price elasticity, which is a measure of how much companies change their R&D investment in response to the change in the user cost of capital for R&D investment. R&D tax policy is thought to influence R&D behaviour through its effect on the user cost of capital. The tax credit decreases the user cost of capital, and should therefore increase R&D expenditure.

The elasticity estimates have been subject to robust quality assurance processes.

From a public policy perspective, the estimates of additional R&D expenditure as a result of the tax credit are of considerable interest. The production of the estimate involves calculating how much additional R&D expenditure is generated from £1 in tax forgone, which is usually called the additionality ratio. This is calculated using the price elasticities obtained from the econometric modelling.

Since the inception of the schemes, companies have been able to claim R&D tax credits against qualifying R&D expenditure each year. By the end of 2012-13, more than 28,500 different companies had made claims under the SME (Small and Medium-Sized Enterprise) scheme since it began in 2000-01, and over 7,000 companies had claimed under the large company scheme, which launched in 2002-03. Overall more than 100,000 claims had been made up to 2012-13.

There was a particularly marked increase in the number of claims in 2012-13, a 26 per cent increase from the 2011-12 level. This most likely reflects changes to the R&D tax credit policy which came into effect on 1 April 2012 (an increase in the generosity of the SME credit and the removal of a minimum expenditure requirement).

Since the launch of the scheme in 2000-01, more than £9.5 billion has been claimed in tax relief and payable credits. The total amount of R&D support claimed rose to £1.4 billion in 2012-13 – an increase of £150 million from the previous year. The cost of support under the SME scheme rose by £170 million from £430 million to £600 million, while the cost of the large company scheme reduced by £20 million from £790 million to £770 million. Total R&D expenditure against which claims were made amounted to £13.2 billion in 2012-13, an increase of 10 per cent on the previous year.

R&D claims are concentrated among companies with a registered office in London, the South East or the East of England (47 per cent of all claims and 66 per cent of the total amount claimed). However, the R&D activity of some companies will take place in a different location from their registered office.

The 'Manufacturing', 'Professional, Scientific and Technical', and 'Information and Communication' sectors had the greatest volume of claims for 2012-13 (77 per cent of claims and 80 per cent of the total amount claimed). However, these figures should be treated with caution as they rely on self-classification into industries and may therefore not directly reflect the industry in which the R&D activity itself is carried out.

From the econometric analysis, the estimated additionality ratios for UK companies indicate that between £1.53 and £2.35 of R&D expenditure is stimulated by £1 of tax forgone. International studies have previously found additionality ratios to range from around 0.3 to around 3.

This is based on an econometric analysis of the tax credit claims, which produces estimate of the elasticity of R&D expenditure with respect to the user cost of R&D of -1.96. Further robustness checks suggest that the elasticity is in the range of -1.5 to -2.0.

The estimated elasticity confirms that companies increase their R&D expenditure when the cost of R&D decreases. The elasticity is in line with economic intuition and within the range indicated in the literature.

In 2010, HMRC published an earlier evaluation. In line with the literature, this found a range of estimates and presented that up to £3 of R&D expenditure might be stimulated by £1 of tax foregone. This was based on R&D claims data available at the time which covered years from the before the financial crisis (up to 2007) only. The new evaluation also includes the post-financial crisis period (2008-09 to 2012-13) and continues to find that tax credits are effective in stimulating investment in R&D.

Our current evaluation suggests that for each £1 of tax foregone, between £1.53 and £2.35 of R&D expenditure is stimulated. The 2010 evaluation suggested a wider range between £0.41 and £3.37. However, the mid-point of both ranges is broadly the same; so, overall the results are consistent. The top-end of the results from the current evaluation is lower than the top end from 2010, while the low-end result is higher than in 2010. Even the low-end result represents a good level of additionality.

2. Introduction

R&D tax credits are a tax relief designed to encourage greater R&D spending, leading in turn to greater investment in innovation. They work by reducing a company's taxable income by an amount equal to a percentage of the company's allowable R&D expenditure. Small and Medium-sized Enterprises (SMEs) can also claim a payable credit if they are loss-making.

Tax credits for companies investing in R&D were introduced for SMEs in 2000-01, extended to larger companies in 2002-03, and enhanced for vaccine research in 2003-04. In 2008, there were substantial changes to the schemes: the rates of enhanced deductions for both large companies and SMEs were increased; and the definition of a SME was expanded to include some companies that were previously classified as 'large'.

The rate of enhanced reduction was further increased for SMEs in 2011 and 2012, while the Research and Development Expenditure Credit (RDEC) scheme was introduced in 2013. This will fully replace the Large Company Scheme from 2016. At Autumn Statement 2014, the Government announced a package of measures to streamline the R&D tax credits application process for smaller companies, to ensure that all companies performing qualifying R&D are able to access the relief.

The relief on R&D has been considerably widened over the last decade through a number of recent announcements. This evaluation and monitoring report allows us to take stock of all these developments.

The objective for this evaluation is to present up-to-date numbers on take-up and use of the relief and, via econometric techniques, assess the impact of tax credits on R&D investment in the UK. The results can be used to inform future HMRC work on the appropriate targeting of the tax credit, ensuring the relief continues to deliver its policy objectives and ensuring value for money.

In technical terms, the evaluation involves estimating the price elasticity of R&D expenditure, which is the relationship between a 1 per cent change in the user cost of capital (the 'price of R&D') and the resulting change to R&D expenditure in percentage terms. This allows us to quantify how responsive R&D expenditure is to a change in the cost of funding that expenditure. We also calculate the additionality ratio implied by the elasticity. The additionality ratio represents how much additional expenditure on R&D is stimulated by an increase in the tax credit rate for every £1 in tax forgone.

It is beyond the scope of this evaluation to assess the impact of tax credits on the wider UK economy. In 2010, HMRC published an earlier evaluation of R&D tax credits. The current evaluation includes more recent data which includes coverage of time periods post-financial crisis, and various changes to the scheme in 2008 and 2012, such as the changes to the enhancement rate and an expansion to the definition of SMEs. The current study also has an improved methodological framework. The differences mean that the estimates from 2010 and this evaluation are not directly comparable.

The structure of the remainder of this paper is as follows: Section 3 describes the policy and recent changes. Section 4 gives up-to-date figures on uptake and cost of the relief. Section 5 summarises the existing literature on R&D tax credit evaluation while section 6 presents the findings from the econometric evaluation. Appendix A presents further statistics on R&D tax credits and Appendix B describes the technical details of the econometric estimation.

3. Policy background

3.1 The policy objectives of R&D Tax Credit

R&D tax credits are designed to encourage greater R&D spending, leading in turn to greater investment in innovation. The policy objective of the recent changes to the SME scheme is to provide further incentives for small and medium sized companies and start-ups to invest in R&D. The recent changes are consistent with the Government's wider objective to support small innovative companies with high growth potential.

3.2 Qualifying expenditure

The relief applies to qualifying revenue expenditure. Although the relief is only available for 'revenue expenditure' – that is day-to-day running costs, as opposed to capital expenditure – companies may be able to claim capital allowances separately for capital expenditure associated with R&D. A company's activity must also adhere to the definition of R&D set out in the guidelines, including the fact that a company or organisation can only claim R&D tax credit if an R&D project seeks to achieve an advance in overall knowledge or capability in a field of science or technology.

3.3 Rates and changes

Tax credits for companies investing in R&D were introduced for SMEs in 2000-01, extended to larger companies in 2002-03, and enhanced for vaccine research in 2003-04. Companies may claim relief for all their qualifying expenditure in a given accounting period (typically one year) in the form of an enhanced deduction when calculating their taxable profits. SMEs whose taxable profits are zero after making all relevant deductions may either carry forward their enhanced losses to a future accounting period, or surrender some or all of these enhanced losses in return for a payable credit.

In 2008, there were substantial alterations to all the schemes. The rates of enhanced deductions for large companies were increased from 125 to 130 per cent. For SME companies they were increased from 150 per cent to 175 per cent. In addition, the SME definition was expanded to include some companies that previously within the scope of the large company scheme. The rate of enhanced deduction was further increased for SMEs in 2011 to 200 per cent and in 2012 to 225 per cent.

The Research and Development Expenditure Credit (RDEC) scheme has been introduced for expenditure incurred on or after 1 April 2013. It will initially be optional, running alongside the Large Company enhanced deduction scheme which it will replace entirely from April 2016.

At Autumn Statement 2014, the Government announced that from 1 April 2015 it would:

- Restrict qualifying expenditure for R&D tax credits so that the costs of materials incorporated in products that are sold are not eligible.
- Increase the rate of the above-the-line credit from 10 per cent to 11 per cent and increase the rate of the SME scheme from 225 per cent to 230 per cent.
- Launch a package of measures to streamline the application process for smaller companies investing in R&D.

At Budget 2015, the Government confirmed that it would:

- Make a number of improvements to the administration of the scheme including announcing that advanced assurances would last three years for smaller businesses making a first claim from autumn 2015.

- Reduce the time taken to process a claim from 2016.
- Introduce new standalone guidance aimed specifically at smaller companies, backed by a 2 year publicity strategy to raise awareness of R&D tax credits.

3.4 International comparison

The UK's scheme is described in the European Commission's 2014 report on R&D tax incentives as comprising both a "tax credit" and an "enhanced allowance" component. The former reduces a company's liability to corporation tax by a percentage of their R&D expenditure, thus reducing their effective tax rate, while the latter allows companies to deduct R&D expenditure from taxable income. These are the two most popular types of R&D tax incentives in the countries surveyed by the Commission (EU and other countries used as benchmarks, such as the United States, Canada and Israel). 21, of the 33 countries, had a tax credit scheme and 16 had an enhanced allowance scheme. The Commission's report highlights the UK as one of the case studies of best practice in terms of eligibility of expenditure, organisation and novelty requirements.

4. Statistics on Research and Development

The following section provides a summary of available figures on research and development expenditure and the relief claimed to support it in the UK. Overall UK revenue expenditure on R&D is provided, followed by the number of claims for R&D relief, the expenditure supported and the corresponding cost to the Exchequer. Next, an analysis of trends in average claim sizes over time and between regular, sporadic and repeat claimants is presented. The trend in the proportion of total UK revenue expenditure on R&D on which claims for R&D relief are made is then shown, followed by an industry breakdown of claims and cost to the Exchequer in 2012-13. An analysis is then provided of trends in the numbers of 'high tech' companies (as defined by the OECD) claiming R&D relief. Finally, a geographical breakdown of the number and cost of claims in 2012-13 is presented.

The figures presented here are consistent with the latest National Statistics release on R&D tax credits[1]. More detailed analysis is provided at annex A of this document.

4.1 R&D revenue expenditure by businesses in the UK

The Office for National Statistics (ONS) conducts the annual Business Enterprise Research and Development (BERD) survey of 400 of the largest R&D spenders and a sample of approximately 4,600 other companies[2]. This provides an estimate of total revenue expenditure on research and development by businesses. Table 4-1 shows R&D expenditure between 2001 and 2013.

Table 4-1 : Total R&D revenue expenditure between 2001 and 2012 (£billion)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total revenue expenditure (£bn)	11.0	11.4	11.3	11.5	12.6	13.2	14.6	15.0	14.6	15.1	16.4	16.0	17.4

Total revenue expenditure on research and development in the UK has been increasing relatively steady since 2001. A peak of £16.4 billion was reached in 2011, decreasing slightly to £16.0 billion in 2012. The effects of the financial crisis of 2008 appear to be relatively small, with a slight decrease in total expenditure from £15.0 billion to £14.6 billion in 2009, followed by an increase to £15.1 billion in 2010.

4.2 Number of R&D tax credit claims, cost and R&D expenditure supported

More than 32,300 companies have claimed R&D relief since it was introduced in 2000-01, with a total tax cost of over £9.5 billion, based on R&D investment by companies of more than £98.4 billion over the 13 year period. From a relatively low base, the annual number and cost of claims have continued to rise strongly. Figure 1 shows the number of claims under each scheme across the whole period.

[1] For latest National Statistics publication, please see: https://www.gov.uk/government/collections/corporate-tax-research-and-development-tax-credits

[2] See Business Enterprise Research and Development, 2013: http://www.ons.gov.uk/ons/rel/rdit1/bus-ent-res-and-dev/2013/index.html

Figure 1: Number of claims received for R&D tax credits by scheme

There was a marked increase (26 per cent) in the number of claims in 2012-13, which most likely reflects the changes to R&D tax credit policy that came into effect on 1 April 2012. The changes included an increase in the rate of enhanced expenditure for SMEs from 200 per cent to 225 per cent and the removal of the rule limiting payable credits to the amount of a SME's Pay-As-You-Earn/National Insurance liability. The requirement for a minimum expenditure of £10,000 on R&D was also removed. SMEs carrying out a lower level of R&D activity are able to make claims that they could not make before the changes, which also encourage higher levels of expenditure from those already able to make claims. Large company claims are generally well in excess of £10,000; so, the removal of the minimum expenditure should not affect the number of large company claims.

Between 2008-09 and 2012-13, the number of claims increased at an average rate of 16 per cent per annum, while the total value of claims rose at an average rate of 8 per cent a year. This adds up to 15,930 claims in 2012-13, with a tax cost of £1.4 billion and qualifying R&D expenditure of over £13.2 billion.

Figures 2 and 3 show the amount claimed and the expenditure supported. Although the numbers of SME and large company scheme claims are split roughly 80:20, the costs are split 45:55. In 2012-13, 12,650 companies made claims under the SME scheme for a total of £600 million in tax credits, whereas £770 million was claimed by 2,860 companies under the large company scheme.

Figure 2: Total support claimed through R&D tax credits by scheme (£million, accounting period end date basis)

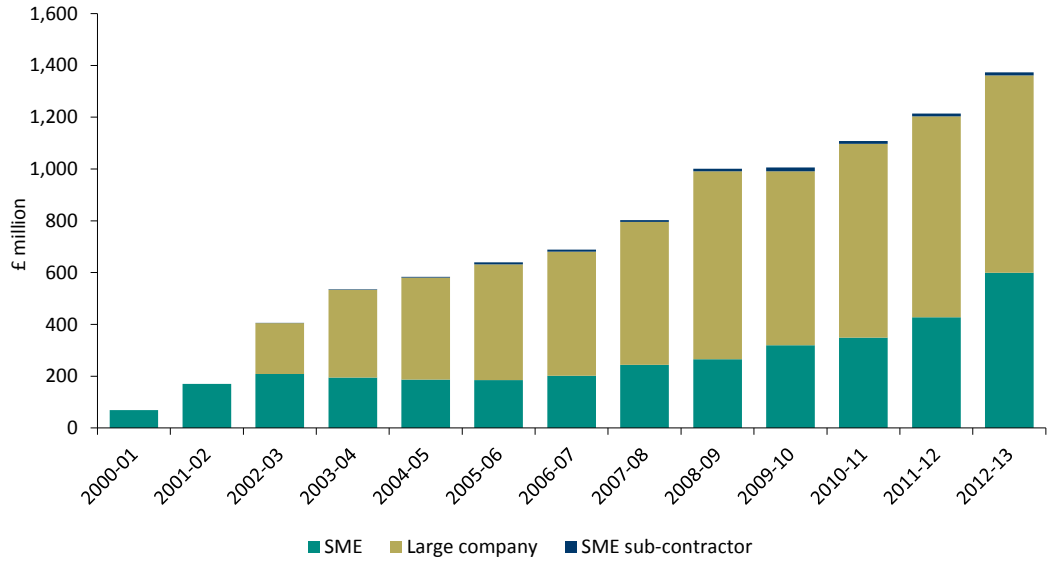

Figure 3: Total R&D expenditure used to claim R&D tax credits by scheme (£million, accounting period end date basis)

The cost of support has increased substantially each year except for 2009-10, which mirrors the situation in terms of the expenditure underpinning the tax credit claims. However, while expenditure fell in 2009-10, the cost of the scheme remained flat due to the changes to enhancement rates for SMEs and large companies (50 per cent to 75 per cent and 25 per cent to 30 per cent respectively) which came into effect from 1 July 2008, leading to proportionately higher costs to the Exchequer for a given level of expenditure. Total expenditure used to claim relief in 2012-13 was £13.2 billion, 10 per cent more than in 2011-12. £10.6 billion (80 per cent) of this was spent under the large company scheme and £2.6 billion (20 per cent) was spent under the SME scheme.

4.3 Average claims between 2008-09 and 2012-13

As Table 4-2 shows, the increase in the cost of the SME scheme has been driven more by an increase in the number of companies claiming under the scheme than by an increase in the average size of claims. For large companies, on the other hand, the average claim has been falling over time while the number of claims has been increasing steadily. This resulted in the cost of the scheme falling by £20 million in 2012-13 despite an additional 200 claims. The fall in the value of claims is mainly due to the fall in the headline corporation tax rate[3]. Claims by SME subcontractors under the large company scheme have increased slightly over the period, but the cost of the scheme has remained flat at around £10million.

Table 4-2 : Average claims (£'000s) from 2008-09 to 2012-13

Year	2008-09	2009-10	2010-11	2011-12	2012-13
SME mean	40	43	42	43	46
SME median	11	14	14	15	17
Large company mean	400	367	382	360	325
Large company median	40	48	46	45	43
SME subcontractor mean	22	29	21	21	19
SME subcontractor median	4	4	5	4	4

4.4 Regular, sporadic and repeat R&D claimants

Some companies, particularly larger ones, undertake R&D as an essential part of their business, and claim every year. Other companies claim in some years but not others, depending on their business development strategies, and some only ever make a one-off investment and claim. The analysis of year-on-year claims shows that around 60 per cent of claims made in any one year are made by 'repeat' claimants, 10 per cent by 'sporadic' claimants, and 30 per cent by 'new' claimants.

Average claims by repeat claimants are significantly higher than those made by sporadic claimants. For example, the average for SMEs that have made just two claims is only £25,000, much lower than the £61,000 average for those that have made six or more claims. For large companies, the average for those who have made two claims is £116,000, while those who have made six or more claims average £499,000 per claim.

In addition, where companies claim in two or more successive years, the average year-on-year increase in investment is around 16 per cent for SMEs and around 3 per cent for large companies over the last 5 years. This is noticeably higher than the year-on-year increases in average claim sizes over the same period.

4.5 R&D expenditure on which claims for relief are made compared to total R&D revenue expenditure

Table 4-3 compares the latest BERD survey estimates and the expenditure used to claim tax relief. BERD data is reported on a calendar year basis, whereas R&D tax credit claims are reported on an accounting period end date basis (i.e. by financial year). For comparing data, the 2012 calendar year basis is most closely related to the 2012-13 financial year. The table

[3] Keeping the enhancement rate and total R&D spend constant, if the CT rate falls, the amount of CT saved by the claimant will reduce (i.e. the amount of relief claimed will reduce). The main rate of CT fell from 26 per cent in 2011-12 to 24 per cent in 2012-13.

indicates an increase over time in the percentage of total R&D expenditure used to claim tax credits. This could be due to greater awareness and generosity of the scheme leading more companies to claim tax credit or leading companies to claim a higher proportion of their R&D expenditure through tax credits.

Table 4-3 : UK R&D expenditure 2008 to 2012 (£ billion)[4]

	2005	2006	2007	2008	2009	2010	2011	2012
Total revenue expenditure (BERD survey, cash terms)	12.57	13.19	14.61	14.95	14.61	15.12	16.42	15.97
Expenditure used to claim tax credits	7.24	7.87	9.05	10.99	9.98	11.07	12.04	13.23
Percentage of total used to claim	58%	60%	62%	74%	68%	73%	73%	83%

4.6 Industry breakdown of R&D claims

Annex A illustrates the breakdown of R&D claims and the amount claimed by industry sector. The classification is based on the UK Standard Industrial Classification 2007 (SIC 2007) standard[5]. The figures show a concentration of claims in the 'Manufacturing' (32.2 per cent), 'Professional, Scientific and Technical' (19.1 per cent) and 'Information and Communication' (25.8 per cent) sectors, accounting for 36.3 per cent, 25.2 per cent and 18.5 per cent of the total amount claimed respectively.

Caution should be taken when interpreting industry breakdowns, as they can be unreliable. There are a number of reasons for this, such as: a change in primary business since registration; current research being conducted in a non-primary business area; or the claim being filed by a group holding company, which would be classified under "activities of holding companies" within the Business Services sector rather than in the sector in which its subsidiary carried out the research.

4.7 Claims by 'high-tech' companies

The OECD has defined high-tech sectors as those in which R&D expenditure exceeds 4 per cent of their turnover. Clearly, within each sector there will be some R&D intensive companies that meet this threshold and others that fall below it. Likewise, in sectors that fall outside the high-tech definition, some companies may nevertheless be R&D intensive. Applying this R&D intensity threshold to individual companies is one way of defining a 'high-tech' company.

Using this definition, many SME claims are made by high tech companies. Indeed, there are some companies whose R&D expenditure far exceeds their trading turnover, which may be due to start-up research costs prior to beginning trading in their newly developed product. The numbers and costs of claims by R&D intensive companies are summarised in Table 4-4. From 2008-09 to 2012-13 the proportion of claims under the SME scheme classified as high-tech companies has declined steadily from 68 per cent to 61 per cent. Meanwhile, the proportion of the total cost of the SME scheme accounted for by these companies decreased from 92 per cent to 82 per cent. The total number of SME claims has been increasing considerably; so, it is possible that a larger number of SMEs who are doing some form of

[4] BERD data is reported on a calendar year basis, whereas HMRC data is on an accounting period basis. For purposes of this table, calendar year 2005 is compared with financial year 2005-06, 2006 with 2006-07 and so on.
[5] The Office for National Statistics (ONS) website provides further information on SIC2007: http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html

R&D but not covered by the high-tech definition becoming aware of the scheme and making claims.

Table 4-4 : SME claims by 'high-tech' companies[6]

Year	2008-09	2009-10	2010-11	2011-12	2012-13
No. claims by high-tech SMEs	4,320	4,750	5,190	6,030	7,600
Total no. claims by SMEs	6,390	7,200	8,030	9,710	12,520
High-tech % of claims	68%	66%	65%	62%	61%
Cost of high-tech SME claims (£m)	227	265	293	347	473
Total cost of SME claims (£m)	247	302	337	410	575
High-tech % of cost	92%	88%	87%	85%	82%

The proportion of claims under the large company scheme made by high-tech large companies has remained fairly steady at around 40 per cent, accounting for around 70 per cent of the total amount of relief claimed by large companies, see Table 4-5.

Table 4-5 : Claims by 'high-tech' large companies

Year	2008-09	2009-10	2010-11	2011-12	2012-13
No. claims by Hi-tech large companies	760	790	790	850	960
Total no. claims by large companies	1,770	1,790	1,920	2,100	2,300
Hi-tech % of claims	43%	44%	41%	40%	42%
Cost of Hi-tech large company claims (£m)	519	501	475	469	508
Total cost of large company claims (£m)	688	646	696	736	727
Hi-tech % of cost	75%	78%	68%	64%	70%

4.8 Geographic split of R&D claims

Annex A shows the distribution of R&D claims and amount claimed by the government office region of the company's registered address. The figures show a concentration of companies with registered offices in London (17 per cent of all claims and 31 per cent of total claimed), the South East (19 per cent of claims and 23 per cent of total claimed), and the East of England (10 per cent of all claims and 12 per cent of total claimed).

As with the SIC 2007 industry breakdown, these numbers should be interpreted with caution. A company may operate at different locations throughout the UK. However, its tax return will be made on behalf of the whole company and linked to its registered office address. This geographical breakdown therefore shows all the company's expenditure and tax liability as originating at the location of the registered office, which may not reflect the location of the company's actual R&D activities.

[6] Totals are not aligned with table 1 as turnover data is not available for all claims.

5. Literature review and comparisons of price elasticity and additionality ratio

There is an extensive literature on empirical estimation of the effect of the user cost of capital on R&D expenditure (price elasticity) and the additionality ratio from R&D tax credits (additional spending on R&D over cost of tax credit scheme). Appendix A of the 2010 HMRC report contains a comprehensive literature review of the literature between 1990 and 2010, and Becker (2014) contains an overview of the evidence since Hall (1993). Table 5-1 updates the table in the 2010 HMRC report with studies published since then.

The studies in Table 5-1 show a relatively wide range of estimates for the price elasticity of R&D expenditure[7], from very inelastic (-0.07 being the least price elastic estimate) to relatively price elastic (three separate studies find price elasticities between -3 and -2.5). Becker (2014) identifies most estimates to be around -1.

Of considerable interest is the additionality ratio, which is calculated as the additional spending on R&D from an increase in the tax credit over the additional cost in foregone tax revenue. This is sometimes called the benefit/cost ratio in the literature, although it is a simplification of that concept. A full cost-benefit appraisal would need to consider the positive externalities associated with R&D spending, which is usually presented as the main rationale for subsidising private R&D. One should therefore assign a value greater than £1 for every £1 spent on R&D, and so the simple additionality ratio is likely to underestimate the benefit to society from increased R&D expenditure.

From a public policy perspective, the additionality ratio is of interest as it allows us to understand if the direct effects of implementing a tax credit are more or less than proportional to expenditure in such a credit scheme. If the additionality ratio is greater than 1, then R&D expenditure increases more than proportionally in relation to the cost of providing tax credits. However, as mentioned before, R&D expenditure has positive externalities, so that, even if the additionality ratio is not greater than 1, the policy may still be beneficial to society. The studies presented in table 5-1 show additionality ratios ranging from around 0.3 to around 3.

The main body of literature remains the same as in 2010, with some new studies since then looking at re-estimating price elasticities of R&D expenditure for more recent periods and looking at more specific research questions.

One of the questions explored in recent literature is the differential impact of tax credit schemes on R&D expenditure of high-tech and low-tech firms. Becker and Hall (2013) find that, within the UK manufacturing sector, tax incentives have a statistically significant impact on R&D expenditure for low-tech firms, but not for high-tech ones. This is in line with previous studies and González and Pazó (2008). There is also a growing body of evidence that finds R&D tax credits to be more effective in increasing expenditure for small firms, the argument being that they are more credit constrained and therefore benefit more from government schemes, whereas large firms tends to be able to access capital markets for risky projects already and therefore there is less additionality for the latter.

[7] In all instances considered in table 3.4.A, the price of R&D expenditure is defined as the user cost of capital.

Table 5-1 Summary of empirical studies of price elasticities and additionality since 1990

Study	Geographical coverage	Data	Time Period	Elasticity estimates	Additionality ratio	Notes
Berger (1993)	United States	Balanced panel of 263 firms from Compustat	1982-1985	-1.5 to -1.0	1.74	---
Hall (1993)	United States	Unbalanced panel of over 800 firms from Compustat	1981-1991	-1.5 to -0.8 (Short Run SR) -2.7 to -2.0 (Long Run LR)	2	---
Hines (1993)	United States	116 multinationals from Compustat	1984-1989	-1.6 to -1.2	1.3 to 2	---
McCutchen (1993)	United States	20 large pharmaceutical companies	1982-1985	-10 to -0.28	0.29 to 0.35	---
Shah (1994)	Canada	18 industries	1963-1983	-0.16 (SR)	1.8	---
Mamuneas and Nadiri (1996)	United States	National Science Foundation and Bureau of Labor Statistics data for 15 industries	1956-1988	-1 to -0.84	0.95	---
Dagenais et al (1997)	Canada	Unbalanced panel of 437 firms from Computstat	1975-1992	-0.07 (SR) -1.08 (LR)	0.98	---
van den Hove et al (1998)	Netherlands	---	1994-1996	---	0.7 to 1.7	---
Bloom et al (2002)	G7, Australia and Spain	OECD BERD survey	1979-1997	-0.14 (SR) -1.09 (LR)	---	---
Koga (2003)	Japan	904 manufacturing firms	1989-1998	-1.03 to -0.68	---	---
Parisi and Sembenelli (2003)	Italy	Balanced panel of 726 firms	1992-1997	-1.77 to -1.5	---	---
Klassen et al (2004)	Canada and United States	Matched sample of 58 Canadian and 110 US firms from Compustat	1991-1997	---	1.3 (Canada) 2.96 (United States)	Comparison of effectiveness of two different types of R&D
Mairesse and Mulkay (2004)	France	765 manufacturing firms	1983-1997	-2.78 to -2.68	2 to 3.6	---
Hægeland and Møen (2007)	Norway	Surveys and government databases	1993-2005	---	1.5 to 3	---

Study	Geographical coverage	Data	Time Period	Elasticity estimates	Additionality ratio	Notes
Lokshin and Mohnen (2007)	Netherlands	Firm-level unbalanced panel from surveys and government datasets	1996-2004	-0.5 to -0.3 (SR) -0.7 to -0.3 (LR)	0.4 to ~3.5	Additionality ratio computed for different types of company as function of time
Wilson (2007)	United States	National Science Foundation R&D by state	1981-2004	-1.2 (SR) -2.2 (LR)	---	Between-state comparison
Harris et al (2009)	Northern Ireland	Firm-level data for 11 manufacturing industries from surveys	1998-2003	-1.36 (LR)	---	---
Baghana and Mohnen (2009)	Quebec	Firm-level data, survey data and province administrative data on amount of incentive received	1997-2003	-0.14 (SR) -0.19 (LR)	1 to ~3	Elasticity estimates for small companies only
HMRC (2010)	United Kingdom	HMRC administrative data and FAME database	2003-2007	-2.59 to -1.6 (SR)	0.41 to 3.37	---
McKenzie and Sershun (2010)	G7, Australia and Spain	---	---	-0.3 to -0.2 (SR) -0.9 to -0.7 (LR)	---	---
Lokshin and Mohnen (2012)	Netherlands	Firm-level unbalanced panel from surveys and government datasets	1996-2004	-0.5 to -0.2 (SR) -0.8 to -0.4 (LR)	0.42 to 3.24	Additionality ratio computed for different types of company as function of time
Mulkay and Mairesse (2013)	France	Large panel	2000-2007	-0.4 (LR)	---	---

6. Impact on R&D investment in the UK

6.1 Methodological discussion

Economic theory predicts the user cost of capital for R&D expenditure to be one of the primary determinants of a firm's decision to invest in R&D. R&D tax policy is thought to influence R&D behaviour through its effect on the cost of finance, with the tax credit decreasing the user cost of capital. This report aims to evaluate the impact of R&D tax credits on firms' decisions to invest in R&D through its impact on the user cost of capital for R&D. The user cost of capital incorporates both the Government's tax credit policy as well as the financial cost of capital to the firm in general.

To assess the effectiveness of the R&D tax credits, we focus on the price elasticity of R&D expenditure. This is a measure for how much companies change their R&D investment in response to a change in the user cost of capital for R&D investment. For this effect to be identified, we rely on changes in the user cost of capital over the period of analysis, which could result, for example, from a change to the R&D scheme or a change to the CT tax rate. There is, however, a risk that changes in the tax credit over the period examined have not translated into a large enough change in the cost of capital to identify an effect on R&D expenditure econometrically. Below we go through the steps taken to ensure that this effect is identifiable.

We use a demand framework for our econometric analysis, in which we try to determine how R&D expenditure changes as the user cost of capital changes. We also include controls for the tax framework, firm-specific effects and other factors (full details are available in Annex B). We use a version of the Arellano-Bond estimator (Arellano and Bond, 1991), which uses first differences in a generalised method of moments (GMM) framework. This is one of the most commonly used frameworks for identifying structural relationships between variables which suffer from endogeneity (e.g. the user cost of capital depends on size, which in turn depends on turnover and on R&D expenditure) in cases where we have a short wide panel – that is, a high number of observations with only a few time periods.

Although a convenient framework for our dataset and for identifying the effect we are interested in, using a dynamic GMM estimator, such as Arellano-Bond, is not without its drawbacks; it can become unstable in the presence of a high number of endogenous variables relative to the sample size. More complex techniques, such as the Blundell-Bond (Blundell and Bond, 1998) estimator, suffer more acutely from this trade-off between sample size, identification of effects and stability. Identification of effects therefore relies on more restrictive assumptions, which are less likely to hold. We have therefore estimated a range of models, ranging from the very simple (ordinary least squares) to a more complex model (Arellano-Bond). We have chosen not to use the Blundell-Bond estimator for the reasons outlined above.

6.2 Preferred model specification

As mentioned in section 6.1 above, the Arellano-Bond (A-B) estimator can become unstable if it is over-specified, that is, if too many variables are included – especially endogenous variables. We therefore use a staged approach, which means that we start by running a simpler regression and gradually introduce complexity (both more variables and dynamics) to understand what the sources of instability might be.

We start by using an ordinary least squares (OLS) estimator to get an estimate of the price elasticity of R&D with respect to the user cost of capital. This is the simplest estimator available, in which we pool all observations together. This is in all likelihood an inconsistent estimator, meaning that we will not be guaranteed to obtain an estimate close to the true

value of the elasticity. The reason for this inconsistency is the fact that we expect there to be firm-specific effects – characteristics that mean that firms are not all alike, which is something we should capture in our model.

The next step, then, is to include these firm-specific effects. To do so, we use a fixed effects (FE) estimator, which is a more realistic model but still relies on the exogeneity of all variables that explain changes to R&D expenditure. This is unlikely to hold – the user cost of capital is determined at the same time as R&D expenditure, which violates the assumptions of the FE estimator. To capture this, we then apply the A-B estimator, which uses instrumental variables (variables that influence R&D expenditure indirectly, through their impact on the user cost of capital) in a dynamic setting to obtain a more robust estimate of the price elasticity of R&D expenditure.

As all models rely on different assumptions, we would expect them to produce different estimates. Table 6-1 summarises the elasticity estimates for our preferred model specification using each of the estimators (OLS, FE and A-B). The details of the preferred model specification can be found in Appendix B.

We looked at ways to control for the effect of the financial crisis in our modelling by including a proxy for the credit conditions, intended to capture the ease of firms obtaining capital. This is particularly important in the wake of the financial crisis as many businesses struggled to get access to finance. This could mean that the effect of the R&D tax credits would be 'drowned out' by the effects of the financial crisis.

The 2010 HMRC evaluation did not include data from the period affected by the financial crisis and there was no need to control for changes in firms' access to credit. In our analysis, we found the proxy for credit conditions to be an important control, which allowed us to more clearly isolate the effect of the user cost of capital on R&D expenditure.

Table 6-1 compares the elasticities from the preferred models with and without controlling for the change in credit conditions. All elasticities are significant at a 1 per cent level and the A-B model passes both misspecification tests[8].

Table 6-1 Elasticity of user cost with respect to R&D expenditure

	OLS	FE	A-B
Model excluding proxy for credit conditions	-0.67	-0.55	-1.09
Model including proxy for credit conditions	-0.67	-0.56	-1.96

As predicted by economic theory, the estimates for the elasticity are negative in all models. This means that a decrease (increase) in the user cost of capital for R&D leads to an increase (decrease) in expenditure on R&D. This verifies the intuition that using tax credits to decrease the user cost of R&D increases R&D expenditure.

The OLS and FE estimates are less elastic, and this is a consequence of the attenuation bias that these estimators suffer from if there is endogeneity. The OLS and FE estimators do not capture as much variation as estimators that take this endogeneity into account, and, as

[8] These are the Arellano-Bond test for zero autocorrelation of first-differenced errors and the Sargan test of overidentifying restrictions.

such, they will produce estimates closer to zero. As A-B is an instrumental variables model that explicitly captures endogeneity, we would expect the estimates to be further away from zero, and this is corroborated by the more elastic estimates in table 6-1. Controlling for credit constraints is found to be very important in the A-B model and changes the elasticity from -1.09 to -1.96. Further robustness testing conducted on the A-B model by changing covariates and numbers of lags resulted in similar estimates, ranging from around -2 to around -1.5.

In general, the estimates obtained from the preferred specification are in all cases in line with economic intuition and well within the range from the literature, with more elastic estimates from the instrumental variables specifications, as would be expected given the properties of the estimators.

6.3 Converting elasticity to additionality ratios

The additionality ratio is calculated as the additional spending on R&D from an increase in the tax credit over the additional cost in foregone tax revenue. Although this is sometimes referred to in the literature as the benefit/cost ratio, it is worth noting that it is not equivalent to a full cost-benefit analysis that the Government would undertake to appraise a policy proposal and for which we would follow the guidelines in the Green Book. Such analysis would require consideration of the value of the positive externalities of R&D investment, as well as the opportunity cost of the investment. Instead, the additionality ratio is inferred from the estimated elasticity. All else being equal, we can calculate the change in the user cost from a change in the tax credit rate and the associated change in R&D expenditure using the elasticity estimate.

The ratio is also called the incrementality ratio, tax sensitivity ratio or 'bang for the buck' ratio, which perhaps is more appropriate, given that it does not take account of all the costs (such as administration) and benefits (social returns on R&D) of the R&D tax credit. Table 6-2 illustrates how the additionality ratio is calculated for a large company in 2012-13 based on the elasticity from the A-B model. The example illustrates the change in R&D expenditure from changing the LC enhancement rate by one percentage point, from 130 per cent to 131 per cent.

Table 6-2 Example of an additionality ratio calculation for large company in 2012-13 paying main CT rate

	Before tax credit change	After tax credit change	Change
Enhancement rate	1.30	1.31	0.01
CT rate	0.24	0.24	-
User cost	0.2263	0.2255	-0.3%
% change in R&D (change in user cost of capital x elasticity)			-0.3 x -1.96 = 0.68%
Increase on £100 investment in R&D	100	100.68	0.68
Exchequer cost of £100 investment	0.30 x 0.24 x 100 = 7.20	0.31 x 0.24 x 100 = 7.49	0.29
Additionality ratio			0.68 / 0.29 = 2.35

The additionality ratio for large companies is estimated to be 2.35. This indicates that £2.35 of R&D expenditure is stimulated for every £1 of tax forgone, i.e. the R&D expenditure

increases more than proportionally in relation to the cost of providing the tax credit for large companies.

For a SME making an enhanced deduction claim, the additionality ratio is 1.88 (following a change in the SME enhancement rate from 225 per cent to 226 per cent), while a change in the credit claim generates a ratio of 1.53 (change in credit rate from 11 per cent to 12 per cent).

The additionality ratios therefore depend both on the estimated price elasticity and on the basis of the enhancement rate. The SME scheme is already more generous, so a 1 percentage point change in the rate generates a smaller percentage change in R&D investment; this means that there are decreasing, but still positive marginal benefits, as economic theory would predict.

We thus find that for UK companies the additionality ratios indicate that between £1.53 and £2.35 of R&D expenditure might be stimulated by £1 of tax forgone. From the literature review, we know that, internationally, additionality ratios range from around 0.3 to around 3.

7. Conclusion

This econometric evaluation estimates that for every pound spent on R&D tax credits, between £1.53 and £2.35 additional expenditure by UK companies is stimulated. These results are in line with previous international studies, which have found additionality ratios to range from around 0.3 to around 3.

HMRC's previous evaluation, produced in 2010, suggested a wider range of additionality ratios, between £0.41 and £3.37. However, the mid-point of both ranges is broadly the same, and overall conclusions are consistent, with a narrower range obtained in this evaluation

The results from the current evaluation are not directly comparable to the estimates found in the 2010 HMRC evaluation, because the current evaluation covers more data, which enables us to produce more precise estimates (narrower range). The current evaluation also uses an improved methodology, which allows us to incorporate more observations from more firms, and therefore obtain more robust estimates. We also analyse large companies and SMEs in the same framework, which allows the population to vary over time, both due to changes in the definition of SMEs for the purposes of the tax credit and due to growth in firm size over time.

In terms of participation in the scheme, the report shows over 100,000 claims made for R&D tax credits since the scheme was introduced in 2000. In 2012-13, the schemes supported £13.2 billion of innovative investment.

The Government has increased the rates of both the SME scheme and the large company scheme over the last five years, with further increases to the scheme being introduced in April 2015. This research confirms the view that R&D tax credits are effective in incentivising additional R&D investment.

Appendix A – R&D Monitoring note

HMRC KAI Direct Business Taxes Monitoring Note on Research and Development (R&D) Tax Credits

A1. Introduction

This note supplements the information provided in the latest National Statistics publication on R&D tax credits. It covers claims for R&D tax credits made in Company Tax returns received for accounting periods ending in financial years up to 2012-13.

First, the geographical and industry sector analyses presented in the National Statistics are expanded with an analysis of long term trends in claims and support claimed by geographical region and a finer grained breakdown of the three industries with the most claims and support.

This is followed by a comparison between trends in the expenditure used to claim R&D tax credits based on HMRC data and trends in total UK expenditure on research and development as estimated by the Office for National Statistics.

Finally, trends in companies which claim R&D tax credits from year to year, those returning to claim after a break, and those which are newcomers to the scheme are presented.

The National Statistics are published on the Gov.uk website: https://www.gov.uk/government/collections/corporate-tax-research-and-development-tax-credits.

For ease of reference the historic rates of relief and corresponding CT rates are provided in the Table in section A6.

A2. Geographical analysis for R&D tax credits

This section expands on the geographic distribution of claims and cost of support under the R&D tax credits scheme provided in the National Statistics publication. The distribution is derived from the postcode of the registered address of the company and may not represent the location of either the company making the claim or where the R&D was carried out. [9]

Table A1 provides the percentage split for the number of claims and amount claimed by registered office and scheme. In the 2012-13 the largest numbers of R&D tax credits claims were filed by companies with registered offices in southern England, with 19.2 per cent of all claims being filed in the South East, 17.2 per cent in London and 10.3 per cent in the East of England. The cost of support in these three regions amounts to £895 million, which is 65.9 per cent of the total cost of support.

[9] For more information on the methodology for classifying by industry sector, please see 'Tables RD4 to RD6' on page 17 of the National Statistics publication.

Tables A2 and A3 show respectively a time series of the percentage of total claims and cost of support by registered office region, from 2000-01 to 2012-13. The number of claims was rounded to the nearest 5 and the cost of support was rounded to the nearest £1m before percentages were calculated.

Between 2000-01 and 2012-13, the proportion of all R&D claims filed by companies with registered offices in London, the South East and the East of England fell gradually from 55 per cent to 47 per cent. However, the proportion of the total cost of R&D support accounted for by companies with registered offices in these regions increased from 68 per cent in 2000-01 to a peak of 77 per cent in 2006-07, gradually falling to 66 per cent in 2012-13.

While a greater proportion of claims have been coming from outside southern England over time, the cost per claim for those registered in southern England moved from nearly double that for claims from the rest of the country to more than 3 times greater in 2008-09. By 2012-13 the cost per claim from southern England was just over twice that for those from elsewhere in the UK.

It should be emphasised that these figures relate to the registered office of the company and will therefore be skewed towards London and the South East since many larger companies will have their head office in London. The actual R&D activity carried out by these companies may well take place elsewhere in the UK. Care should therefore be taken in interpreting these results.

Table A1. Percentage of R&D tax claims by registered office address, 2012-13 [1 2 3]

	SME R&D scheme		Large companies R&D scheme				All schemes	
			Large companies		SME sub-contractors			
Government Office Region	% of claims	% of amount claimed	% of claims	% of amount claimed	% of claims	% of amount claimed	% of claims	% of amount claimed
London	16.8%	24.2%	20.1%	36.4%	13.9%	27.3%	17.2%	31.0%
South East	18.8%	20.5%	20.7%	25.3%	20.0%	27.3%	19.2%	23.2%
East of England	10.1%	12.6%	10.6%	11.1%	13.9%	18.2%	10.3%	11.8%
West Midlands	8.4%	5.9%	6.3%	7.3%	7.8%	9.1%	8.1%	6.8%
North West	10.4%	8.1%	8.9%	4.5%	7.0%	9.1%	10.1%	6.1%
South West	8.0%	7.4%	7.1%	3.2%	10.4%	0.0%	8.0%	5.0%
East Midlands	6.6%	4.9%	5.6%	4.7%	7.0%	9.1%	6.4%	4.8%
Scotland	5.3%	4.9%	7.8%	2.3%	7.0%	0.0%	5.7%	3.5%
Yorkshire and The Humber	7.0%	4.9%	5.8%	1.9%	4.3%	0.0%	6.7%	3.2%
North East	3.6%	3.0%	2.6%	1.2%	2.6%	0.0%	3.4%	2.0%
Wales	2.7%	2.0%	1.9%	1.2%	4.3%	0.0%	2.7%	1.5%
Northern Ireland	2.1%	1.8%	2.8%	1.1%	2.6%	0.0%	2.2%	1.4%
Channel Islands / Isle of Man	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100%	100%	100%	100%	100%	100.0%	100%	100%

1. Regional allocation is based on the postcode of the company's registered address, which might not correspond to where the R&D activity takes place; so, caution must be exercised when interpreting these figures.

2. Figures exclude claims where region is not known.

3. Numbers are rounded to the nearest 5 and amounts to the nearest £1m before percentages are calculated.

Table A2. Percentage of claims per registered office region, 2000-01 to 2012-13[1] [2] [3]

Registered Office Region	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
London	20.7	20.0	19.3	17.2	16.8	16.2	16.1	16.2	17.1	17.2	17.0	17.3	17.2
South East	21.5	22.0	21.8	22.5	22.3	22.6	22.2	21.6	21.6	20.9	20.8	19.3	19.2
East of England	12.8	11.5	12.3	12.2	12.1	12.5	12.6	11.9	11.3	11.0	10.6	10.6	10.3
West Midlands	6.0	6.7	7.1	7.3	7.7	7.3	6.9	6.9	6.8	7.2	7.4	7.9	8.1
North West	8.4	9.0	9.8	9.1	9.4	10.0	10.1	9.9	9.7	9.4	9.3	9.7	10.1
South West	7.6	7.2	6.7	7.6	8.1	8.0	7.7	8.0	7.8	8.0	7.9	8.2	8.0
East Midlands	4.6	5.5	6.0	6.6	6.1	5.9	5.7	6.1	6.0	6.2	6.2	6.2	6.4
Scotland	6.8	5.6	4.9	4.4	4.8	4.6	5.0	5.5	5.7	6.0	6.4	6.3	5.7
Yorkshire and The Humber	5.4	5.9	5.7	6.5	6.1	6.1	6.1	6.3	6.5	6.6	6.7	6.7	6.7
North East	2.2	2.4	2.0	2.0	2.3	2.3	2.7	2.6	2.4	2.6	2.8	3.1	3.4
Wales	2.5	2.7	2.8	3.2	2.5	2.7	3.1	3.1	3.0	2.7	2.8	2.7	2.7
Northern Ireland	1.1	1.3	1.5	1.4	1.8	2.1	1.8	1.9	2.1	2.2	2.1	2.0	2.2
All	100	100	100	100	100	100	100	100	100	100	100	100	100
Base (No of claims)	1,840	3,380	5,300	6,180	6,600	6,410	6,910	7,980	8,870	9,720	10,720	12,610	15,820

1. Regional allocation is based on the postcode of the company's registered address, which might not correspond to where the R&D activity takes place; so, caution must be exercised when interpreting these figures.
2. Figures exclude claims where region is not known.
3. Numbers are rounded to the nearest 5 before percentages are calculated.

Table A3. Percentage of support cost by registered office region, 2000-01 to 2012-13[1] [2] [3]

Registered Office Region	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
London	29.0	27.2	35.8	33.6	31.5	30.9	33.0	32.7	30.5	28.3	31.6	29.9	31.0
South East	27.5	25.4	22.0	29.0	28.8	28.6	29.1	28.4	33.7	31.6	29.3	26.8	23.2
East of England	11.6	13.0	14.3	12.9	15.8	16.1	14.6	14.8	12.5	14.3	13.7	13.0	11.8
West Midlands	2.9	3.6	7.7	7.3	6.5	6.6	4.9	4.7	4.9	2.8	3.0	6.1	6.8
North West	7.2	7.7	4.7	3.9	3.6	3.8	3.9	4.2	4.0	5.4	4.7	5.1	6.1
South West	7.2	6.5	5.2	4.3	4.1	4.4	4.2	4.4	4.4	4.9	4.5	4.8	5.0
East Midlands	4.3	2.4	3.0	2.8	3.6	3.4	2.9	3.1	2.5	3.3	3.4	3.8	4.8
Scotland	5.8	5.3	3.2	2.2	1.9	2.0	2.3	2.9	2.6	3.2	3.6	3.5	3.5
Yorkshire and The Humber	1.4	3.0	2.0	2.1	1.9	1.7	1.7	2.0	2.0	2.5	2.5	3.2	3.2
North East	1.4	1.2	0.7	0.7	0.7	0.8	1.3	1.0	1.0	1.4	1.4	1.5	2.0
Wales	1.4	1.8	1.0	0.9	0.7	0.9	1.5	1.1	1.3	1.5	1.5	1.4	1.5
Northern Ireland	0.0	1.8	0.5	0.4	0.7	0.6	0.6	0.6	0.7	0.8	0.9	1.0	1.4
All	100	100	100	100	100	100	100	100	100	100	100	100	100
Base (£m)	70	170	410	540	580	640	690	800	1,000	1,000	1,100	1,200	1,360

1. Regional allocation is based on the postcode of the company's registered address, which might not correspond to where the R&D activity takes place, so caution must be exercised when interpreting these figures.
2. Figures exclude claims where region is not known.
3. Amounts are rounded to the nearest £1m before percentages are calculated.

A3. Industry sector analysis for R&D tax credits

The following section expands on the National Statistics publication by providing a more detailed breakdown of claims for R&D tax credits by industry sector. As mentioned in the main publication, for 2012-13 most claims fall within three main Standard Industrial Classification (SIC2007) sections: 'Manufacturing' (32.2 per cent claims, 36.4 per cent support claimed), 'Professional, Scientific and Technical' (19.1 per cent claims, 25.3 per cent support claimed) and 'Information and Communication' (25.8 per cent claims, 18.6 per cent support claimed).

It is important to note that the industry information available reflects only the main economic activity of the business, which may not be the same activity as the actual R&D[10].

Tables A4 and A5 below provide a more fine-grained breakdown of the number of claims and the amount of support claimed within the 3 main sectors mentioned above than that provided in table RD6 of the National Statistics. The breakdown of these sectors is provided at the SIC2007 division level, with the percentages shown reflecting the proportion of total claims/support rather than the proportion in that SIC section.

[10] For more information on the methodology for classifying by industry sector, please see 'Tables RD4 to RD6' on page 17 of the National Statistics publication.

Table A4. Number of claims under the R&D tax credit scheme by industry for the financial year 2012-13

	SIC section description - SIC division & description	Number of R&D claims by SIC group (actual) SME	LC	Total	Distribution of R&D claims by SIC group (%) SME	LC	Total
A	**Agriculture, Forestry, Fishing**	50.0	20.0	70.0	0.4	0.7	0.4
B	**Mining & Quarrying**	20.0	30.0	50.0	0.2	1.0	0.3
C	**Manufacturing (Total)**	3,970	1,140	5,110	30.6	39.5	32.2
	C: 10 - Manufacture of food products	140.0	70.0	215.0	1.1	2.4	1.4
	C: 11 - Manufacture of beverages	10.0	15.0	25.0	0.1	0.5	0.2
	C: 12 - Manufacture of tobacco products	0.0	*	*	0.0	*	*
	C: 13 - Manufacture of textiles	45.0	15.0	60.0	0.3	0.5	0.4
	C: 14 - Manufacture of wearing apparel	20.0	*	20.0	0.2	*	0.1
	C: 15 - Manufacture of leather and related products	*	5.0	10.0	*	0.2	0.1
	C: 16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	40.0	*	45.0	0.3	*	0.3
	C: 17 - Manufacture of paper and paper products	50.0	20.0	70.0	0.4	0.7	0.4
	C: 18 - Printing and reproduction of recorded media	75.0	10.0	85.0	0.6	0.3	0.5
	C: 19 - Manufacture of coke and refined petroleum products	15.0	*	^	0.1	*	^
	C: 20 - Manufacture of chemicals and chemical products	290.0	135.0	425.0	2.2	4.7	2.7
	C: 21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	70.0	45.0	115.0	0.5	1.6	0.7
	C: 22 - Manufacture of rubber and plastic products	255.0	55.0	310.0	2.0	1.9	2.0
	C: 23 - Manufacture of other non-metallic mineral products	60.0	25.0	85.0	0.5	0.9	0.5
	C: 24 - Manufacture of basic metals	65.0	25.0	90.0	0.5	0.9	0.6
	C: 25 - Manufacture of fabricated metal products, except machinery and equipment	570.0	^	665.0	4.4	^	4.2
	C: 26 - Manufacture of computer, electronic and optical products	695.0	190.0	885.0	5.4	6.6	5.6
	C: 27 - Manufacture of electrical equipment	340.0	80.0	420.0	2.6	2.8	2.6
	C: 28 - Manufacture of machinery and equipment n.e.c.	530.0	160.0	690.0	4.1	5.5	4.4
	C: 29 - Manufacture of motor vehicles, trailers and semi-trailers	120.0	35.0	155.0	0.9	1.2	1.0
	C: 30 - Manufacture of other transport equipment	75.0	45.0	115.0	0.6	1.6	0.7
	C: 31 - Manufacture of furniture	55.0	10.0	65.0	0.4	0.3	0.4
	C: 32 - Other manufacturing	370.0	85.0	455.0	2.9	2.9	2.9
	C: 33 - Repair and installation of machinery and equipment	80.0	15.0	95.0	0.6	0.5	0.6
D	**Electricity, Gas, Steam and Air Conditioning**	15.0	15.0	35.0	0.1	0.5	0.2
E	**Water, Sewerage and Waste**	75.0	20.0	95.0	0.6	0.7	0.6
F	**Construction**	235	65	300	1.8	2.3	1.9
G	**Wholesale & Retail Trade, Repairs**	1,200	180	1,375	9.2	6.2	8.7
H	**Transport & Storage**	70.0	20.0	90.0	0.5	0.7	0.6
I	**Accommodation & Food**	25.0	*	30.0	0.2	*	0.2
J	**Information & Communication (Total)**	3,585	510	4,095	27.6	17.7	25.8
	J: 58 - Publishing activities	150.0	20.0	170.0	1.2	0.7	1.1
	J: 59 - Motion picture, video and television programme production, sound recording and music publishing activities	60.0	10.0	70.0	0.5	0.3	0.4
	J: 60 - Programming and broadcasting activities	^	*	^	^	*	^
	J: 61 - Telecommunications	180.0	35.0	210.0	1.4	1.2	1.3
	J: 62 - Computer programming, consultancy and related activities	3,000	425	3,425	23.1	14.7	21.6
	J: 63 - Information service activities	190.0	15.0	210.0	1.5	0.5	1.3

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Table A4. Number of claims under the R&D tax credit scheme by industry for the financial year 2012-13 - continued

	SIC section description - SIC division & description	Number of R&D claims by SIC group (actual)			Distribution of R&D claims by SIC group (%)		
		SME	LC	Total	SME	LC	Total
K	**Financial & Insurance**	145.0	60.0	205.0	1.1	2.1	1.3
L	**Real Estate**	25.0	*	25.0	0.2	*	0.2
M	**Professional, Scientific & Technical (Total)**	2,410	615	3,025	18.6	21.3	19.1
	M: 69 - Legal and accounting activities	40.0	5.0	45.0	0.3	0.2	0.3
	M: 70 - Activities of head offices; management consultancy activities	495.0	85.0	580.0	3.8	2.9	3.7
	M: 71 - Architectural and engineering activities; technical testing and analysis	670.0	185.0	855.0	5.2	6.4	5.4
	M: 72 - Scientific research and development	625.0	250.0	875.0	4.8	8.7	5.5
	M: 73 - Advertising and market research	180.0	15.0	190.0	1.4	0.5	1.2
	M: 74 - Other professional, scientific and technical activities	390.0	80.0	470.0	3.0	2.8	3.0
	M: 75 - Veterinary activities	10.0	*	15.0	0.1	*	0.1
N	**Admin & Support Services**	685.0	135.0	820.0	5.3	4.7	5.2
O	**Public Admin, Defence & Social Services**	0.0	5.0	5.0	0.0	0.2	0.0
P	**Education**	75.0	*	80.0	0.6	*	0.5
Q	**Health & Social Work**	90.0	15.0	100.0	0.7	0.5	0.6
R	**Arts, Entertainment & Recreation**	75.0	15.0	90.0	0.6	0.5	0.6
S	**Other services activities**	225.0	35.0	260.0	1.7	1.2	1.6
T	**Households**	0.0	0.0	0.0	0.0	0.0	0.0
U	**Overseas**	0.0	0.0	0.0	0.0	0.0	0.0
	Known industry sector	12,975	2,885	15,860	1.0	1.0	1.0
	Unknown industry sector	30.0	35.0	65.0			
	All sectors	13,005	2,920	15,925			

1. Industry sector is based on primary SIC2007 coding of registered company. This coding might not correspond to the industry sector of the R&D activity, so caution must be exercised when interpreting these figures.
2. Figures exclude claims where industry sector is not known.
3. Numbers are rounded to the nearest 5. Totals may not sum due to rounding.
4. Statistics in this table are consistent with HMRC's policies on dominance and disclosure.

* Value suppressed as cell count less than 5

^ Value suppressed to protect taxpayer confidentiality

Table A5. Support claimed under the R&D tax credit schemes by industry sector for the financial year 2012-13

		Support claimed (£million)			Distribution of R&D claims by SIC group (%)		
	SIC section description - SIC division & description	SME	LC	Total	SME	LC	Total
A	**Agriculture, Forestry, Fishing**	1.2	1.6	2.9	0.2	0.2	0.2
B	**Mining & Quarrying**	2.5	10.7	13.2	0.4	1.4	1.0
C	**Manufacturing (Total)**	167.4	323.8	491.2	28.0	43.2	36.5
	C: 10 - Manufacture of food products	4.2	7.3	11.5	0.7	1.0	0.9
	C: 11 - Manufacture of beverages	0.2	3.3	3.5	0.0	0.4	0.3
	C: 12 - Manufacture of tobacco products	0.0	*	*	0.0	*	*
	C: 13 - Manufacture of textiles	0.9	0.7	1.6	0.2	0.1	0.1
	C: 14 - Manufacture of wearing apparel	0.4	*	0.4	0.1	*	0.0
	C: 15 - Manufacture of leather and related products	*	0.1	0.2	*	0.0	0.0
	C: 16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.6	*	0.6	0.1	*	0.0
	C: 17 - Manufacture of paper and paper products	1.3	4.6	5.9	0.2	0.6	0.4
	C: 18 - Printing and reproduction of recorded media	2.7	0.9	3.6	0.5	0.1	0.3
	C: 19 - Manufacture of coke and refined petroleum products	0.4	*	^	0.1	*	^
	C: 20 - Manufacture of chemicals and chemical products	11.1	13.5	24.6	1.9	1.8	1.8
	C: 21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	6.1	10.7	16.8	1.0	1.4	1.2
	C: 22 - Manufacture of rubber and plastic products	6.8	2.9	9.7	1.1	0.4	0.7
	C: 23 - Manufacture of other non-metallic mineral products	1.9	1.0	2.9	0.3	0.1	0.2
	C: 24 - Manufacture of basic metals	2.3	10.2	12.5	0.4	1.4	0.9
	C: 25 - Manufacture of fabricated metal products, except machinery and equipment	17.8	^	50.5	3.0	^	3.8
	C: 26 - Manufacture of computer, electronic and optical products	36.6	38.4	75.1	6.1	5.1	5.6
	C: 27 - Manufacture of electrical equipment	15.9	11.1	27.0	2.7	1.5	2.0
	C: 28 - Manufacture of machinery and equipment n.e.c.	22.4	21.3	43.6	3.7	2.8	3.2
	C: 29 - Manufacture of motor vehicles, trailers and semi-trailers	12.2	78.6	90.8	2.0	10.5	6.7
	C: 30 - Manufacture of other transport equipment	3.1	47.9	51.0	0.5	6.4	3.8
	C: 31 - Manufacture of furniture	1.3	0.2	1.4	0.2	0.0	0.1
	C: 32 - Other manufacturing	15.7	20.2	35.9	2.6	2.7	2.7
	C: 33 - Repair and installation of machinery and equipment	3.3	2.3	5.6	0.5	0.3	0.4
D	**Electricity, Gas, Steam and Air Conditioning**	0.6	4.4	5.0	0.1	0.6	0.4
E	**Water, Sewerage and Waste**	2.6	3.3	5.9	0.4	0.4	0.4
F	**Construction**	4.8	7.0	11.9	0.8	0.9	0.9
G	**Wholesale & Retail Trade, Repairs**	33.6	32.2	65.8	5.6	4.3	4.9
H	**Transport & Storage**	1.5	2.7	4.2	0.2	0.4	0.3
I	**Accommodation & Food**	0.6	*	0.6	0.1	*	0.0
J	**Information & Communication (Total)**	178.4	72.3	250.7	29.9	9.6	18.6
	J: 58 - Publishing activities	6.8	4.5	11.2	1.1	0.6	0.8
	J: 59 - Motion picture, video and television programme production, sound recording and music publishing activities	1.6	0.6	2.2	0.3	0.1	0.2
	J: 60 - Programming and broadcasting activities	^	*	^	^	*	^
	J: 61 - Telecommunications	12.4	5.5	18.0	2.1	0.7	1.3
	J: 62 - Computer programming, consultancy and related activities	146.8	57.2	204.0	24.6	7.6	15.1
	J: 63 - Information service activities	9.8	4.2	14.0	1.6	0.6	1.0

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Table A5. Support claimed under the R&D tax credit schemes by industry sector for the financial year 2012-13- continued

	SIC section description - SIC division & description	Support claimed (£million)			Distribution of R&D claims by SIC group (%)		
		SME	LC	Total	SME	LC	Total
K	**Financial & Insurance**	8.9	30.6	39.4	1.5	4.1	2.9
L	**Real Estate**	0.5	*	0.5	0.1	*	0.0
M	**Professional, Scientific & Technical (Total)**	142.6	197.2	339.7	23.9	26.3	25.2
	M: 69 - Legal and accounting activities	1.1	0.0	1.1	0.2	0.0	0.1
	M: 70 - Activities of head offices; management consultancy activities	14.6	36.3	50.8	2.4	4.8	3.8
	M: 71 - Architectural and engineering activities; technical testing and analysis	28.0	43.8	71.8	4.7	5.8	5.3
	M: 72 - Scientific research and development	80.1	110.2	190.4	13.4	14.7	14.1
	M: 73 - Advertising and market research	6.2	0.9	7.1	1.0	0.1	0.5
	M: 74 - Other professional, scientific and technical activities	12.2	5.9	18.1	2.0	0.8	1.3
	M: 75 - Veterinary activities	0.4	*	0.4	0.1	*	0.0
N	**Admin & Support Services**	26.7	29.8	56.5	4.5	4.0	4.2
O	**Public Admin, Defence & Social Services**	0.0	8.0	8.0	0.0	1.1	0.6
P	**Education**	1.6	*	2.0	0.3	*	0.1
Q	**Health & Social Work**	9.2	1.4	10.6	1.5	0.2	0.8
R	**Arts, Entertainment & Recreation**	8.5	22.4	30.9	1.4	3.0	2.3
S	**Other services activities**	6.5	2.0	8.4	1.1	0.3	0.6
T	**Households**	0.0	0.0	0.0	0.0	0.0	0.0
U	**Overseas**	0.0	0.0	0.0	0.0	0.0	0.0
	Known industry sector	597.5	749.8	1,347.4	1.0	1.0	1.0
	Unknown industry sector	1.6	24.0	25.6			
	All sectors	599.2	773.8	1,373.0			

1. Industry sector is based on primary SIC2007 coding of registered company. This coding might not correspond to the industry sector of the R&D activity, so caution must be exercised when interpreting these figures.
2. Figures exclude claims where industry sector is not known.
3. Amounts are rounded to the nearest £1m. Totals may not sum due to rounding.
4. Statistics in this table are consistent with HMRC's policies on dominance and disclosure.

* Value suppressed as cell count less than 5

^ Value suppressed to protect taxpayer confidentiality

A4. Business Enterprise Research and Development (BERD) survey - estimate of R&D expenditure

The Office for National Statistics (ONS) conducts the annual Business Enterprise Research and Development (BERD) survey of 400 of the largest R&D spenders and a sample of approximately 4,600 other companies[11]. The 400 largest R&D spenders account for approximately 78 per cent of the total R&D expenditure by businesses, not including government, higher education and research council expenditure. The survey response rate for 2012 was 91 per cent.

Table A6 shows the latest BERD survey estimates of R&D revenue expenditure by businesses, and the expenditure used to claim R&D tax credits.12 The BERD figure for 2012 of £15.97 billion compares with our claims-related expenditure figure of £13.23 billion for 2012-13. This indicates that 83 per cent of all R&D revenue expenditure by business was used to claim R&D tax credits. Note that BERD data is reported on a calendar year basis, whereas R&D tax credit claims are reported on an accounting period end date basis (i.e. by financial year). For comparing data, the 2012 calendar year basis is most closely related to the 2012-13 financial year.

Table A6. UK R&D expenditure 2005 to 2012 (£ billion)[13]

	2005	2006	2007	2008	2009	2010	2011	2012
Total revenue expenditure (BERD survey, cash terms)	12.6	13.2	14.6	15.0	14.6	15.1	16.4	16.0
Expenditure used to claim tax credits	7.2	7.9	9.1	11.0	10.0	11.1	12.0	13.2
Percentage of total used to claim (%)	57.6	59.7	62.0	73.5	68.3	73.2	73.3	82.8

Both BERD and HMRC recorded expenditures have followed upward trends up until 2011. However, in 2012 the BERD estimate of total R&D expenditure decreased by 3 per cent, while the expenditure used to claim tax credits increased by 17 per cent.

The percentage of total R&D expenditure used to claim tax credits has increased steadily from 50 per cent in 2003 to 83 per cent in 2012 with a small number of large cases causing a spike in R&D tax credit expenditure in 2008. This steady increase may be explained partly by the increased number and size of claims, and also by a small number of large claimants underestimating their expenditure in earlier years.

It is also possible that greater awareness and the increasing generosity of the schemes may be leading to a larger proportion of companies carrying out R&D activity making claims. The increase in expenditure used to claim credits despite the reduction in the expenditure recorded by BERD may also be a reflection of some SMEs who previously carried out R&D activity but could not claim due to the £10,000 minimum expenditure now claiming under

[11] See Business Enterprise Research and Development, 2012: http://www.ons.gov.uk/ons/rel/rdit1/bus-ent-res-and-dev/2012/stb-berd-2012.html

[12] See Table 13 of the BERD survey. http://www.ons.gov.uk/ons/rel/rdit1/bus-ent-res-and-dev/2012/stb-berd-2012.html

[13] BERD data is reported on a calendar year basis, whereas HMRC data is on an accounting period basis. For purposes of this table, calendar year 2005 is compared with financial year 2005-06, etc.

the scheme. SMEs are also likely to be taking advantage of the 125 per cent deduction rate and spending more on R&D.

The latest BERD figures also show that, alongside R&D revenue expenditure, R&D capital expenditure by business has continued its upward trend. Having reached £1bn in 2011 it increased to £1.34 billion in 2012. This is just under 7 per cent of the total R&D expenditure in 2012 of £17.1 billion. R&D capital expenditure attracts separate tax relief.

A5. Companies claiming R&D tax credits from year to year

In this section the figures and trends show in detail which companies claim R&D tax credits from year to year, which ones return to claim after a break, and which are newcomers to the scheme. Table A7 shows the incidence of companies claiming R&D tax credits under the SME scheme from year to year. Those claiming in any particular year are either (a) continuing companies who claimed the previous year, (b) returning companies who have claimed before but not in the previous year, or (c) new companies that are making a SME claim for the first time.

Table A7. Companies claiming under the SME scheme from year to year

Finance Year	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
Previous year's companies	5,120	5,820	6,520	7,260	8,090	9,800
Of which not claimed this year	1,640	1,860	1,940	2,220	2,250	2,440
Of which have claimed again this year (a)	3,490	3,960	4,580	5,040	5,830	7,360
as percentage of previous year's claimants	68%	68%	70%	69%	72%	75%
Returning companies who claimed before last year (b)	530	610	660	730	870	1,060
as percentage of dormant pool	5%	5%	5%	5%	6%	6%
Companies who have not claimed before (c)	1,800	1,950	2,030	2,310	3,100	4,220
Companies claiming this year (a+b+c)	5,820	6,520	7,260	8,090	9,800	12,650
Cumulative number who have ever claimed SME credits	15,150	17,100	19,130	21,440	24,530	28,760

The number of companies continuing to claim from one year to the next (a) has increased each year. The number of returning claimants (b) has been relatively consistent at around 5 per cent of the (expanding) pool of "dormant" claimants, increasing to 6 per cent in 2011-12 and 2012-13. In contrast, new companies (c) have steadily increased since 2006-07 (not shown). These trends are shown in Figure A1 below.

Figure A1. Companies claiming under the SME scheme from year to year

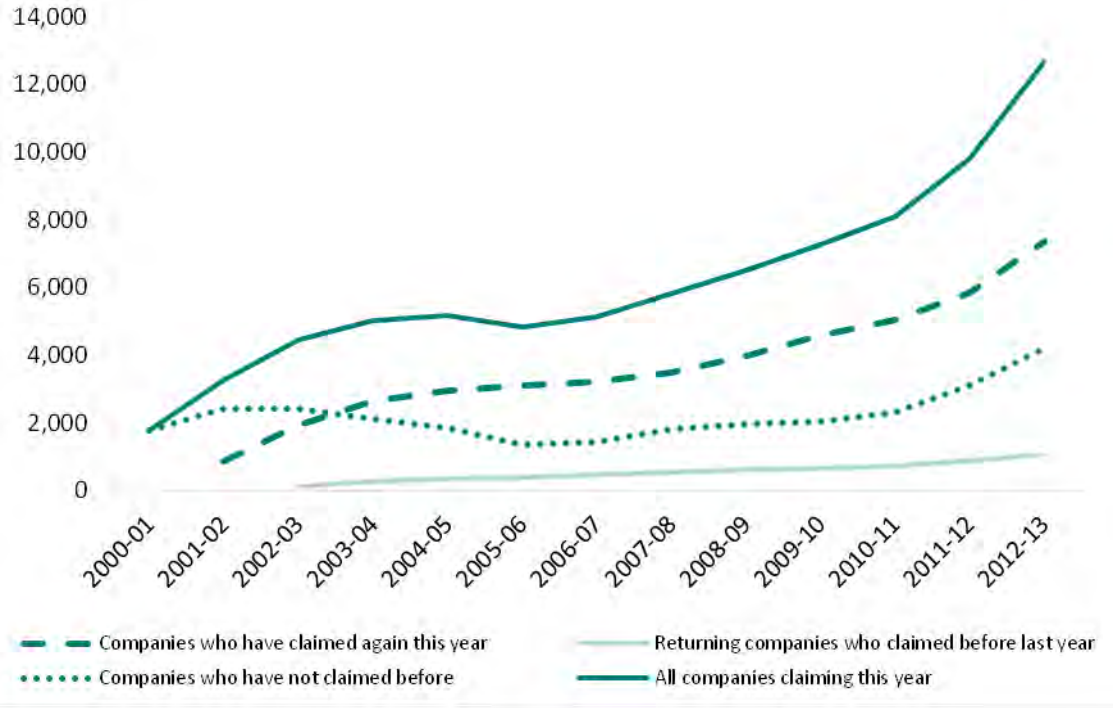
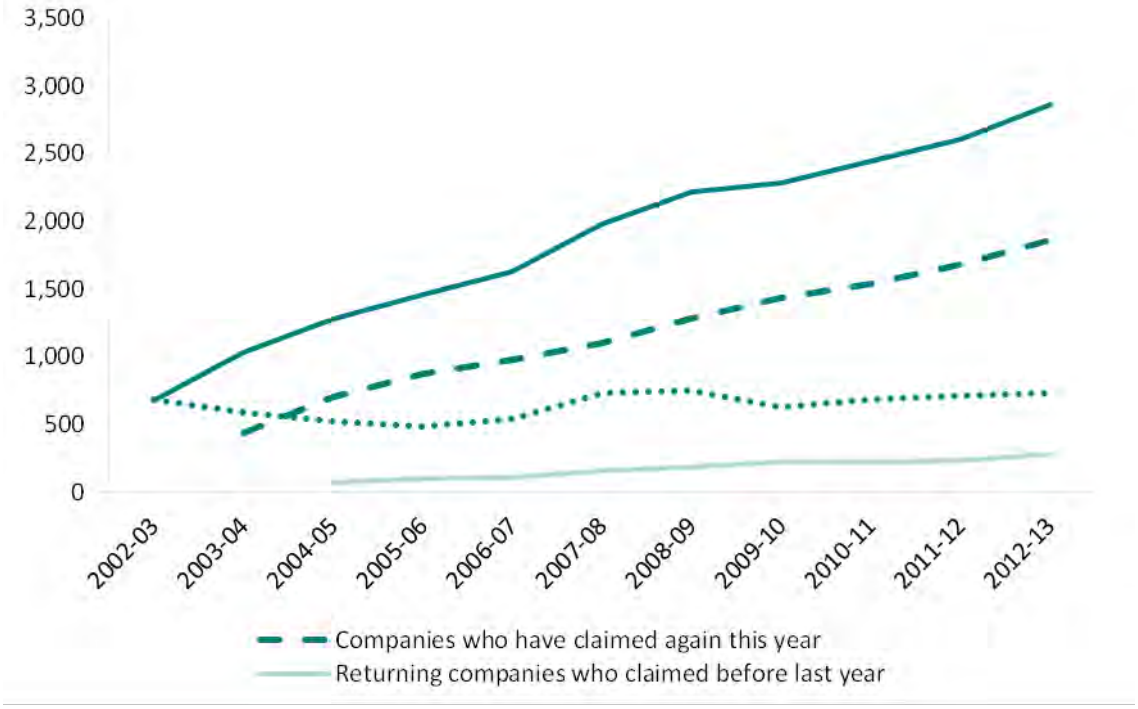


Table A8 shows the incidence of companies claiming R&D tax credits under the Large Company scheme, including SMEs claiming as subcontractors to a large company. The number of companies continuing to claim from one year to the next has risen each year in absolute numbers, with over two-thirds of companies claiming in one year also claiming in the next. These have been supplemented by a small but increasing number of returning companies (stable at around 6 per cent of the dormant pool in 2012-13) and by companies claiming for the first time under the Large Company scheme – around 700 a year. These trends are shown in figure A2 below.

Table A8. Companies claiming under the Large Company scheme from year to year

Finance Year	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
Previous year's companies	1,630	1,980	2,220	2,280	2,450	2,610
Of which not claimed this year	530	700	790	740	770	750
Of which have claimed again this year	1,100	1,280	1,430	1,540	1,680	1,860
as percentage of previous year's claimants	67%	65%	64%	68%	69%	71%
Returning companies who claimed before last year	160	190	220	220	230	280
as percentage of dormant pool	9%	8%	8%	7%	6%	6%
Companies who have not claimed before	730	750	630	680	710	730
Companies claiming this year	1,980	2,220	2,280	2,450	2,610	2,860
Cumulative number who have ever claimed LC credits	3,540	4,290	4,930	5,610	6,320	7,050

Figure A2. Companies claiming under the Large Company scheme from year to year



Comparing the two schemes, the patterns of continuing and returning claimants are broadly similar.

A6. Key features of the R&D tax credit schemes

Table A9 at the end of Section A6 provides historic rates of relief for the R&D tax credit schemes and corresponding CT rates.

Scheme to 2007-08

Research & Development (R&D) tax credits were introduced in April 2000 for companies that are Small and Medium-sized Enterprises (SMEs). A separate scheme was extended to non-SME companies in April 2002 (often called the 'Large Company' scheme), and a vaccines research relief was also introduced with effect from April 2003.

R&D is defined for tax purposes in Section 1138 Corporation Tax Act 2010. This follows generally accepted accounting practice with some modifications for tax purposes as set out in BIS guidelines. Broadly, R&D takes place where a project seeks to achieve an advance in science or technology.

Where a company is conducting R&D, certain costs of undertaking the R&D may qualify for R&D tax credits. Principally these are expenditure on staffing costs; materials used in R&D; externally provided workers; and in certain cases some of the costs of sub-contracted R&D.

Until 2007-08 the R&D tax credit worked by allowing companies to deduct 150 per cent (under the SME scheme) or 125 per cent (under the large company scheme) of qualifying expenditure on R&D activities when calculating their profit for Corporation Tax (CT) purposes. As standard tax treatment would normally allow companies to deduct 100 per cent of R&D expenditure when calculating their taxable profits anyway, this represents an extra deduction of 50 per cent under the SME scheme and 25 per cent under the large company scheme. This extra deduction was worth between £5 and £15 for every £100 of R&D expenditure, depending on the company's marginal CT rate.

SMEs are allowed to claim payable tax credits in cash from HMRC if they have no CT liability for the accounting period. The payable tax credit could amount to £24 for every £100 of actual R&D expenditure (16 per cent of the enhanced expenditure), but all the enhanced relief (worth up to £45) must be surrendered to receive this maximum payment.

Some of these SMEs therefore choose to surrender some but not all of the enhanced deduction in return for a payable credit. Such claims are called combination claims.

The vaccines research relief allowed companies to deduct a further 50 per cent of qualifying expenditure on R&D into certain vaccines and medicines when calculating their profit for tax purposes. This was in addition to the enhanced deductions from the R&D tax credit schemes. Loss-making SMEs (i.e. those with no CT liability) could also surrender (some of) this enhanced relief for a cash payment, as with the SME R&D tax credit.

Developments from 2008-09

From 1 April 2008 companies could deduct an extra 30 per cent (up from 25 per cent) of their qualifying R&D expenditure under the large company scheme. From 1 August 2008, the SME relief was extended to include companies with up to 500 employees and either turnover under €100 million or balance sheet assets under €86 million. Under the extended SME scheme, companies could deduct an extra 75 per cent (up from 50 per cent) of their qualifying R&D expenditure, or receive a payable credit of 14 per cent of the surrenderable loss (the previous rate was 16 per cent). Also from 1 August 2008, companies could deduct an extra 40 per cent (change from 50 per cent) of their qualifying vaccine research expenditure.

Changes taking place from 1 April 2011

From 1 April 2011 to 31 March 2012, SME companies could deduct an extra 100 per cent (up from 75 per cent) of their qualifying R&D expenditure, or receive a payable credit of 12.5 per cent of the surrenderable loss. However, the additional 40 per cent deduction available to SMEs for vaccines research expenditure was reduced from 40 per cent to 20 per cent.

Changes taking place from 1 April 2012

From 1 April 2012, SME companies can deduct an extra 125 per cent (up from 100 per cent) of their qualifying R&D expenditure, or receive a payable credit of 11 per cent of the surrenderable loss. The rule limiting payable credits to the amount of a SME's PAYE/National Insurance liability was also removed. For both SMEs and large companies, the requirement for a minimum expenditure of £10,000 on R&D was removed. Taken together, this allows SMEs carrying out lower level R&D activity (i.e. spending less than £10,000) to make claims where they could not before and encourages higher levels of expenditure from those already able to make claims. Large company claims are generally well in excess of £10,000, so the removal of the minimum expenditure would not affect the number of large company claims. Additionally, Vaccines Research Relief was abolished for SME's in relation to expenditure incurred on or after 1 April 2012.

Research and development expenditure credit for large companies

An optional, 'Above-the-Line', expenditure credit scheme for large companies was introduced in April 2013. Companies can choose the new Research and Development Expenditure Credit scheme (RDEC) or the large company scheme until 2016, when the RDEC scheme will replace the large company scheme. A company with no tax liability that claims the expenditure credit may now claim a cash payment. The new RDEC is not reflected in these statistics because it was not available during the period which they cover.

Developments from 1 April 2014

At Budget 2014 it was announced that the rate of R&D payable credit available to loss-making SMEs conducting R&D activities will be increased from 11 per cent to 14.5 per cent from 1st April 2014. This increases the rate of the cash credit payable to SMEs that conduct qualifying R&D activity but do not have corporation tax liabilities. Again, this change will not be reflected in these statistics.

Further information on the R&D tax credit schemes can be found on the HM Revenue & Customs website at: www.hmrc.gov.uk/randd.

Table A9. Historic rates of relief for the R&D tax credits schemes and CT rates

Scheme	Rate	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
SME	payable credits	16%	16%	16%	16%	16%	16%	16%	16%	14%*	14%	14%	13%	11%
	deductions	50%	50%	50%	50%	50%	50%	50%	50%	75%*	75%	75%	100%	125%
LC	deductions	-	-	25%	25%	25%	25%	25%	25%	30%	30%	30%	30%	30%
CT	small profits	19%	19%	19%	19%	19%	19%	19%	19%	21%	21%	21%	20%	20%
	large profits	-	-	30%	30%	30%	30%	30%	30%	28%	28%	28%	26%	24%

* Change took effect from 1 August 2008

Appendix B – Details of the econometric evaluation

B1. Theoretical framework

Following Bloom et al. (2000), Harris et al. (2006) and Becker(2014), most studies of R&D expenditure use as a starting point an R&D demand equation with various determinants of R&D investment. The general form of the econometric model for a company *i* at time *t* is:

$$R_{it} = \alpha_0 + \gamma C_{it} + \beta X_{it} + \varepsilon_{t\tau} \qquad (1)$$

where R_{it} is R&D investment, α_0 is a constant C_{it} is the user cost of R&D, X_{it} stands for various control variables (lagged R&D, turnover, growth in turnover, profit, number of employees, liquidity ratio, real interest rate, growth in gdp by industry) and $\varepsilon_{t\tau}$ is a stochastic error term.

Specific firm heterogeneity (e.g. scientist's availability, managerial ability and macroeconomic factors) cannot be observed but are important for R&D investment. So long as these are stable over time, they can be captured by firm fixed effects and controlled for in the regression. Some studies capture common technology shocks and other time-variant common effects by including time dummies (Becker (2014)). Model (1) can then be rewritten as the with-in groups or least-squares dummy variables estimator:

$$R_{it} = \gamma C_{it} + \beta X_{it} + f_i + v_{it} \qquad (2)$$

where *f* denotes the fixed effects.

R&D investment has a number of characteristics suggesting that it should not be analysed in a static framework. Therefore, one generally allows for dynamics, e.g. due to high adjustment costs. Following Bloom et al (2002), we specify a simple dynamic model by introducing a lagged dependent variable:

$$R_{it} = \rho R_{i,t-1} + \gamma C_{it} + \beta X_{it} + f_i + v_{it} \qquad (3)$$

The focus is to estimate γ, which is the short run elasticity of R&D investment with respect to the user cost of R&D.

B2. Econometric methodology

There are a number of potential issues with using the with-in estimator to estimate a dynamic R&D equation.

There is a worry that the user cost of R&D may be endogenous leading to a bias in our estimates. User cost depends not only on the tax system but also on other economic variables, such as the real interest rate, which is generally procyclical and thus positively correlated with R&D expenditure. Furthermore, including lagged R&D as a regressor will also lead to bias in the FE estimation because the transformed lagged dependent variable is correlated to the (transformed) error term.

The lack of strict exogeneity can be dealt with by using instrumental variables. Using lagged regressors as instruments for other explanatory variables can also address concerns of simultaneity, e.g. for output.

The R&D literature has widely used the first-differences generalised method of moments (GMM) estimator (Arellano and Bond 1991) to overcome these issues. The A-B estimator uses difference GMM. It transforms the model to first difference to eliminate individual fixed effects from the model and is useful for mitigating issues caused by endogeneity (profit,

sales, lagged dependent variable and user costs are predetermined variables as R&D investments may influence their future values), which is usually solved by using Instrumental Variables (IV). When IVs are not readily available, the A-B estimator can take suitably lagged values of first differenced dependent and endogenous variables and use them as instruments.

The A-B estimator has been designed for small T, large N panels. In large T panels a shock to the fixed effects will decline with time. Similarly, the correlation of the lagged dependent variable with the error term will be insignificant. In these cases one does not have to use the A-B estimator.

Although a convenient framework for our dataset and for identifying the effect we are interested in, using a dynamic GMM estimator such as Arellano-Bond is not without its drawbacks; it can become unstable in the presence of a high number of endogenous variables relative to the sample size. More complex techniques, such as the Blundell-Bond (Blundell and Bond, 1998) estimator, suffer more acutely from this trade-off between sample size, identification of effects and stability; identification of effects therefore relies on more restrictive assumptions, which are unlikely to hold. We have therefore estimated a range of models, ranging from the very simple (ordinary least squares) to a more complex model (Arellano-Bond). We have chosen not to use the Blundell-Bond estimator for the reasons outlined above.

A dynamic GMM model might be unstable as it tries to accommodate many issues (firm heterogeneity and endogenous variable). It can potentially not be relied upon to produce robust outcomes. We therefore adopt a staged approach where we:

i) Run a pooled OLS model on a static specification (OLS-model);

ii) Run a dynamic FE model (Fixed effect model using first-differences; FE-model);

iii) Run a dynamic GMM (Using the Arellano-Bond estimator; A-B model).

Using this staged approach should allow us to determine why the GMM model might become unstable.

B3. The dataset

The data on R&D expenditure used for the analysis comes from the administrative data used to compile National Statistics on R&D tax credits and it is derived from information provided by companies on the Company Tax return (CT600). The data cover all CT returns received by HMRC and records are available for all SME and large company (LC) claims made in those returns

The CT return collects information on the enhanced level of R&D expenditure and the amount of any R&D payable tax credit. Companies also specify whether they are claiming under the SME or the large company scheme, and declare the expenditure they are claiming under the SME sub-contractor or vaccines research relief scheme, if applicable (R&D Tax Credit statistics 2014).

The R&D data is enhanced with company level data from FAME (Financial Analysis Made Easy) on turnover, profits, number of employees and liquidity ratio. Furthermore, the companies have been assigned to a SIC 2007 sector (the UK Standard Industrial Classification 2007 standard) based on information from the ONS's Inter-Departmental Business Register (IDBR) survey where there was a unique match, or otherwise from information provided by the firms to Companies House.

B3.1 The sample

The identification strategy applied in this evaluation requires us to calculate an effective tax credit rate for each company. The effective tax credit rate calculation will vary depending on what option of the scheme the company has claimed under. We calculate the effective rate for LCs making an enhanced deduction claim and for SMEs claiming enhanced deduction, payable credit or a combination of both.

A SME can also claim relief if they have carried out R&D work as a subcontractor to a large company. These claims constitute only a very small proportion of all claims and we therefore do not include them in this analysis. We also exclude the Vaccines Research Relief for the same reason.

Some companies have filed several claims within the same financial year. In some cases, companies will genuinely have had two claims within the year and therefore the claims should be summed. In other cases, the company will have changed their accounting period, in which case their claim should be standardised. There are very few cases of multiple claims within the year and for ease we use only the claim with the latest accounting period.

For the explanatory variables we interpolate missing values at time *t* if we have a value for time *t-1* and *t+1*. If two or more consecutive values are missing, we exclude the company from the sample.

In line with standard data cleaning processes, we strip out the effect of outliers, especially because there can be very large disparities in size between companies and their R&D expenditure. This involved removing the top 1 per cent of claims from both SMEs and LCs and remove claims below a certain threshold.

The 2010 evaluation looked at the LC and the SME schemes separately. One of the main drawbacks of this is that each might suffer from small sample sizes. The changes to the SME/LC definition in 2008 also meant that some companies previously claiming under the LC scheme will now be claiming under the SME scheme. Separate analyses of the two schemes would exclude the companies affected by this change. In this evaluation, we use the variability across companies to strengthen identification of the parameters we want to estimate consistently and take account of the two schemes by calculating a user cost of capital for each company depending on which scheme they have claimed under.

Table B1 summarises the sample sizes in the dataset and available for each of the model specifications we use in our analysis by scheme (LC and SME). Unfortunately, it was not possible to obtain data for all companies for the control variables in the regression. We therefore face a trade off in the identification between running a simpler model with fewer controls but for a larger sample and running a more complex model, with controls for other factors affecting R&D expenditure but with a reduced sample size.

There is another trade-off between sample size and choice of estimator for the price elasticity of R&D expenditure. A pooled OLS model allows us to include every claim made by companies over the period while the A-B estimator, requires companies to claim tax credits continuously for at least three years due to the use of differences and lagged values as regressors. It is important to note that companies claiming continuously over a period might differ in unobserved ways from companies claiming intermittently. As such, there might be self-selection into the sample, and that the A-B estimator will only capture the effect of the user cost of R&D expenditure for companies claiming continuously.

Table B1 Sample size (number of companies in each year) for R&D data and different model approaches

Year	R&D data		OLS		Fixed Effects		A-B estimator	
	LC	SME	LC	SME	LC	SME	LC	SME
2003/04	4,036	840	2,878	697	979	27	969	27
2004/05	3,993	988	2,785	815	1,355	369	1,339	371
2005/06	3,787	1,071	2,557	869	1,472	555	1,474	560
2006/07	4,037	1,187	2,611	941	1,519	614	1,524	620
2007/08	4,601	1,478	2,855	1,139	1,514	636	1,517	641
2008/09	5,462	1,608	3,174	1,239	1,620	660	1,626	660
2009/10	5,861	1,621	3,392	1,239	1,800	737	1,808	737
2010/11	6,641	1,729	3,703	1,323	1,901	812	1,901	811
2011/12	8,033	1,886	4,279	1,410	2,008	850	2,013	851
2012/13	9,715	2,010	4,910	1,494	2,265	912	2,270	914

Variables

B3.2 Dependent variable: Real R&D actual expenditure

Companies report the enhanced R&D expenditure for which they claim tax credit. We strip out the enhancement to get to actual expenditure and convert it into real prices using the GDP deflator at market prices. Financial year 2013/14 is the base year for indexation, although this has no impact on the results.

B3.3 Structural parameter: user cost of capital for R&D expenditure

The coefficient on the user cost of capital for R&D expenditure is the key variable of interest in this study. The user cost of capital is the main explanatory variable we are concerned with – as explained in the structural model in Chapter 6 – and the coefficient on this variable is the basis for the estimate of the price elasticity of R&D expenditure.

To incorporate the effect of R&D tax credits on the user cost of capital for R&D expenditure, we construct the latter variable based on the standard Hall-Jorgensen formula (adopted by Bloom et. al (2002)) for the real user cost of fixed capital:

$$C_{it} = B^*(r_{it} + \delta) \quad (4)$$

where $B = \dfrac{(1-\lambda)}{(1-\tau)}$

is the B-index. The policy component is implemented as tax credit rate, λ and τ represents a statutory corporation tax rate. In the UK, the rate varies according to whether the firm is a SME or LC. The δ stands for the depreciation rate of capital; assumed to be 15 per cent per year in line with the existing literature; and r_{it} stands for the general-purpose financial cost of capital to the firm in general, i.e. it is not specific to the type of investment within the firm. In line with Harris et. Al. (2006), we assume a rate of 10 per cent per annum as an approximation.

$\lambda = (1+\rho)\tau$ represents the reduction in corporation tax liability for each pound of R&D investment, where ρ is the enhancement rate. To calculate the B-index for each company in each period, we first calculate the effective tax credit rate, λ. For a large company that may claim relief for all its qualifying expenditure in a given accounting period (typically one

year) in the form of an enhanced deduction when calculating their taxable profits, the effective tax credit rate in 2012 will have been 130 per cent of 24 per cent, or 31 per cent.

For a SME with a pure deduction claim (i.e. after the enhanced deduction, the company is still in profit), the effective tax credit rate is calculated similarly to the LC calculation using the appropriate rates.

A SME company whose taxable profits are zero after making all relevant deductions may either carry forward their enhanced losses to a future accounting period, or surrender some or all of these enhanced losses in return for a payable credit. For a SME company with a pure credit claim in year 2012 the effective tax credit rate is 11 per cent of 225 per cent, or 25 per cent.

The effective tax credit rate calculation for a combined claim for a SME company is complicated as it depends on the relation between the expenditure on R&D, the net loss and the surrendable loss. As such, there is no generic effective tax credit rate applicable to all combined claims. For these claims we have instead calculated the actual individual effective tax credit rate claim based on the value of the company's expenditure and their loss. This could lead to a simultaneity issue in the identification as the user cost of capital will depend on the expenditure on R&D and the actual expenditure is explained by the change in user cost. However, in 2012-13 only 3,050 claims out of 13,010 total SME claims were combined claims, so we believe this does not invalidate the analysis. Nevertheless, we control for claims of this type in the final specification.

For the 2010 evaluation, the B-index was calculated assuming that Large Companies pay the main rate of corporation tax and SMEs pay the Small Profits rate (SPR). The tax credit rates and corporation tax rates can be seen in table B2.

Table B2 Corporation tax credit rates and R&D tax credit enhancement rates (in percentage points)

	Corporation tax rate			Enhancement rate	
Year	Start	Small Profit	Main	LC	SME
2000/01	10	20	30	-	150
2001/02	10	20	30	-	150
2002/03	0	19	30	125	150
2003/04	0	19	30	125	150
2004/05	0	19	30	125	150
2005/06	0	19	30	125	150
2006/07	-	19	30	125	150
2007/08	-	20	30	125	150
2008/09	-	21	28	130	175
2009/10	-	21	28	130	175
2010/11	-	21	28	130	175
2011/12	-	20	26	130	200
2012/13		20	24	130	225

Internal evidence shows that a significant number of large companies pay the Small Profit Rate (SPR) and a significant number of SMEs pay the main corporation tax rate. We therefore calculate the payable CT rate for each company based on the profits chargeable submitted on the CT600 tax return rather than applying the statutory rate directly.

We apply the actual payable CT rate in the calculation of the effective tax credit rate and the user cost of capital. For loss-making companies, however, it does not make sense to apply a CT rate of 0 per cent, as the relevant rate for economic decisions is the one they would have paid were they loss-making. LCs can carry their losses forward to claim the deduction in future years and SMEs can claim payable credit. For the loss-making companies, we therefore assume that LCs would pay the main rate and SMEs would pay the SPR.

B3.4 Non-tax determinants of R&D

The main aim of the analysis is to isolate and consistently estimate the effect of the user cost on R&D expenditure. To do so, we include other control variables in the regression. These are variables that capture other reasons for variability in the investment decisions of companies and which allow us to isolate the various structural characteristics of each company. The control variables are included in our dataset are presented below:

Turnover: this controls for the firm's general ability to invest, as this depends on its ability to generate revenues from sales. In the A-B model, we assume that turnover is endogenous

Number of employees: this controls for the size of the company, which influences the overall level of R&D expenditure.

Profit: real profits before tax are assumed to be a highly important factor in a firm's decision about its investment in general. In the R&D tax credit scheme it affects whether the firm can claim enhanced deduction or payable credit. We use profit to create indicator variables for whether the company is profit-making or loss-making and, within each of the two categories, under which option of the scheme it claims[14]. These company type controls are important for our results.

Liquidity ratio: this influences a firm's ability to pay off its short-term debt obligations, and therefore its ability to spend money on R&D expenditure on a short-term basis. It is calculated as current assets divided by current liabilities.

Credit constraints proxy: this is intended to capture the ease of firms obtaining capital, and it is particularly important in the wake of the financial crisis as many businesses struggled to get access to finance. This could mean that the effect of the R&D tax credits is getting 'drowned out' by the effects of the financial crisis.

We have therefore looked at ways to control for the effect of the financial crisis in our modelling by including a series calculated as the sum of a risk free interest rate (as measured by the yield on 10-year gilts) and the spread on non-financial BBB-rated corporate debt. This is intended to be a more responsive series to changes in credit conditions than the real interest rate, which is often highly influenced by monetary policy. The spread for corporate debt, on the other hand, is not directly affected by monetary policy, meaning that it is a truer reflection of lending conditions in the market.

Growth in gross value added at industry level: this controls for industry-specific effects, and it measures the growth in GVA at industry level (SIC 2007 code)

[14] Profit making SMEs should not be able to claim the payable credit. However, the profit variable used to identify profit/loss is the FAME variable profit before real tax which does not necessarily correspond to taxable profit. We identify 5,871 claims of this type over the period 2004/05 - 2012/13 and have excluded them from the analysis.

High-tech/low-tech firms: this controls for whether the company is a high technology company according to the OECD definition where a high tech company spends more than 4 per cent of its turnover on R&D. Recent literature has identified differential effects of R&D on high- and low-tech firms.

Time controls: In the OLS model we seek to capture common technology shocks and other time-variant common effects by including time dummies. In the differenced models, we include a shift dummy in year 2008/09 to control for the changes to SME definition (allowing previously LCs to claim under the more generous SME scheme).

B3.5 Descriptive statistics of the dataset

The summary statistics in B3 show that R&D expenditure presents with skewness (high concentration of firms with low R&D expenditure) and excess kurtorsis (high peaks in the distribution). In line with common practice, we have transformed it using logs which mitigates the issue.

Table B3 Summary statistics for R&D expenditure

	R&D expenditure	Log R&D expenditure
Observations	78,322	78,322
Sample mean	538,953.2	11.89
Sample standard error	1,472,138	1.47
Sample variance	2.17×10^{12}	2.16
Sample skewness	6.18	0.6
Sample kurtosis	50.86	3.05

It is possible to estimate the model in either double-log – that is, taking logs of both R&D spend and the user cost of capital – or log-linear form – i.e. taking the log of R&D spend but not of user cost. A double-log specification is also referred to as isoelastic specification, as it implies that the elasticity remains constant along the demand curve. The double-log model can also be interpreted as a transformation of a Cobb-Douglas function, which has constant elasticities and it is therefore a widely used econometric specification.

The main advantage of this specification is that (particularly for static models) it allows us to directly obtain elasticity estimates with no transformation required; the elasticity estimates are the estimates of the coefficients of the model. In the log-linear form, the elasticity depends on the level of price (in this case, the user cost of capital), and we usually estimate the elasticity at the average user cost of capital. The double-log specification is usually favoured when the range of variation in both variables is not very large. In our dataset, however, there is large variation in R&D expenditure, and so we use the log-linear specification as our preferred model for the OLS and A-B estimator, preferring the double-log specification only for the FE model for reasons of stability of the coefficients.

B4. Estimation results

B4.1 Preferred model specification

As mentioned in section B.2, the A-B model can become unstable if it is over-specified, that is, if there are too many controls and endogenous variables. Using the staged approach of estimating a static pooled OLS, a dynamic fixed effect and a dynamic GMM model can be informative, but caution should be exerted in terms of how much weight we put on the size of the coefficients. If there are firm-specific effects, then the pooled OLS estimator is

inconsistent, and instead the within (FE) estimator should be used (Cameron et al., 2010). The FE model eliminates fixed effects but relies on the unrealistic assumption of exogeneity of all regressors, which is unlikely to hold in a dynamic setting. The A-B model uses consistent estimators by IV estimation of the parameters in the first-differenced model, using appropriate lags of regressors as instruments. We therefore expect the different models to produce different estimates.

We present in table B4 the elasticities for our preferred model specification for the three different estimators used (OLS, FE and A-B) and compare the elasticities to those obtained from the models without controlling for the change in credit conditions. All elasticities are significant at a 1 per cent level and the A-B model passes both misspecification tests (Arellano-Bond test for zero auto correlation in first-differenced errors and Sargan test of overidentifying restrictions).

Table B4 Elasticity of user cost with respect to R&D expenditure

	OLS	FE	A-B
Model excluding credit conditions	-0.67	-0.55	-1.09
Model including credit conditions	-0.67	-0.56	-1.96

As predicted by economic theory, the estimates for the elasticity are negative in all models. This means that a decrease (increase) in the user cost of capital for R&D leads to an increase (decrease) in the expenditure on R&D. This verifies the intuition that using tax credits to decrease the user cost of R&D can significantly increase R&D expenditure.

The OLS and FE estimates are less elastic, and this is a consequence of the attenuation bias that these estimators suffer from if there is endogeneity; this essentially means that the OLS and FE estimators will not capture as much variation as estimators that take this endogeneity into account, and as such they will produce estimates closer to zero. As A-B is an instrumental variables model that explicitly captures endogeneity, we would expect the estimates to be further away from zero, and this is corroborated by the more elastic estimates in table 8-1. Controlling for credit constraints is found to be very important in the A-B model and changes the elasticity from -1.09 to -1.96. Further robustness testing conducted on the A-B model by changing covariates and numbers of lags resulted in similar estimates, ranging from around -2 to around -1.5.

In general, the estimates obtained from the preferred specification are in all cases in line with economic intuition and well within the literature range, with more elastic estimates from the instrumental variables specifications, as would expected given the properties of the estimators.

B4.2 Converting elasticity to additionality ratios

The additionality ratio is calculated as the additional spending on R&D from an increase in the tax credit over the additional cost in foregone tax revenue. Although this is sometimes referred to in the literature as the benefit/cost ratio, it is worth noting that it is not equivalent to a full cost-benefit analysis that the Government would undertake to appraise a policy proposal and for which we would follow the guidelines in the Green Book. Such analysis would require consideration of the value of the positive externalities of R&D investment, as well as the opportunity cost of the investment. Instead, the additionality ratio is inferred from the estimated elasticity. All else being equal, we can calculate the change in the user cost from a change in the tax credit rate and the associated change in R&D expenditure using the elasticity estimate.

The ratio is also called the incrementality ratio, tax sensitivity ratio or 'bang for the buck' ratio, which perhaps is more appropriate, given that it does not take account of all the costs (such as administration, crowding out) and benefits (social returns on R&D) of the R&D tax credit. Table B5 illustrates how to the additionality ratio is calculated for a LC in 2012/13 based on the elasticity from the A-B model. The example illustrates the change in R&D expenditure from changing the LC enhancement rate by one percentage point from 130 to 131.

Table B5 Example of an additionality ratio calculation for LC in 2012/13 paying main CT rate

	Before tax credit change	After tax credit change	Change
Enhancement rate	1.30	1.31	0.01
CT rate	0.24	0.24	-
User cost	0.2263	0.2255	-0.3%
% change in R&D			-0.3 x -1.96 = 0.68%
Increase on £100 investment in R&D	100	100.68	0.68
Exchequer cost of £100 investment	0.30 x 0.24 x 100 = 7.20	0.31 x 0.24 x 100 = 7.49	0.29
Additionality ratio			0.68 / 0.29 = 2.35

The additionality ratio for LC is 2.35. This indicates that £2.35 of R&D expenditure is stimulated for every £1 of tax forgone, i.e. the R&D expenditure increases more than proportionally in relation to the cost of providing the tax credit for LC. For a SME enhanced deduction claim the additionality ratio is 1.88, while a SME credit claim generates a ratio of 1.53. We thus find that for UK companies the additionality ratios indicate that between £1.53 and £2.35 of R&D expenditure might be stimulated by £1 of tax forgone. From the literature review, we know that, internationally, additionality ratios range from around 0.3 to around 3.

B4.3 Robustness checks and alternative specifications

Table B6 shows the coefficient estimates for all the control variables in our three preferred model specifications. Our preferred model specification for the A-B model included one lag of the dependent variable as regressor and maximum of two lags as instruments, the proxy for the credit condition, shift dummy and company type controls were included as exogenous variables; user cost and turnover with two lags were included as endogenous variables with max two lags as instruments and liquidity ratio was included as a predetermined variable with max two lags as instruments. This amounted to a total of 100 instruments and 16,228 observations across 4,685 firms. The final model equation can thus be written as:

$$\begin{aligned}\Delta \ln \mathrm{R\ \&\ D\_exp}_t &= \alpha + \beta_1 \Delta \mathrm{usercost}_t + \beta_2 \Delta \mathrm{usercost}_{t-1} + \beta_3 \Delta \mathrm{usercost}_{t-2} \\ &+ \delta_1 \Delta \ln \mathrm{turnover}_t + \delta_2 \Delta \ln \mathrm{turnover}_{t-1} + \delta_3 \Delta \ln \mathrm{turnover}_{t-2} \\ &+ \phi \Delta \ln \mathrm{R\ \&\ D\_exp}_{t-1} + \gamma_1 \Delta \mathrm{liquidity\_ratio}_t + \gamma_2 \Delta \mathrm{cdebt\_infl}_t \\ &+ \gamma_3 \Delta \mathrm{dum2009}_t + \gamma_4 \Delta \mathrm{loss\_comb}_t + \gamma_5 \Delta \mathrm{loss\_ded}_t + \gamma_6 \Delta \mathrm{profit\_comb}_t\end{aligned}$$

$$+\gamma_7 \Delta \text{profit\_ded}_t + \gamma_8 \Delta \text{lc}_t + u_t$$

Note, that the coefficient on user cost (i.e. the differenced user cost at *t* and *t-1*) is not significant but the first lag of user cost is. We are not concerned with the significance of user cost at the individual level, but instead with the joint significance of the user cost, which is significant at 0.1 per cent level.

The coefficient on the proxy for credit conditions is positive, while the coefficient on the regime shift dummy in 2008-09 is negative (not shown). This can seem counterintuitive, but can be caused by difficulties in separately identifying the two variables correctly. The changes to the definition of SMEs (which the shift dummy should control for) took effect immediately prior to the financial crisis. It is possible that the two effects cannot be controlled for separately by the two variables.

The price elasticity of R&D expenditure with respect to the user cost of capital is calculated by capturing the full impact of the user cost on R&D expenditure, including all the lags explicitly captured in the regression equation. To convert the coefficients into an elasticity, we take the derivative of R&D expenditure with respect to the user cost ($\beta_1 + \beta_2 + \beta_3$) and then multiply it by the average first difference in user cost for each lag in order to obtain the average marginal effect.

$$\varepsilon_{\text{usercost}}^{\text{R\&D\_exp}} = \frac{\partial \Delta \ln \text{R \& D\_exp}}{\partial \Delta \ln \text{usercost}} = \frac{\partial \Delta \ln \text{R \& D\_exp}}{\frac{\partial \Delta \text{usercost}}{\Delta \text{usercost}}} = \frac{\partial \Delta \ln \text{R \& D\_exp}}{\partial \Delta \text{usercost}} \times \Delta \text{usercost}$$

Table B6 Coefficient estimates for preferred model specification

	OLS	FE[a]	A-B
User cost of capital	-3.16***	-0.55***	-1.80
Lagged user cost	-	-	-6.67**
2nd Lagged user cost	-	-	-0.66
Log Turnover	0.39***	0.13***	-0.05
Lagged log turnover	-	-	-0.04
2nd Lagged log turnover	-	-	0.03
Lagged log R&D spend	-	-0.22***	0.16***
Log Employees	0.28***	0.21***	-
High tech	1.74***	0.80***	-
Liquidity ratio	0.02***	0.00	0.01
GVA growth per industry	1.52***	-	-
Proxy for credit conditions	0.03***	0.01***	0.03***
Time controls	Year dummies	Shift 2008/09	Shift 2008/09
Company type controls	Yes	Yes	Yes
Constant	5.22***	-	13.25***
Joint coefficient of user cost[b]	-	-	-9.13***
User cost elasticity	-0.67***	-0.55***	-1.96***

[a] The fixed effect model is estimated using first-differences in all variables and using ln user cost. The coefficient on user cost is therefore the elasticity

[b] Only relevant for the A-B estimator, due to the lags on the user cost. This is used as the basis for the marginal effects calculation from which we derive the elasticity.

The results from the misspecification test can be seen in table B7. We reject serial autocorrelation of order 1 for a significance level of 0.1 per cent, but do not reject at higher orders as expected. 83 instruments were used to estimate 16 parameters, so there were 67 over-identifying restrictions. We cannot reject the hypothesis that the population moment conditions are correct so the model passes this misspecification test.

Table B7 Results from misspecification tests on the A-B model

Arellano-Bond test for zero auto correlation in first-differenced errors			Sargan test of overidentifying restrictions (H_0: restrictions are valid)		
Order	Test statistic under H_0	p-value	Distribution of test statistic	Test statistic under H_0	p-value
1	-10.11	<0.001	$\chi^2(67)$	61.752	0.658
2	1.15	0.251			
3	-1.20	0.230			

To test the robustness of the results to the specification of the model, we have tested a number of alternative specifications. These include:

(i) Testing the sensitivity of the preferred specification of the A-B model to changes in the number of instruments;

(ii) Testing the sensitivity of the estimates from all three models to the choice of control variables included;

(iii)Testing the sensitivity of the estimates to the choice of period included (pre-financial crisis vs. post-financial crisis).

Regarding (i) the sensitivity of the A-B model with respect to changes in the number of instruments, we tested eight models with different numbers of lags and max lags of exogenous, endogenous and predetermined variables. We found the elasticity estimates to range between -1.68 and -2.06, with our preferred model elasticity of -1.96 yielding estimates in the middle of the range. The only model that did not pass the test of zero autocorrelation was a model that only included one lag of the endogenous regressors. All models passed the Sargan test and all elasticities were significant at the 1 per cent level.

Regarding (ii), the estimated elasticities from the OLS model ranged from -2.23 in the most simple model including only the user cost of capital, time dummies and the company type dummies to -0.67 in our chosen model specification. The fixed effects model produced elasticities ranging from -0.83 in a simple model including only lagged R&D spend, user cost, shift dummy and company type dummies to -0.55 in our chosen model specification. And finally, the elasticities from the A-B model ranged from -1.96 from our preferred model specification to -0.93 in a very simple model including only user cost, a shift dummy and company type dummies. Furthermore, we included an indicator for whether the company was in the high growth (top 25 percentile in terms of turnover growth), medium growth (between 25th and 50th percentile) or low growth (bottom 25 percentile) segment. This did not significantly alter the elasticity estimates.

With respect to (iii), running the preferred A-B model for the post financial crisis period 2008/09 to 2012/13 produced an elasticity of -1.60 (significant at 1 per cent level), while running the model for the pre financial crisis 2003/04 to 2007/08 produced and insignificant elasticity of -1.54. However, when we dropped the two lags of the endogenous variables and thereby increased the number of observations in the regression for the pre financial crisis

period we found an elasticity of -7.12 significant at 1 per cent level. We would, however, be concerned about the robustness of this estimate for the pre-crisis period only, as the sample is smaller and it is not as well aligned with all the other estimates we have obtained.

As shown above, we have run a significant number of variations of the model, and have obtained consistent results across specifications. We therefore feel confident that the results are robust to the choice of specification.

B5. References

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