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Evaluation of the Research and Development Expenditure Credit (RDEC)

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Abstract

This report studies the effectiveness of the Research and Development Expenditure Credit scheme (RDEC), which is designed to incentivise greater business investment in Research and Development (R&D). We estimate the user cost elasticity of R&D through econometric regressions before deriving the additionality ratio of the scheme. Our preferred econometric model suggests an additionality ratio between 2.4 and 2.7. The estimated cost of RDEC for 2017-18 was £2.4bn, which means RDEC could have stimulated between £5.8bn and £6.5bn of additional R&D expenditure for that year. This evaluation only focuses on the intensive margin, which is the additional R&D expenditure among businesses already claiming the relief. This does not include new claims nor 'spillover' benefits for the wider economy. As such, the additionality ratio is not a complete measure of the relief's effectiveness.

Acknowledgements and disclaimer

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Table of contents

Introduction

1. This report studies the effectiveness of the Research and Development Expenditure Credit scheme (RDEC). RDEC is one of the two UK Corporation Tax reliefs designed to incentivise greater business investment in Research and Development (R&D). RDEC was introduced in April 2013 and gradually replaced the Large Company (LC) scheme which was abolished in 2016-17. The UK also has the Small and Medium Enterprise (SME) scheme, which offers more generous relief for SMEs.

2. HMRC has already evaluated designs of the SME and LC schemes (HMRC, 2010; HMRC, 2015; HMRC, 2019). This study provides the first insights on the effectiveness of the RDEC scheme.

3. We follow the two-step approach from previous HMRC evaluations and routinely used in the literature. This consist in estimating the user cost elasticity of R&D through econometric regressions, before deriving the additionality ratio of the scheme[1]. We exploit administrative data from the Corporation Tax return (form CT600) supplemented with accounting information from Financial Analysis Made Easy (FAME).

4. Our preferred econometric model estimates a user cost elasticity between -2.5 and -2.9 which suggests an additionality ratio between 2.4 and 2.7. The latest National Statistics (HMRC, 2020) estimated the cost of RDEC for 2017-18 was £2.4bn on an accruals basis, based on the results from the Fixed Effects (FE) models RDEC could have stimulated between £5.8bn and £6.5bn of additional R&D expenditure for that year. These results are robust in removing subcontracting claims and the running of models on the unbalanced panel data.

5. Our findings are consistent with those found in previous studies for the UK and neighbouring countries. They suggest the additionality ratio of RDEC is very close to that of the former LC scheme, estimated around

[1] The user cost elasticity of R&D measures the change in R&D expenditure (as a percentage) when the cost of doing R&D changes by one percent. The additionality ratio is a measure of additional R&D expenditure generated for each additional pound of tax foregone.

2.35 (HMRC, 2015). It is larger than the SME scheme and the French and Belgium schemes.

6. This evaluation only focuses on the intensive margin, which is the additional R&D expenditure among businesses already claiming the relief. This does not include new claims nor 'spillover' benefits for the wider economy. As such, the additionality ratio is not a complete measure of the relief's effectiveness.

7. In the next section we provide an overview of the policy context. In the following section we review the related literature. The next two sections describe our data and present some summary statistics. After that, we explain our methodology, present our results and perform robustness checks. We finally discuss our findings before concluding.

Policy background

8. Research and Development refers to activities undertaken by businesses to innovate and seek an advancement in their field. Without additional incentives, such activities tend to receive sub-optimal business investment as the social benefits exceed private returns, for example through knowledge spillovers (HM Treasury, 2018). Tax reliefs are a useful instrument to address this market failure, as they lower the cost of undertaking R&D to better align the private returns with the social benefits.

9. R&D tax credits for Corporation Tax (CT) were introduced for SMEs in 2000 and extended to large companies from 2002. The UK currently has two R&D tax relief schemes[2], which are intended to boost productivity and hence economic growth.

10. In 2018 R&D expenditure in the UK represented 1.71% of GDP; this is up from 1.67% in 2017. The UK's Industrial Strategy committed to increase total R&D expenditure to 2.4% of GDP by 2027[3].

11. The SME R&D Relief allows SMEs to deduct an extra 130% of their qualifying costs from their yearly profit, as well as the normal 100%

[2] https://www.gov.uk/guidance/corporation-tax-research-and-development-rd-relief
[3] https://www.ukri.org/about-us/increasing-investment-in-r-d-to-2-4-of-gdp/

deduction, to make a total 230% deduction. Loss-making SMEs can also claim a credit worth up to 14.5% of the surrenderable loss[4].

12. The Research and Development Expenditure Credit (RDEC) was introduced in April 2013, and gradually replaced the Large Company (LC) scheme that was abolished in 2016-17. It can also be claimed by SMEs who have been subcontracted to do R&D by a Large Company. RDEC is a tax credit which has increased from 12% to 13% of qualifying expenditure since 1 April 2020. When introduced in 2013 the rate was 10%, which increased to 11% in 2014 and then again to 12% in 2017. The credit is itself subject to the CT main rate (19% since 2017-18). The main difference between RDEC and the LC scheme is that loss making companies can claim credits under the RDEC scheme, whereas only profit-making companies could benefit from the LC scheme.

13. HMRC publishes National Statistics for R&D tax credits which include their cost, and the nature of the companies claiming them[5]. In 2017-18, there were 8,085 RDEC claims with a corresponding cost of £2.4bn, as shown in Table 1 below.

Table 1– Key RDEC statistics

	2015/16	2016/17	2017/18
Number of claims	5,650	7,575	8,085
Cost (£bn)	2.2	2.2	2.4

Related literature

14. There is a rich literature that has investigated the effectiveness of R&D reliefs. The prevalent approach consists in estimating the effect of the user cost of capital on R&D expenditure, (like a price elasticity of demand) in order to derive an additionality ratio. This is a measure of additional R&D expenditure generated for each additional pound of tax foregone.

15. HMRC summarised the existing evidence in previous evaluations of the UK R&D schemes (HMRC, 2015; HMRC, 2019). This review will therefore

[4] The SME scheme was also evaluated by HMRC in 2019.

[5] https://www.gov.uk/government/statistics/corporate-tax-research-and-development-tax-credit

focus on only the findings that are most relevant to RDEC and recent evidence which wasn't captured in previous evaluations. For simplicity and conciseness, we only report the additionality ratios.

UK Government evaluations

16. HMRC (2010) evaluated the earliest design of the SME and Large Company (LC) schemes covering the period 2003-07. The study shows a wide range of additionality ratios that indicate that up to £3 of R&D expenditure might be stimulated by £1 of tax foregone.

17. HMRC (2015) refreshed and extended the evidence on the SME and LC schemes from 2003 to 2013. The study finds an additionality ratio of 2.35 for the LC scheme, 1.88 for SME deduction claims and 1.53 for SME credit claims.

18. The first two HMRC evaluations derived additionality ratios from user cost elasticities estimated from a mix of LC and SME scheme claims. There is 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 are more able to access capital markets and bank loans (HMRC, 2015; Dechezleprêtre et al., 2019). This suggests that evaluations should avoid estimating the user cost elasticity on a mix of small and large companies to allow for heterogeneous responses.

19. HMRC (2019) takes that recommendation into account to update the evidence on the effectiveness of the SME scheme, as the evaluation is based only on companies claiming under that scheme between 2000 and 2017. This study reports an additionality ratio ranging from 0.75 to 1.28 for deduction claims and 0.6 to 1.00 for credit claims.

Academic and foreign research

20. The UK SME scheme was also recently investigated by Guceri and Liu (2019) by exploiting a change in the definition of an SME, which allowed companies with between 250 and 500 employees to claim for that scheme. Their differences in differences approach suggests that £1 of tax foregone generates between £1 and £1.50 of additional R&D.

21. Dechezleprêtre et al. (2019) exploit the same policy change, which expanded the eligibility to access the SME relief, and implement Regression Discontinuity design to estimate an additionality ratio of 2.9 for credit claims, 3.9 for deduction claims and 1.5 for LC claims.

22. Some evidence on the effectiveness of the French and Belgium R&D tax relief schemes was recently published. Bozio et al. (2019) evaluated the French scheme based on data from 2004–2010. They estimate an additionality ratio between 1.1 and 1.5. Dumont (2019) explored the effectiveness of the Belgium scheme and finds an additionality ratio of 0.22. Table 2 summarises the literature reviewed in this paper.

Table 2 Summary of related literature

Study	Country	Scheme	Period	Approach	Additionality ratio
HMRC, 2010	UK	LC and SME	2003-2007	Arellano-Bond	0.9 to 1.2 (LC) 0.4 to 1.4 (SME scheme)
HMRC, 2015	UK	LC and SME	2003-2012	Arellano-Bond	2.35 (LC) 1.88 (SME deduction) and 1.53 (SME credit)
HMRC, 2019	UK	SME	2000-2017	Arellano-Bond	0.75 to 1.28 (SME deduction) 0.60 to 1.00 (SME credit)
Guceri and Liu, 2019	UK	SME	2002-2011	Differences-in-Differences	1 to 1.5
Dechezleprêtre et al., 2019	UK	LC and SME	2006-2011	Regression Discontinuity Design	1.5 (LC) 3.9 (SME deduction) 2.9 (SME credit)
Bozio et al., 2019	France	French scheme	2004–2010	Differences-in-Differences	1.1 to 1.5
Dumont, 2019	Belgium	Belgium scheme	2003-2015	Selection model	0.14 (mean) 0.22 (median)

Data

23. This evaluation is mainly based on the analysis of administrative data from the Corporation Tax return (form CT600), supplemented with accounting information from Financial Analysis Made Easy (FAME). We also generate the user cost of R&D, which value depends on the R&D scheme and whether the company is profit or loss-making.

RDEC and LC Claims

24. We use RDEC and Large Company (LC) claims data from 2010-11 to 2017-18 (8 years) received by HMRC up to June 2019. LC claims allow a sufficiently long time series for the evaluation at the expense of a slightly less specific population. We compared the characteristics of companies claiming each scheme in Annex 5.

25. The CT return (form CT600) 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, Large Company or RDEC scheme, and declare any expenditure they are claiming under the SME sub-contractor or vaccines research relief scheme, if applicable.

Additional Corporation Tax data

26. We include additional information on the companies' profit from the Corporation Tax return. Our preferred measure of profit is the trading profit reported in box 155 of the CT600 return, as it comes directly from HMRC's administrative data. We use trading profit to determine whether a company is profit-making or loss-making as this affects its user cost of R&D. There are about a third of company-year pairs where the observation for trading-profit is missing. After comparing the trading profit variable against the profit variable from FAME, we decided to treat these company-year pairs as loss-making as this was the most consistent approach across the two data sources (see Annex 2).

Additional financial information from FAME

27. We also match additional financial and accounting information from FAME. This includes measures for the number of employees and turnover which we use to control for the companies' size; the liquidity ratio which is used as an indicator of financial health; and a measure of profit which we use to check the consistency with the information reported in the CT600 return.

User cost of R&D – main explanatory variable

28. We generate the gross[6] user cost of R&D which measures the unit cost for the use of an R&D capital asset for one period. The formulas set-out in Table 3 and derived in Annex 1 depend on the Corporation Tax and RDEC or LC rates that applied in a given year, the depreciation and interest rates[7], and whether the company is profit or loss-making (Creedy & Gemell, 2015; HMRC, 2015; HMRC, 2019). For companies who claim both RDEC and LC in the same year, we take the weighted average based on qualifying expenditure used for each claim.

Table 3 User cost of R&D

Scheme	User cost	User cost for 2017-18
RDEC for a profit-making company	$(1 - s).(r + \delta)$	0.222
RDEC for a loss-making company	$[1 - s.(1 - t)].(r + \delta)$	0.227
Large Company	$\frac{1-(1+\alpha)t}{1-t}.(r+\delta)$	0.232[8]

Parameters (and values for 2017-18):

- Real interest rate r (10%)
- Capital depreciation rate δ (15%)
- Corporation Tax rate t (19%)
- RDEC rate s (the rate was 11% until 31 December 2017 then 12% from 1 January 2018 so we assume a value of 11.25% for that year)
- Enhancement rate for the Large Company scheme α (30%[8])

Data cleansing

29. We apply the methodology set-out in our National Statistics publication to derive the R&D expenditure and tax cost, and to also carry-out the same quality assurance checks to remove errors and outliers[9]. We

[6] The difference between gross and net user cost is whether depreciation is included or not. This means the discount rate for the gross user cost is (r+δ) while the discount rate for the net user cost is (r+δ) – δ = r.

[7] We assume the depreciation rate and interest rate are constant over time and set respectively at 15% and 10% which is consistent with previous evaluations (HMRC, 2015; HMRC, 2019).

[8] The scheme was abolished in 2016-17 so this is the value of the user cost if the scheme had still existed in 2017-18.

[9] https://www.gov.uk/government/statistics/corporate-tax-research-and-development-tax-credit

also apply additional data cleansing for the specific purpose of this econometric evaluation and in line with previous ones.

a) We balance the panel by only keeping companies who are claiming for at least 6 consecutive years to avoid any composition effects of companies who quickly enter then leave the claiming population (Bozio, Cottet, & Loriane, 2019).

b) We apply the log transformation to R&D expenditure to address the wide dispersion of this measure (HMRC, 2015; HMRC, 2019).

c) We remove the top and bottom 1% of claims to further address the large dispersion of the expenditure variable.

30. Because of this additional data cleansing, the data is not entirely consistent with HMRC's National Statistics. Moreover, the data in this report for years prior to 2014-15 will pick-up some additional cases that were not incorporated into the 2019 National Statistics. This is because HMRC improved their data-source and methodology but have only revised the published statistics from 2014-15 onwards.

Summary statistics

31. We produce some summary statistics on the data which has not had additional cleansing for econometrics for each year, which is unbalanced and has not had the top and bottom 1% of claims removed.

32. These figures may differ slightly from the most recent National Statistics publication (HMRC, 2020), especially for the two most recent years as the National Statistics include claims received by HMRC up to June 2020 while the data for this evaluation contains claims received up to June 2019. Note also that the figures presented below only include the latest claim for businesses that claimed several times within a given year.

33. Table 4 focuses on the R&D claims relating to the LC and RDEC schemes. The number of claims increased from 2,440 in 2010-11 to 6,384 in 2016-17. The strong growth over this period can largely be explained by the introduction of RDEC in 2013-14 and subsequent rate increases which made RDEC more attractive. The slight fall in 2017-18 reflects the

fact that some claims had not yet been received by HMRC. The next rows report the mean and total value of R&D expenditure and tax support.

Table 4 Summary statistics for R&D claims

	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Number of companies with an RDEC or LC claim	2,440	2,601	3,409	4,920	5,357	6,182	6,384	6,125
As a percentage of claims in the National Statistics	*98%*	*98%*	*115%*	*131%*	*93%*	*94%*	*84%*	*76%*
Mean R&D expenditure (thousand £'s)	3,430	3,633	3,507	3,195	3,802	3,756	3,717	3,624
Total R&D expenditure (million £'s)	8,370	9,446	11,951	15,672	20,323	23,153	23,732	22,199
Mean cost of support (thousand £'s)	287	293	257	237	293	317	327	327
Total cost of support (million £'s)	700	762	876	1,165	1,567	1,951	2,085	2,000

34. Tables 5a to 5d present some summary statistics for the other variables from the CT returns and FAME as well as the user cost variable which we constructed for this study. Annexes 2 and 5 also contain additional statistical information on the split between profit and loss-making companies and the characteristics of companies claiming LC and RDEC.

Table 5a User cost of R&D summary statistics

User cost of R&D	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Observations	2,440	2,601	3,409	4,920	5,357	6,182	6,384	6,125
mean	22.1%	22.4%	22.7%	22.7%	22.8%	22.6%	22.5%	22.5%

Table 5b Turnover summary statistics

Turnover	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Observations	2,436	2,594	3,399	4,909	5,348	6,167	6,371	6,102
mean (million £'s)	188	171	228	185	201	171	173	172

Table 5c Number of employees summary statistics

Employees	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Observations	2,404	2,560	3,368	4,880	5,319	6,124	6,321	6,069
mean	605	527	581	551	541	570	605	503

Table 5d Liquidity ratio summary statistics

Liquidity ratio	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Observations	2,359	2,510	3,326	4,781	5,214	5,982	6,216	5,961
mean	1.8	1.9	1.9	1.8	1.9	1.9	1.9	2.1

Methodology

35. The evaluation strategy is broken down into two steps. The first step estimates the user cost elasticity of R&D; that is by how much R&D expenditure will increase (in percentage) when the cost of doing R&D falls by 1%. In the second step we apply the elasticity to the user cost and simulate a 1 percentage point change to the RDEC rate to estimate the additionality ratio. This is a measure of additional R&D expenditure generated for each additional pound of tax foregone.

User cost elasticity

36. We follow HMRC (2015) and HMRC (2019) by estimating the user cost elasticity through three econometric techniques, starting from the simplest model and progressively adding complexity: Ordinary Least Squares (OLS), Fixed Effects (FE) and Arellano-Bond (AB).

Ordinary Least Squares

37. For the pooled OLS regressions, we assume demand for R&D is determined as:

$$(1)\ Y_{it} = \beta_0 + \beta_1 C_{it} + \theta' X_{it} + \varepsilon_{it}$$

Where Y_{it} denotes R&D expenditure for company *i* and time *t* (measured in log), C_{it} is the user cost, X_{it} is a set of controls for size (measured by the number of employees and turnover) and financial health (measured by the liquidity ratio) and ε_{it} is the error term. β_0, β_1 and θ' are the regression parameters and β_1 is the main outcome of interest as it measures how demand for R&D responds to changes to the user cost.

Fixed Effects

38. FE regressions allow us to control for any unobserved company-level characteristics that could potentially bias the results, as long as they are constant over time. For the FE regressions, we assume demand for R&D is determined as:

$$(2)\ Y_{it}^{*} = \beta_1 C_{it}^{*} + \theta' X_{it}^{*} + \varepsilon_{it}^{*}$$

Where for instance $Y_{it}^{*} = Y_{it} - \overline{Y}_{i}$ and $\overline{Y}_{i} = \frac{1}{T}\sum_{t}^{T} Y_{it}$. The other variables are defined in the same way and their definitions are consistent with the OLS model.

Arellano-Bond

39. AB (Arellano & Bond, 1991) is part of the General Method of Moment (GMM) class of models that assume a dynamic relationship in the outcome variable. This means that it assumes that current R&D expenditure is determined by previous levels. AB combines the first-difference transformation (to remove unobserved firm-level heterogeneity) and the use of instrumental variables (to address dynamic panel bias and simultaneity):

$$(3)\ \Delta Y_{it} = \gamma_1 \Delta Y_{i,t-1} + \beta_1 \Delta C_{it} + \theta' \Delta X_{it} + \Delta u_{it}$$

Where Δ is the first-difference operator; and u_{it} is the idiosyncratic error term.

Additionality ratio

40. Having estimated the user cost elasticity through the three econometric approaches, we derive the additionality ratio by simulating a one percentage point increase in the generosity of RDEC (from 12% to 13%). This has a knock-on impact on the user cost and the user cost elasticity allows us to estimate the change in the demand for R&D, and the corresponding change in Exchequer cost. The ratio of the two figures is the additionality ratio.

41. As the user cost of R&D depends on whether the company is making a profit or a loss, we weigh the results according to that split (67% of companies make a profit and 33% make losses, see Annex 2). Annex 3 presents the steps to compute the additionality ratio for both profit and loss-making companies.

Limitations

42. The strengths and weaknesses of each model are discussed in more detail in HMRC (2019) and can be summarised as follows:

a) OLS is appealing as it is the simplest model to run and interpret but the estimates may suffer from omitted variable biases.

b) FE is an improvement from OLS as it controls for any time-invariant, unobserved company-level characteristics. However, neither OLS nor FE perform well if we assume that current R&D expenditure is determined by its past values.

c) AB can robustly estimate models with a dynamic relationship in the dependant variable. However, both FE and AB impose more restrictions on the data as they require companies to be claiming for consecutive years. To address this last point, we impose the same restrictions on the data for all three approaches (see Data cleansing section).

43. Our approach to estimate the user cost elasticity assumes the same responsiveness from companies claiming LC and RDEC, and that any factor affecting the user cost triggers the same change in R&D expenditure. In practice, companies may be more responsive to changes in the CT or RDEC rate than changes to the depreciation rate, which would be more difficult to observe.

44. This evaluation only focuses on the intensive margin which is the additional R&D expenditure among businesses already claiming the relief. This does not include new claims nor 'spillover' benefits for the wider economy. As such, the additionality ratio is not a complete measure of the relief's effectiveness.

Results

User cost elasticity

45. Results from the econometric models are reported in Annex 4. The OLS approach yields the highest user cost elasticity which ranges from -19.3 to -21.5 depending on the model. FE produces the most central estimate between -2.5 and -2.9. Results from the AB models range between -1.7 and -2.8.

46. All three approaches find a negative relationship between the user cost and R&D expenditure, which is what economic theory predicts as

demand tends to have a downward sloping curve with respect to prices. They are also robust in including additional controls for the company size (measured by turnover and the number of employees) and the liquidity ratio.

47. Our OLS results are likely inflated by omitted variable biases. Our preferred results are those from the FE models as they produce the most central estimates.

Additionality ratio

48. Table 6 presents the additionality ratios derived from the user cost elasticities. As explained in the data and methodology sections, the user cost varies depending on whether the company is making a profit or a loss, so we compute the additionality ratio for each case to produce the weighted average (67% of companies make a profit and 33% make losses, see Annex 2).

Table 6 User cost elasticity and additionality ratio

	OLS	FE	AB
User cost elasticity	**-19.3 to -21.5**	**-2.5 to -2.9**	**-1.7 to -2.8**
Additionality ratio for companies making a profit	7.03 to 7.19	2.53 to 2.87	1.98 to 2.78
Additionality ratio for companies making a loss	6.57 to 6.75	2.12 to 2.42	1.63 to 2.34
Weighted average	**6.88 to 7.04**	**2.39 to 2.72**	**1.86 to 2.63**

49. The additionality ratios derived from OLS models range between 6.88 and 7.04. For FE, the results are between 2.39 and 2.72 and for AB they are between 1.86 and 2.63. The latest National Statistics (HMRC, 2020) estimated the cost of RDEC for 2017-18 was £2.4bn on an accruals basis, so based on the results from the FE models, RDEC could have stimulated between £5.8bn and £6.5bn of additional R&D expenditure for that year.

Robustness checks

50. We test the robustness of the results by replicating the OLS, FE and AB regressions on the subset without subcontracting claims and on the unbalanced panel.

Removing subcontracting claims

51. RDEC can be claimed by SMEs who have been subcontracted to do R&D work by a Large Company. There is evidence that SMEs are more responsive to R&D tax incentives than large businesses because they have fewer alternative options to finance their investments (HMRC, 2015; Dechezleprêtre et al., 2019). Removing subcontracting claims made by SMEs allows us to test this hypothesis.

52. As reported in Table 7 and Annex 4, the user cost elasticities are higher for all three models compared to Table 6. This is consistent with findings from the literature. The findings also confirm the negative relationship between the user cost and R&D expenditure. The user cost elasticities estimated with FE are less statistically significant because of the smaller number of observations.

Table 7 User cost elasticity and additionality ratio after removing subcontracting claims

	OLS	FE	AB
User cost elasticity	**-15.7 to -16.2**	**-1.9 to -2.3**	**-0.8 to -2.2**
Additionality ratio companies making a profit	6.20 to 6.69	2.09 to 2.43	1.00 to 2.31
Additionality ratio companies making a loss	6.15 to 6.64	1.73 to 2.03	0.81 to 1.92
Weighted average	**6.48 to 6.53**	**1.97 to 2.30**	**0.94 to 2.18**

Results from the unbalanced panel

53. In our main regressions we balance the panel to avoid any composition effects of companies who quickly enter then leave the claiming population (Bozio, Cottet, & Loriane, 2019).

54. Table 8 tests whether the results still hold when we remove this restriction. The results from all three models are sensitive to the restrictions applied to balance the data. They could be affected by a selection bias as the type of companies that appear regularly across consecutive years could be systematically different than those that appear a couple of times in terms of characteristics such as their R&D expenditure and profitability (which in turn affects their user cost).

55. The OLS and FE models still find a negative user cost elasticity which is consistent with previous results and with the economic theory. Removing this restriction results in a fall in the user cost elasticities

estimated with OLS, and a pronounced increase for the FE estimates which are no longer statistically significant.

56. The results from the AB models are not consistent with the economic theory and with the other approaches as they find a positive relationship between the user cost and R&D expenditure. As expected, the AB estimations based on the unbalanced panel will not work well because any gaps between observations of a given company cause problems for the first-differencing and also upset the use of lagged values as instruments.

57. Our preferred approach is to balance the panel to avoid any composition effects of companies who quickly enter then leave the claiming population.

Table 8 User cost elasticity and additionality ratio from the unbalanced panel

	OLS	FE	AB
User cost elasticity	**-29.4 to -30.6**	**-0.4 to -0.7**	**3.4 to 4.2**
Additionality ratio companies making a profit	7.42 to 7.78	0.75 to 0.93	-15.99 to -9.89
Additionality ratio companies making a loss	7.35 to 7.72	0.44 to 0.55	-9.31 to -6.41
Weighted average	**7.60 to 7.66**	**0.51 to 0.87**	**-13.79 to -8.74**

Discussion

58. Our findings are consistent with those found in previous studies for the UK and neighbouring countries. Our results are very close to those for the LC scheme where the additionality ratio was estimated around 2.35 (HMRC, 2015). The additionality ratio of RDEC appears to be greater than the SME scheme (HMRC, 2019; Guceri & Liu, 2019) which may seem counter-intuitive as we expect SMEs to be more responsive to R&D tax incentives. The difference may come from the greater generosity of the SME scheme, as there could be decreasing returns to scale regarding the generosity of the scheme. In other words, the first pound of government tax support stimulates a higher increase in R&D than the second pound of support and so on and so forth.

59. The greater generosity of the French scheme could also explain why the additionality ratio of RDEC is greater than those estimated for France

which range from 1.1 to 1.5 (Bozio, Cottet, & Loriane, 2019). We are unable to explain why the additionality ratio of RDEC is much larger than the relief in Belgium (0.22 according to (Dumont, 2019)).

Conclusion

60. The findings in this paper offer the first insights on the effectiveness of the RDEC scheme. We exploited variations in the user cost of R&D to estimate the user cost elasticity and the corresponding additionality ratio of the scheme through three econometric techniques (OLS, FE and AB). Our preferred econometric model suggests an additionality ratio between 2.4 and 2.7. The cost of RDEC for 2017-18 was £2.4bn which means RDEC could have stimulated between £5.8bn and £6.5bn of additional R&D expenditure for that year. The results are robust to removing subcontracting claims and running the models on the unbalanced panel data and consistent with findings from previous studies for the UK and neighbouring countries.

61. This evaluation only focuses on the intensive margin which is the additional R&D expenditure among businesses already claiming the relief. This does not include new claims nor 'spillover' benefits for the wider economy. As such, the additionality ratio is not a complete measure of the relief's effectiveness.

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Annex 1 Deriving the gross user cost of capital for R&D

Parameters

- Real interest rate r
- Capital depreciation rate δ
- Corporation Tax rate t
- RDEC rate s
- Enhancement rate for the Large Company scheme α
- Unit price of capital p
- Marginal product of capital MPK[10]

RDEC claims for companies making a profit and those making a loss

1. The **Unit cost of capital without tax** is equal to the interest rate plus the depreciation rate multiplied by the price of a unit of capital.

$$(1)\ Pre-tax\ unit\ cost\ of\ capital = p.(r+\delta)$$

The intuition is that you could invest the capital instead of investing in R&D and receive interest (so the interest rate is the opportunity cost of investing the capital instead) and that the value of capital would depreciate over time.

2. **Post-tax unit cost of capital**

$$(2)\ Post-tax\ unit\ cost\ of\ capital = (p-pt).(r+\delta)$$
$$= p(1-t).(r+\delta)$$

the cost p reduces your profits and hence your CT liability

3. **Post-tax unit cost of capital with RDEC subsidy for a <u>profitable company</u>**

$$(3)\ Post-tax\ unit\ cost\ of\ capital\ with\ RDEC\ subsidy$$
$$= [p-pt-ps+pst].(r+\delta)$$
$$= (p-pt).(1-s).(r+\delta).$$
$$= p.(1-t).(1-s).(r+\delta)$$

p - pt is the unit cost of capital with Corporation Tax

- some of the cost p is recovered by the credit '-ps'
- this credit itself is subject to tax '+pst'

4. **Post-tax unit cost of capital with RDEC subsidy for an <u>unprofitable company</u>**

$$(4)\ Post-tax\ unit\ cost\ of\ capital\ with\ RDEC\ subsidy$$
$$= [p-ps+pst].(r+\delta)$$

[10] This is the additional production (or income) that results from an extra unit of capital.

$$= p.(1 - s + st).(r + \delta)$$
$$= p.[1 - s(1 - t)].(r + \delta)$$

This time, only the subsidy is subject to Corporation Tax.

5. **Post tax income for a <u>profitable company</u>**

$$(5)\ Post - tax\ income = MPK.(1 - t)$$

6. **Post tax income for an <u>unprofitable company</u>**

$$(6)\ Post - tax\ income = MPK$$

Because loss-making companies don't pay Corporation Tax

7. **In equilibrium, the unit cost of capital (3 and 4) is equal to the post-tax income (5 and 6)**

   For profit-making companies (3) = (5)

$$(7)\ MPK.(1 - t) = p.(1 - t).(1 - s).(r + \delta)$$

   For loss-making companies (4) = (6)

$$(8)\ MPK = p[1 - s(1 - t)].(r + \delta)$$

8. **Rearrange step 7 to express the user cost of capital for companies making an RDEC claim**

   For profit-making companies:

$$(9)\ \frac{MPK}{p} = (1 - s).(r + \delta)$$

   For loss making companies

$$(10)\ \frac{MPK}{p} = [1 - s.(1 - t)].(r + \delta)$$

Large Company claims

1. **Post-tax unit cost of capital with LC subsidy**

$$(11)\ Post - tax\ unit\ cost\ of\ capital\ with\ LB\ subsidy$$
$$= p[(1 - (1 + \alpha)t].(r + \delta)$$

2. **Recall that the post-tax income**

$$(5)\ Post - tax\ income = MPK.(1 - t)$$

3. **In equilibrium, the unit cost of capital (11) is equal to the post-tax income (5)**

$$(12)\ Post - tax\ unit\ cost\ of\ capital\ with\ LB\ subsidy$$
$$= Post - tax\ income$$
$$(12)\ p[(1 - (1 + \alpha)t].(r + \delta) = MPK.(1 - t)$$

This is a standard result of profit maximisation

4. **Rearrange (8) to express the user cost of capital for companies making a claim under the Large Company scheme**

$$(13)\ \frac{MPK}{p} = \frac{1-(1+\alpha)t}{1-t}\,.\,(r+\delta)$$

Annex 2 Additional summary statistics

Table A1 Profit -making companies (CT600)

Profit-making companies	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Frequency	1,529	1,665	2,264	3,328	3,730	4,252	4,425	4,061
Percentage	*63%*	*64%*	*66%*	*68%*	*70%*	*69%*	*69%*	*66%*

Table A2 Loss-making companies (CT600)

Loss-making companies	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Frequency	911	936	1,145	1,592	1,627	1,930	1,959	2,064
Percentage	*37%*	*36%*	*34%*	*32%*	*30%*	*31%*	*31%*	*34%*

Source: CT600, box 155, treating companies with a missing observation as loss-making

Figure A1 Distribution of profit and loss-making companies (FAME)

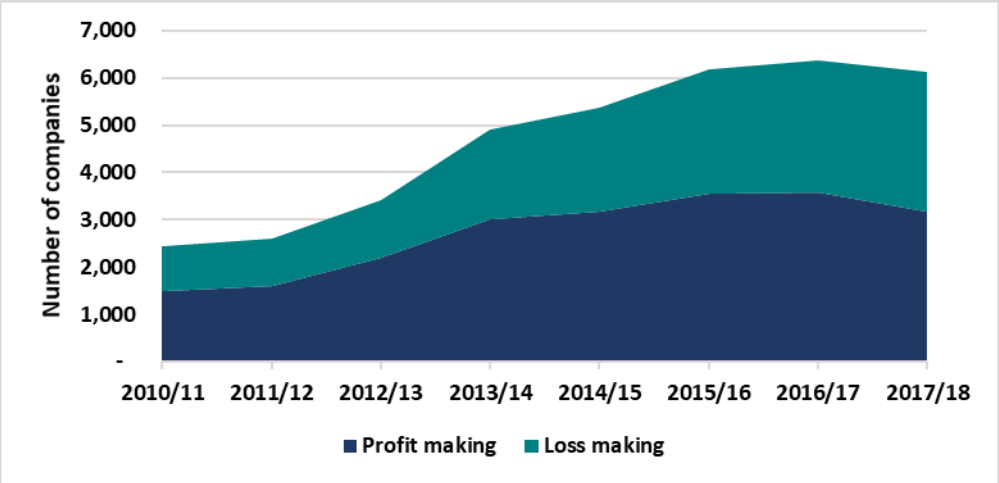
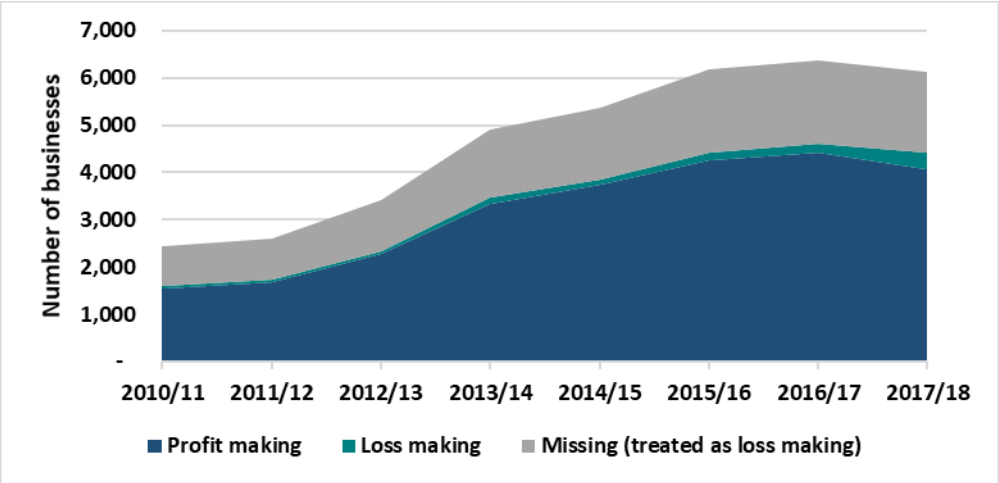


Figure A2 Distribution of profit and loss-making companies (CT600)



Annex 3 Deriving the additionality ratio

Companies making a	Before	After
User cost of capital	(1-12%)*(15%+10%)=22.00%	(1-13%)*(15%+10%)=21.75%
R+D expenditure (£)	100.000	100+100*(-2.46)*(21.75%/22%-1)=102.80
Exchequer cost (£)	(100*12%)*(1-19%)=9.72	(102.80*13%)*(1-19%)=10.82
Additionality ratio	(102.80-100)/(10.82-9.72)=2.54	

Companies making a loss	Before	After
User cost of capital	(1-12%*(1-19%))*(15%+10%)=22.57%	(1-13%*(1-19%))*(15%+10%)=22.37%
R+D expenditure (£)	100.000	100+100*(-2.46)*(22.37%/22.57%-1)=102.21
Exchequer cost (£)	(100*12%)*(1-19%)=9.72	(102.21*13%)*(1-19%)=10.76
Additionality ratio	(102.21-100)/(10.76-9.72)=2.12	

Note: The first row of these tables presents the formulas for the user cost of capital. These are set-out in Table 3 and derived in Annex 1. The left hand-column assumes a rate of 12% while the right-hand column assumes a rate of 13%. All the other parameters such as the interest and depreciation rates and the Corporation Tax rate are held constant. In the second row, the user cost of capital (-2.46, see FE model in Annex 4) is applied to the percentage change in user cost to estimate the additional R&D expenditure. The third row presents the Exchequer costs for a baseline expenditure of £100 (left-hand column), and for the additional R&D expenditure incentivised by the more generous RDEC rate (13% instead of 12% in the right-hand column). The additionality ratio is derived in the bottom row from the additional R&D expenditure divided by the additional Exchequer cost (respectively 2.21 and 1.04 in the second table). This yields an additionality ratio of 2.12 for companies making a loss.

Annex 4 User cost elasticity regressions

OLS

Main models

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-95.73***	-92.03***	-93.72***
	(7.496)	(7.448)	(7.459)
Implied user cost elasticity	*-19.25381*	*-21.53936*	*-21.08596*
Turnover	-	1.77e-11	1.71e-11
		(9.95e-12)	(9.67e-12)
Employees	-	0.0000445***	0.0000434***
		(0.0000120)	(0.0000118)
Liquidity ratio	-	-	-0.0280***
			(0.00450)
Constant	34.83***	33.97***	34.39***
	(1.657)	(1.646)	(1.649)
Year dummy	yes	yes	yes
N	12,387	12,364	12,204
adj. R^2	0.018	0.032	0.036

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Excluding sub-contracting claims

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-71.83***	-67.92***	-69.95***
	(9.124)	(9.054)	(9.111)
Implied user cost elasticity	*-16.15613*	*-15.27782*	*-15.73438*
Turnover	-	1.47e-11	1.42e-11
		(8.74e-12)	(8.50e-12)
Employees	-	0.0000441***	0.0000430***
		(0.0000120)	(0.0000118)
Liquidity ratio	-	-	-0.0262***
			(0.00545)
Constant	29.67***	28.76***	29.25***
	(2.016)	(2.000)	(2.013)
Year dummy	yes	yes	yes
N	10,084	10,069	9,936
adj. R^2	0.019	0.034	0.038

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Unbalanced panel

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-135.5***	-130.8***	-130.1***
	(3.513)	(3.517)	(3.538)
Implied user cost elasticity	*-30.58769*	*-29.52928*	*-29.36569*
Turnover	-	4.67e-11*	4.70e-11*
		(2.21e-11)	(2.22e-11)
Employees	-	0.0000359***	0.0000341***
		(0.0000105)	(0.00000996)
Liquidity ratio	-	-	-0.0148***
			(0.00223)
Constant	42.85***	41.80***	41.67***
	(0.777)	(0.779)	(0.783)
Year dummy	yes	yes	yes
N	36,625	36,266	35,421
adj. R^2	0.045	0.056	0.057

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fixed Effects

Main models

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-13.03**	-13.36**	-10.94*
	(4.540)	(4.537)	(4.543)
Implied user cost elasticity	*-2.93261*	*-3.004972*	*-2.461309*
Turnover	-	4.48e-12	4.47e-12
		(2.64e-12)	(2.59e-12)
Employees	-	-0.00000770	-0.00000894
		(0.00000711)	(0.00000642)
Liquidity ratio	-	-	-0.0147***
			(0.00363)
Constant	16.45***	16.53***	16.02***
	(1.003)	(1.002)	(1.003)
Year dummy	yes	yes	yes
N	12,387	12,364	12,204
adj. R^2	0.047	0.047	0.054

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Excluding sub-contracting claims

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-10.37*	-10.75*	-8.507
	(5.248)	(5.241)	(5.213)
Implied user cost elasticity	*-2.332883*	*-2.418647*	*-1.913467*
Turnover	-	4.09e-12	4.10e-12
		(2.51e-12)	(2.47e-12)
Employees	-	-0.00000650	-0.00000791
		(0.00000713)	(0.00000640)
Liquidity ratio	-	-	-0.0114**
			(0.00389)
Constant	16.08***	16.17***	15.69***
	(1.158)	(1.157)	(1.150)
Year dummy	yes	yes	yes
N	10,084	10,069	9,936
adj. R^2	0.039	0.040	0.045

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Unbalanced panel

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	-3.256	-3.297	-1.856
	(2.808)	(2.817)	(2.819)
Implied user cost elasticity	*-.7352016*	*-.7443752*	*-.4190387*
Turnover	-	7.60e-12	7.51e-12
		(4.96e-12)	(4.82e-12)
Employees	-	0.00000149	0.000000748
		(0.00000384)	(0.00000379)
Liquidity ratio	-	-	-0.00932**
			(0.00289)
Constant	13.31***	13.33***	13.01***
	(0.623)	(0.625)	(0.625)
Year dummy	yes	yes	yes
N	36,625	36,266	35,421
adj. R^2	0.031	0.031	0.036

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Arellano-Bond

Main models

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User Cost	-7.901	-10.81	-12.43
	(8.760)	(8.581)	(8.847)
Implied user cost elasticity	*-1.782084*	*-2.439146*	*-2.80301*
Lagged log(R&D)	0.404***	0.436***	0.429***
	(0.0476)	(0.0427)	(0.0426)
Turnover	-	-9.72e-13	-3.89e-13
		(1.08e-12)	(1.07e-12)
Employees	-	-0.0000101***	-0.00000919**
		(0.00000289)	(0.00000290)
Liquidity ratio	-	-	-0.0321**
			(0.0111)
Year dummy	yes	yes	yes
N	8,093	8,076	7,933
N of instruments	19	33	40
Hansen test[11]			
Degrees of freedom	χ(9)	χ(21)	χ(27)
Test statistic	18.48	29.16	32.85
p-value	0.030	0.110	0.202
A-B test AR(2)[12]			
p-value	0.071	0.059	0.090

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[11] The Hansen test (Hansen, 1982) checks that the instruments used in the AB models are valid (strong first stage and exclusion restriction). It is desirable to 'fail to reject' this test (high p-value).

[12] The Arellano-Bond test checks the absence of autocorrelation in the disturbance term. It is desirable to 'fail to reject' this test (high p-value).

Excluding sub-contracting claims

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User Cost	-3.527	-9.388	-9.626
	(9.528)	(9.168)	(9.661)
Implied user cost elasticity	*-0.7955391*	*-2.117754*	*-2.171325*
Lagged log(R&D)	0.416***	0.473***	0.474***
	(0.0566)	(0.0485)	(0.0480)
Turnover	-	-1.50e-12	-1.26e-12
		(1.14e-12)	(1.14e-12)
Employees	-	-0.0000104***	-0.0000102***
		(0.00000291)	(0.00000295)
Liquidity ratio	-	-	-0.0218
			(0.0139)
Year dummy	yes	yes	yes
N	6,403	6,393	6,271
N of instruments	19	33	40
Hansen test			
Degrees of freedom	χ(9)	χ(21)	χ(27)
Test statistic	15.49	27.98	29.47
p-value	0.078	0.141	0.339
A-B test AR(2)			
p-value	0.052	0.043	0.056

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Unbalanced panel

	(1) Log(R&D)	(2) Log(R&D)	(3) Log(R&D)
User cost	18.83*	19.03*	15.32*
	(7.762)	(7.672)	(7.789)
Implied user cost elasticity	*4.24687*	*4.290735*	*3.453807*
Lagged log(R&D)	0.246***	0.246***	0.252***
	(0.0346)	(0.0330)	(0.0335)
Turnover	-	-2.59e-12*	-1.25e-12
		(1.19e-12)	(1.19e-12)
Employees	-	0.00000260	0.00000355**
		(0.00000153)	(0.00000130)
Liquidity ratio	-	-	-0.00230
			(0.00985)
Year dummy	yes	yes	yes
N	13,797	13,734	13,354
N of instruments	19	33	40
Hansen test			
Degrees of freedom	χ(9)	χ(21)	χ(27)
Test statistic	31.65	43.77	48.30
p-value	0.000	0.003	0.007
A-B test AR(2)			
p-value	0.426	0.433	0.571

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Annex 5 Comparing the characteristics of companies claiming LC to those claiming RDEC[13]

Figure A3 Number of claims

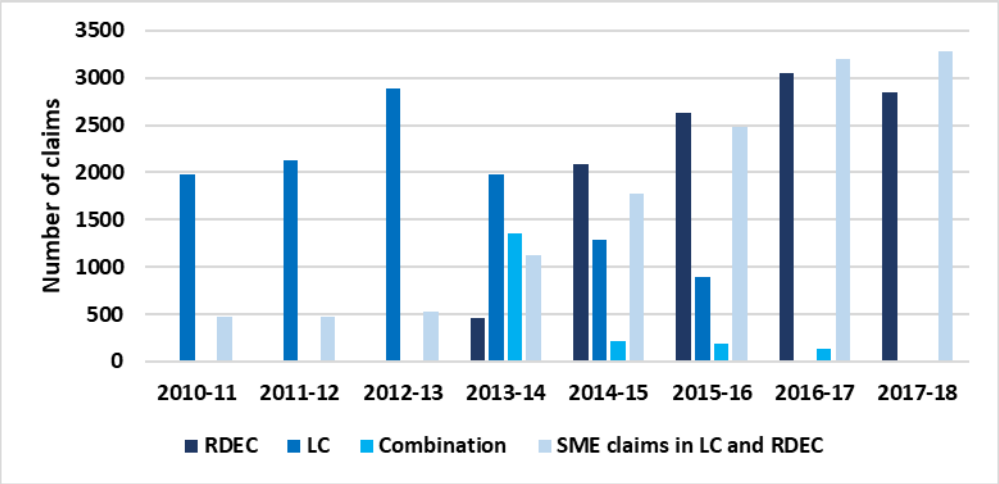
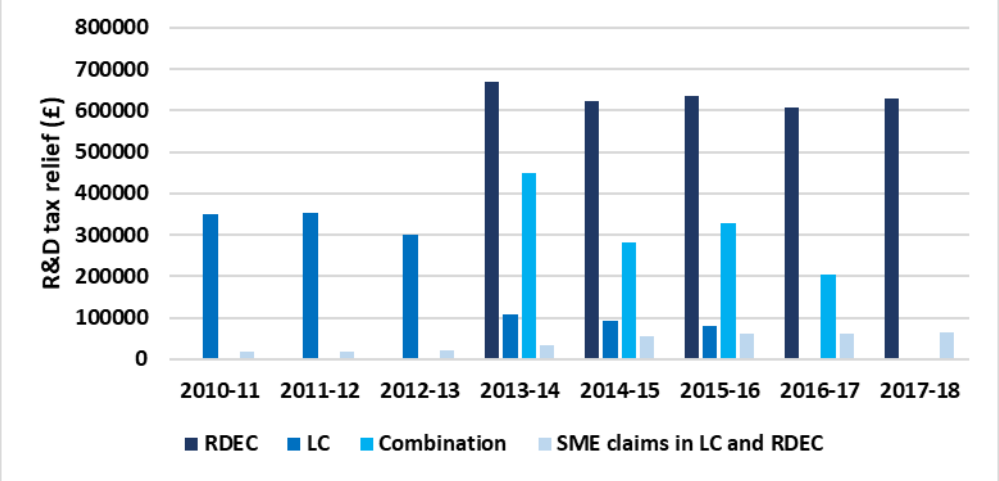


Figure A4 Average amount of R&D tax relief



[13] In the following charts, combination claims denote companies making both an RDEC and a LC claim. SME claims in LC and RDEC are subcontracting claims.

Figure A5 Average qualifying R&D expenditure

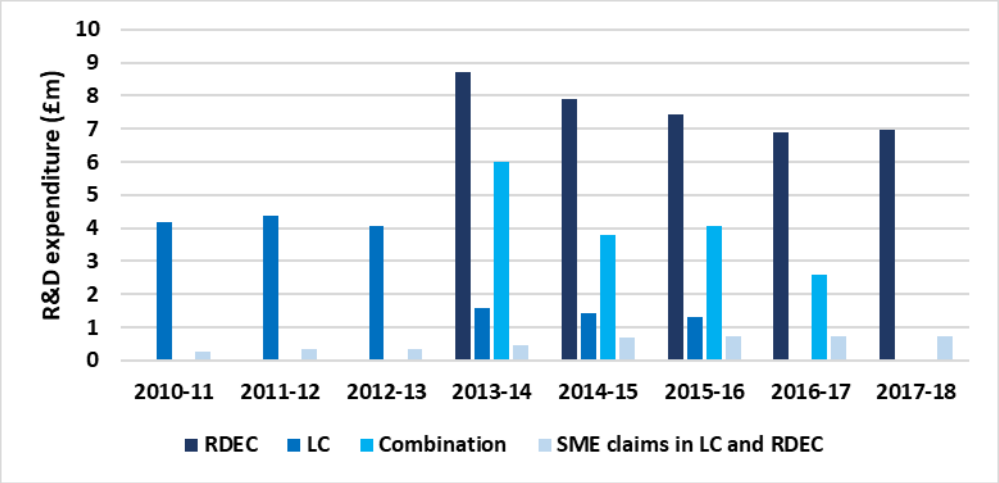


Figure A6 Average number of employees

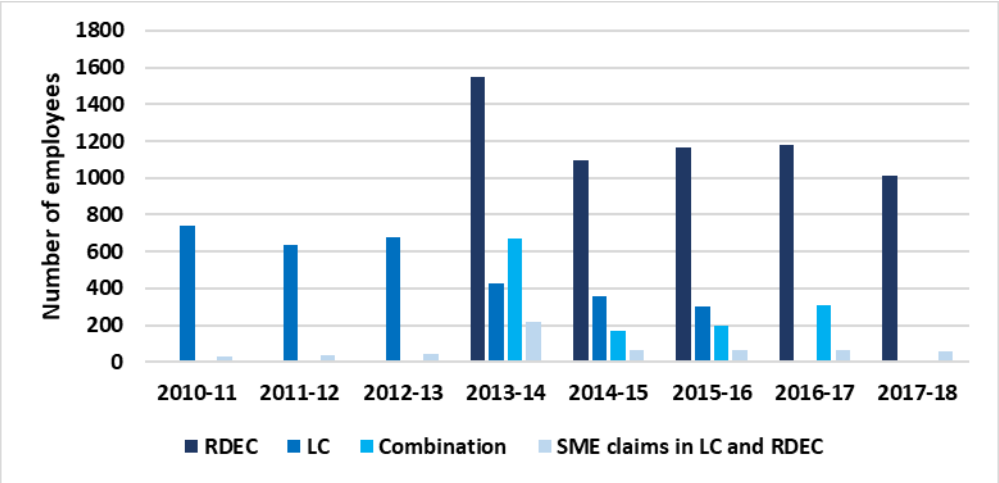


Figure A7 Average trading profit

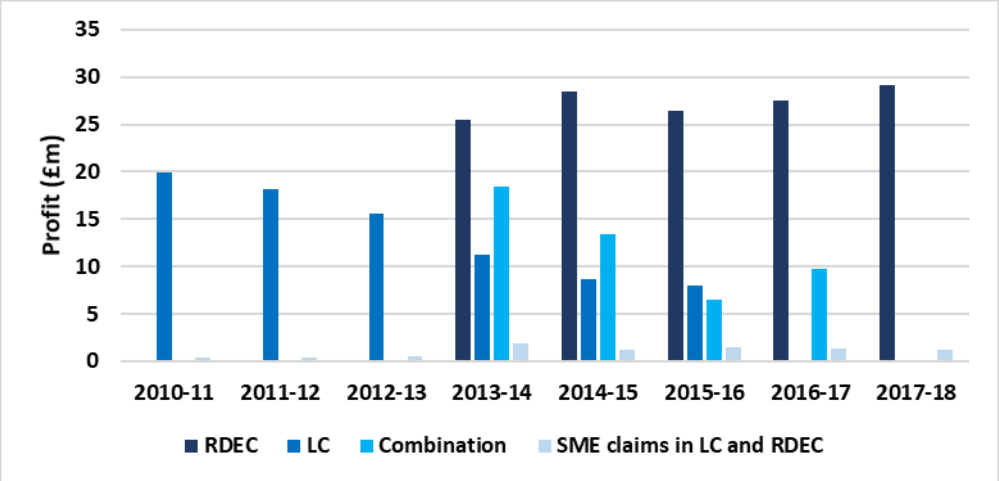


Figure A8 Average turnover

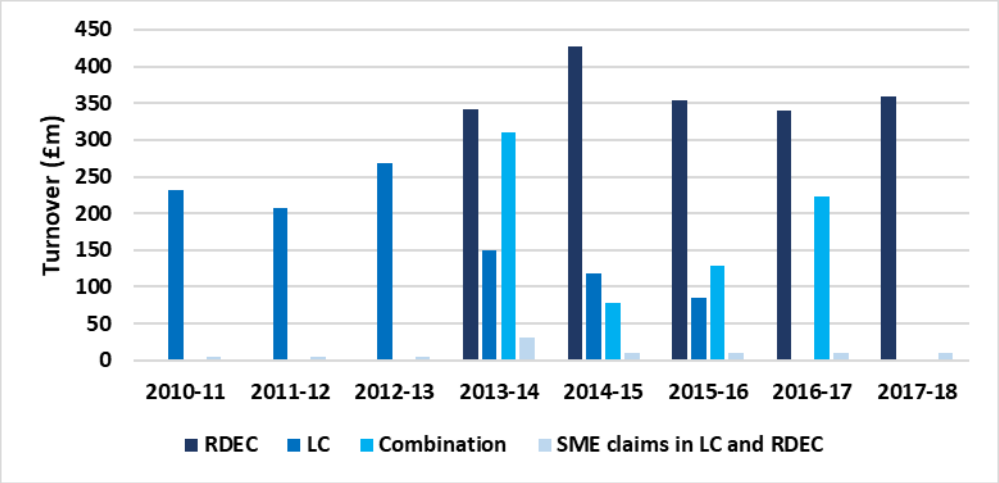


Figure A9 Average liquidity ratio (assets/liabilities)