The effectiveness of R&D tax relief in the life sciences sector

Methodological note

LE London Economics

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Executive Summary

Context

- The UK operates R&D tax relief schemes to incentivise investment in R&D by firms.[1] These schemes have been subject to policy changes in recent years, including reductions and increases to rates of relief for different firms. Further changes were announced in the 2023 Autumn Statement to take effect in 2024.
- The R&D tax relief is of high importance to firms in sectors, such as the life sciences, for which R&D is part of the core business activities and innovation is the core determinant of commercial success. Industry stakeholders report that receiving the relief in a predictable and timely manner is integral to their firms' ability to conduct R&D and succeed in the global marketplace.
- Many effects of the UK's R&D tax relief schemes are not sufficiently evaluated. These include "direct" effects of the relief on R&D spending and "indirect" effects on outcomes beyond firm turnover and hiring. There is also a lack of *sector-specific* estimates of effects. As a result, policy changes could have unintended consequences that run contrary to government policy.
- This document proposes a survey-based, cross-sector study to investigate the effects of UK R&D tax relief for SMEs and fill these evidence gaps.

Existing evidence – about a limited set of effects

- A report produced by London Economics in 2019 on behalf of HMRC (henceforth, "the 2019 Report") is the most recent evaluation of the R&D tax relief scheme for UK SMEs. The report was commissioned to study a limited set of effects of the relief. The 2019 Report assessed:
  - the direct effect of the R&D tax relief on R&D spending by firms who *already conduct R&D (intensive margin)*. It did not assess effects on R&D spending by firms who would not conduct R&D if not for the relief (*extensive margin*), such as firms who would not have been founded in the UK, or at all, or firms who would have gone out of business in periods of otherwise lower investments.
  - the indirect effects of the R&D tax relief on a limited set of firm-level outcomes (turnover and patent filings).
- Due to the scope of the 2019 Report, which was defined by the European Commission's evaluation requirements, the included indicators may fail to capture the benefits of R&D tax relief for certain types of firms. For example, the benefits of R&D tax relief are unlikely to be reflected in firm turnover for firms in the life sciences industry due to the long time it takes from R&D to commercialisation.
- As a result, the data collection and analysis for both direct and indirect effects, need to consider sector-specific characteristics.

[1] "R&D Tax Reliefs: consultation", available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/965501/Condoc_-_RD_review_.pdf

Characteristics of the life sciences sector and related evidence gaps

- The life sciences sector has distinct characteristics that distinguish it from many other R&D conducting sectors. Some of the most relevant characteristics include:
  - R&D part of core business activities (and sometimes the only substantial activity)
  - High R&D intensity
  - Business growth and R&D spend funded by successive venture capital rounds
  - Internationally mobile firms and capital
  - Long timelines to commercialisation, revenue- and profit-making
  - High risk associated with R&D investments (i.e., relatively low probability of any single project succeeding)
  - Exponentially increasing R&D spending (as projects progress along the pipeline)
  - Employment of high-skilled, high-earning labour
  - Large involvement of local R&D supply networks
- Because of these characteristics, the amount of R&D spending, turnover and patent filings (as analysed in the 2019 Report) do not sufficiently capture the benefits of the tax relief for the life sciences sector. Instead, it is likely that the R&D tax relief:
  - Increases the number of firms being created in the UK and conducting R&D in the UK and improves startups' access to funding, improving chances of survival and success.
  - Leads to greater output, supply chain spending, and job creation, leading to higher exchequer revenues.
  - Enables firms to initiate more R&D projects in the present, which increases the number of ongoing R&D projects even *several years in the future.*
  - Enables firms to finish R&D projects faster; achieve more new product approvals and commercialisations; and raise more equity.
- Although the discussion in this report is focused on the life sciences sector, the points made are generalisable to other sectors with similar characteristics.
- The above characteristics and potential effects in the life sciences sector exemplify the need for a more nuanced assessment of the effects of the R&D tax relief and a reflection on the most appropriate methodology.

Challenges using secondary data and natural experiments

- While natural experiments based on secondary data are widely considered as one of the most robust estimation strategies, methodologies based on administrative data and "natural experiments" are not suitable to address the identified gaps in the evidence. The main reasons for this limitation are the lack of suitable data and the challenge to identify an appropriate counterfactual group.
- Secondary datasets do not capture all the variables required to study the effects of interest (particularly for firms within the life sciences sector). Given that the proposed study aims to assess the effect of the R&D tax relief on outcomes which preceding evaluations have not been able to study, primary data collection (i.e., via a survey) is, almost by definition, a necessity.
- It is challenging to find appropriate counterfactual groups to identify the causal effects of the R&D tax relief. The ideal counterfactual group to identify the effects of the R&D tax relief would be a group of firms *not receiving the tax relief* (or receiving less of it) who are identical in every other way to firms who do receive relief. Identifying a suitable

counterfactual group is particularly challenging for R&D intensive sectors, such as the life sciences sector, since conducting R&D is at the core of their business. Approaches other than looking to historical natural experiments are needed to study the causal effects of interest.

Proposed methodology: survey-based approach

- In light of the above, a survey-based methodology is proposed to study the effects of interest. This approach allows for data to be collected on sector-specific outcomes of interest which do not appear in secondary data and provides opportunities for identifying causal effects through means other than natural experiments. The analysis would also allow the identification of differences in the effect of R&D tax relief across firm characteristics, such as sectors and R&D intensity.
- The methodology consists of a large-scale survey for a representative cross-sector sample of UK firms. The proposed methodology consists of three subparts:
  - Hypothetical scenarios: Applying a vignette study approach, firms would be asked to make hypothetical decisions about variables such as R&D expenditure; hiring; and whether to move R&D abroad under different hypothetical R&D tax relief policies. As long as assignment of hypothetical policies to firms is *random*, any differences between average decisions of firms "treated" with different policies – e.g., different rates of relief or filing requirements – can be interpreted as causal effects of policy differences.
  - Self-assessed effects: Respondents will be asked to *self-assess* the effect that the R&D tax relief has had on their firm in recent years, including on outcomes such as their volume and speed of R&D; new products developed; and equity fundraising. This offers a direct and simple means of investigating effects which cannot be assessed using other means because relevant indicators are challenging to measure and/or effects are challenging to identify. Results can be compared across sub-samples, which would allow inferences on whether the effect in a particular sector is different from the average across all other sectors (in the sample).
  - Historical data: Respondents will be asked to provide historical data on variables of interest to retrospectively construct a panel dataset. Historical data can be analysed to consider whether firm outcomes and behaviour have changed in response to historical policy changes.
- The methodology also includes an accompanying survey for a sample of venture capital investors based in the UK and abroad (e.g., US and EU). Surveying *investors* allows for consideration of whether the relief affects the willingness of investors to found and fund UK start-ups, an effect life emphasised by sciences sector stakeholders.

1 Introduction

The UK operates R&D tax relief schemes to incentivise investment in R&D by firms. The generosity and conditions of UK Research and Development (R&D) tax relief have been a subject of policy debate in recent years. R&D tax relief is currently available to profit-making small and medium-sized enterprises (SMEs) in the UK as an "enhanced" deduction from corporation tax liability and to loss-making SMEs as a cash credit[2]. Large firms are eligible for the Research and Development Expenditure Credit (RDEC), which can be claimed as a cash credit or used to offset corporation tax liability. Changes to the R&D tax relief schemes were announced in the 2022 Autumn Statement to take effect in the Spring of 2023. In April 2023, the enhanced R&D deduction for profit-making SMEs was reduced from 130% to 86%. The R&D credit for most loss-making SMEs was reduced from 14.5% to 10%, remaining at 14.5% only for "R&D intensive" loss-making SMEs[3]. The RDEC for large firms, in contrast, saw a rate increase from 13% to 20%. In the 2023 Autumn Statement, the Government has announced that the SME scheme and the RDEC will be merged into a single scheme from accounting periods beginning on or after April 2024. Under the merged scheme, the R&D intensiveness threshold at which loss-making firms qualify for the highest rate of relief will be reduced from 40% of costs to 30%.

In 2019, London Economics (LE) conducted a study (henceforth, "the 2019 Report")[4] on behalf of HM Revenue and Customs (HMRC) to evaluate and estimate the effect of the UK's R&D tax relief scheme for SMEs. The scope of the study, which was defined by the evaluation requirements set out by the European Commission (EC)[5], includes a limited range of effects. While the 2019 Report presents important findings, it does not capture *all* relevant effects of the UK's R&D tax relief. In particular, the study did not investigate effects on outcome variables that are particularly relevant to the life sciences sector and other R&D intensive sectors like it. The 2019 Report also did not discuss differences, which are likely to exist, between the effects of the tax relief *on different sectors* (e.g., the life sciences sector versus others).

In October 2020, a subsequent HMRC report, "Evaluation of the Research and Development Expenditure Credit (RDEC)", was published, focusing on the support provided to larger companies through the RDEC ("The 2020 Report")[6]. In November 2021, HM Treasury published its R&D Tax Reliefs Report[7], contrasting the findings on additionality[8] in the 2019 report with the findings of the

[2] https://www.gov.uk/guidance/corporation-tax-research-and-development-rd-relief#types-of-rd-tax-relief

[3] In the current scheme, a firm is defined as "R&D intensive" if R&D costs account for at least 40% of total costs.

[4] "Evaluation of the Research and Development Tax Relief for Small and Medium-sized Enterprises", available at: https://assets.publishing.service.gov.uk/media/5fae77c18fa8f55debcc5fd4/HMRC_Research_Report_598_R-and-D_tax_relief_for_SMEs.pdf

[5] The 2019 Report explains that: "According to Article 107 of the Treaty on the Functioning of the European Union (EU), the R&D tax relief scheme for SMEs constitutes State Aid; therefore, it requires approval by the European Commission". The Commission's 21 December 2015 decision letter approving the UK scheme set out evaluation requirements for the scheme. The decision letter is available at https://ec.europa.eu/competition/state_aid/cases/258021/258021_1709375_48_6.pdf

[6] "Evaluation of the Research and Development Expenditure Credit (RDEC)" available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/934270/Evaluation_report_-_R_D_RDEC.pdf

[7] "R&D Tax Reliefs Report", available at https://www.gov.uk/government/publications/rd-tax-reliefs-report - page 3, paragraph 1.7

[8] Ratio of R&D spending incentivised by a marginal change in rate of R&D tax relief relative to cost of marginal change to the exchequer.

2020 Report, concluding that "while the RDEC scheme generates £2.40-£2.70 of additional R&D expenditure for each £1 of tax relief claimed, the SME scheme generates £0.60-£1.28."

In the subsequent Autumn Statement 2022, the Chancellor announced – as part of the ongoing review of R&D tax reliefs – the government's intention to "rebalance" the rates of the reliefs in favour of the "better value" RDEC scheme[9]. This decision shows the value and the importance of the above-mentioned research to inform policy. It also highlights the importance of understanding any differences in the effect of R&D tax relief across sectors or other characteristics, such as R&D intensity, to ensure that the tax reliefs are creating as much value as possible.

This document proposes a methodology for a survey-based study (henceforth "the proposed study") that aims to address the gaps in the literature and evidence on the benefits of UK R&D tax relief for SMEs to inform policy making.

The proposed study intends to identify any evidence about effects of the R&D tax relief scheme that were not captured in the 2019 Report and to provide *sector-specific* estimates of effects. The 2019 Report considered effects of the R&D tax relief on firms which already conduct R&D (i.e., *intensive* margin effects) for a set of outcome variables specified by the EC, including patent filings and firm turnover. Building on these results, the proposed study considers the possibility that R&D tax relief may not only affect firms who already conduct R&D but may also induce or enable *a larger number of firms* to conduct R&D. The contributions of these firms to the UK economy constitute possible (direct and indirect) *extensive* margin effects of the R&D tax relief. The proposed study also uses a wider set of indicators to assess the indirect benefits of relief at firm-level – including indicators more suitable for capturing benefits for life sciences firms. Understanding these further effects should lead to more comprehensive estimates of the additionality ratio of UK R&D tax relief and to a richer understanding of the "indirect" effects of relief (i.e., effects on outcomes other than R&D spending). The proposed study seeks to obtain *sector-specific* estimates of these direct and indirect effects (which are very likely heterogeneous).

The proposed methodology is based on primary data-collection through a large-scale survey of UK firms. This survey would ask respondent firms to self-assess effects they have experienced because of the R&D tax relief; to consider their behaviour in various hypothetical policy scenarios; and to report historical data on outcomes of interest. The constructed dataset would facilitate a variety of analytical approaches which aim to overcome issues with constructing appropriate counterfactuals for identifying effects of the relief.

The remainder of this document is organised as follows. Section 2 discusses the 2019 Report and the limitations in the evidence it provides about the effects of the R&D tax relief. Section 3 discusses characteristics of the life sciences sector which imply that a different set of outcome variables and methodologies must be used to capture effects in this sector and others like it. Section 4 discusses econometric methodologies considered and rejected for the proposed study. Section 5 presents the methodology chosen for the proposed study.

[9] "Autumn Statement 2022", available at https://www.gov.uk/government/publications/autumn-statement-2022-documents - page 35, paragraph 3.30

2 The 2019 Report by London Economics

This section discusses the methodology of LE's 2019 Report. One objective of this discussion is to introduce key concepts and approaches from the 2019 methodology which inform the proposed study. Another objective is to highlight areas in which it is necessary to *extend* the evidence base provided by the 2019 Report.

The 2019 Report sought to understand "direct" and "indirect" effects of the R&D tax relief; the former refer to the effect of the tax relief on R&D spending by UK firms, while the latter refer to the effect of the tax relief on other outcomes of interest, such as firm revenues.

To estimate the **direct effect** of the R&D tax relief, the 2019 Report followed studies using an R&D demand framework (Bloom et al., 2002; HMRC, 2010; Fowkes, Sousa, and Duncan, 2015; Dechezleprêtre et al., 2019). Broadly, the approach consists of the following steps:

1) Express the price ("user cost") of R&D as a function of the R&D tax relief.
2) Estimate econometrically the "user cost elasticity" of R&D – how much the average firm's demand for R&D changes in response to a change in the user cost of R&D.
3) Combine the results of the above two steps, to estimate, for a marginal change in the R&D tax relief, the effect on the average firm's demand for R&D (via the effect on user cost).
4) Consider how much UK R&D would change due to a marginal change in the rate of relief if R&D spending by all firms (who currently conduct R&D) responded as the average firm's (from step 3)).
5) Compare change in UK R&D spending from step 4) to exchequer revenues lost/gained due to change in the rate of relief. This allows an additionality ratio to be computed for marginal changes – i.e., how much extra R&D is stimulated per pound that the Treasury foregoes.

As the 2019 Report makes clear, the direct effects this methodology estimates are driven entirely by the responses of firms *who already conduct R&D* to marginal changes in the tax relief – i.e., *intensive* margin effects. These measures of direct effects and additionality *do not* capture direct effects at the *extensive* margin – i.e., the value of R&D spending by firms who would not have been conducting R&D in the UK if not for the marginal change in the R&D tax relief. To avoid underestimating the direct effects, there is a need for methodological adaptations to account for effects at the extensive margin.

In addition to the direct effect, the 2019 Report also considered several potential **indirect effects** of R&D tax relief; namely, on firm turnover; firm innovativeness (as measured by patent applications); and distortions to market competition. Indirect effects at the firm-level (i.e., on turnover and patent applications) were estimated by comparing outcomes between firms who did claim R&D tax relief (treatment group) and firms who did not (counterfactual group); and by comparing outcomes within firms before and after claiming relief. For the estimates to be accurate, it is important that the firms in the treatment group are similar to those in the counterfactual group. Otherwise, it is unclear whether differences in outcomes between the treatment and counterfactual group are being driven by differences in the R&D tax relief, or other factors. Since R&D is one of the core activities of firms in the life sciences sector, most firms can be expected to conduct R&D and to claim the R&D tax relief. As a result, it is likely that firms from the life sciences sector are not sufficiently represented in the counterfactual group, which consists solely of firms not claiming the relief. This illustrates the difficulty with finding a suitable counterfactual group for "treated" firms in the life sciences sector. Since there are few *untreated* life sciences firms, it is challenging to obtain estimates of the effect

of the R&D tax relief which are specific to this sector. These sector-specific estimates are necessary because the effect may well be different for life sciences firms relative to others.

Although important, the indirect effects considered in the 2019 Report represent only a subset of the potential indirect effects of the R&D tax relief. These indicators may fail to capture the benefits of R&D for certain types of firms. For example, for firms in the life sciences industry who may be months or years away from commercialisation, the benefits of R&D tax relief are unlikely to be reflected in firm turnover. Benefits may instead be reflected in, say, the speed at which a firm is able to complete R&D projects. A more extensive list of possible effects within the life sciences sector is presented in Section 4. As in the case of direct effects, the 2019 Report also does not provide evidence about the possible *indirect* effects of the R&D tax relief at the *extensive* margin, which may include jobs and supplier contracts created by firms who would not otherwise have been conducting R&D in the UK. With these concerns in mind, there is a need to gather evidence on a wider set of indicators of indirect effects of the tax relief, both at the intensive and extensive margins. These indicators are presented in the next section.

3 Characteristics of the life sciences sector and related evidence gaps

Evidence is currently lacking on several potential direct and indirect effects of the R&D tax relief. This section provides more detailed consideration of what these effects might be, and articulates hypotheses about them, which are summarised in the three boxes below. As before, a distinction is drawn between direct and indirect effects at the intensive and extensive margins. Although the discussion is focused on the life sciences sector, the points made are generalisable to other sectors with similar characteristics (i.e., risk, timelines to commercialisation, global options) and R&D intensity.

The effects of the R&D tax relief on the life sciences sector may be heightened, relative to other sectors, by certain key characteristics of this sector. This underlines the importance of estimating *sector-specific* effects of the R&D tax relief. Key characteristics of the life sciences sector which are referred to in the subsequent discussion are:

- R&D part of core business activities (and sometimes the only substantial activities)
- High R&D intensity
- Internationally mobile firms and capital
- Business growth and R&D spend funded by successive venture capital rounds
- Long timelines to commercialisation, revenue- and profit-making
- High risk associated with R&D investments (i.e., relatively low probability of any single project succeeding)
- Exponentially increasing R&D spending (as projects progress along the pipeline)
- Employment of high-skilled, high-earning labour
- Large involvement of local R&D supply networks

3.1 Extensive margin effects

The possibility that R&D tax relief affects the number of firms doing R&D in the UK means that studies focused on intensive margin effects of the relief may miss important direct and indirect

effects at the extensive margin. For this reason, it is vital to gather evidence on whether R&D tax relief can induce or enable firms to conduct R&D in the UK who would not have done so otherwise.

Direct effects – more firms conducting R&D

Box 1 Hypothesis 1

R&D tax relief increases the number of firms conducting R&D in the UK, and improves startups' access to funding, especially in R&D intensive and internationally mobile sectors.

Considering direct effects, the R&D tax relief is likely to stimulate R&D spending by firms who were *not previously conducting R&D in the UK*. This means that the true additionality ratio of the relief is likely more favourable than that estimated solely based on intensive margin effects.

In sectors where R&D accounts for a large proportion of firm costs, and where firms and investors are highly internationally mobile, availability of R&D tax relief can influence whether firms are set up and survive in the UK[10]. For example, UK R&D tax relief incentivises some firms to conduct R&D activities in the UK instead of the US. This hypothesis is corroborated in the literature. Knoll et al. (2021)[11] find that multi-national enterprises (MNEs) respond to an increase in R&D tax relief in one country by increasing R&D spending in that country and *decreasing* R&D spending in other countries.

Relative to the average firm in the economy, firms in the life sciences sector are particularly internationally mobile, with choices relatively unconstrained by need for proximity to final markets or raw materials. These firms are therefore likely to be especially responsive to international differences in tax incentives. Indeed, the UK Government's 2021 "Life Sciences Vision" policy paper recognises that "the UK's competitive tax environment and generous system of tax reliefs benefitting the Life Sciences industry, including R&D tax credits" are important to ensuring that "the UK remains a financially attractive location for R&D"[12].

The R&D tax relief may also make UK firms more viable prospects for venture capital (VC) investments, increasing equity funding for these startups and scaling companies. It may also increase VC firms' willingness to found start-ups in the UK when they take part in location decisions. This is likely to be the case in R&D intensive sectors and represents another effect of the relief which would not be detected by, say, considering only turnover. A larger number of R&D intensive firms being funded and founded in the UK could naturally be expected to result in more R&D in the UK.

Stakeholders from the life sciences sector reported to LE that the relief has historically helped the UK compete with countries such as the US for life sciences investments, but that this advantage has been eroded by recent reductions in the rate of the UK relief. The competitive pull of the relief may be especially important in the post-Brexit environment given that European Union (EU) VC funds which have the European Investment Bank (EIB) as a limited partner cannot allocate any more than 20% of their funds to investments outside of the EU. This means that, post-Brexit, the UK must compete with non-EU countries, such as the US and China, for a smaller portion of EU VCs' funds.

Interestingly, anecdotal evidence suggests that the R&D tax relief is valued by life sciences firms not only because of its effect on the price of R&D but also because of its utility as a *cash runway*. In

[10] LE consultations (2023) with a small number of CEOs from firms in the life sciences sector.

[11] Knoll, Bodo, et al. "Cross-border effects of R&D tax incentives." Research Policy 50.9 (2021): 104326

[12] "Life Sciences Vision", available at https://www.gov.uk/government/publications/life-sciences-vision

other words, the cash credit can help loss-making firms survive between funding rounds. Firms who survive difficult years (partly) because of the R&D tax relief may, in subsequent years, conduct R&D spending which they would not have had they shut down. This R&D spending is then, to some extent, attributable to the tax relief which prevented them from shutting down.

The notion that many firms benefiting from the relief are cash constrained is supported by Dechezleprêtre et al. (2023)[13]. These authors suggest that their surprisingly large observed effect of the R&D tax relief on innovation may be driven partly by the fact that many firms benefiting from the relief face cash constraints. In the absence of cash constraints, a reduction in the price of R&D would cause R&D projects to be undertaken which were previously at the margin of profitability. In the presence of cash constraints, however, the R&D tax relief enables firms to undertake R&D projects which would be profitable even at the pre-relief price of R&D, but which they lack cash to pursue.

Indirect effects of more firms conducting R&D

If the R&D tax relief does in fact induce or enable firms to conduct R&D in the UK which would not have done so otherwise, what might this mean in terms of the indirect effects of the relief?

Box 2 Hypothesis 2

R&D tax relief leads to greater output, supply chain spending, and job creation in R&D-intensive sectors such as the life sciences, which may also lead to higher exchequer revenues.

The addition of R&D intensive firms to the UK economy may result in a variety of indirect effects of the tax relief. In the case of the life sciences sector, the economic contribution of firms is clear. A 2022 report by PricewaterhouseCoopers (PwC) estimated that in the year 2019, the UK life sciences industry contributed £36.9bn to UK GDP – consisting of £16.9bn direct contribution (i.e., own output); £7.7bn indirect contribution (i.e., spending on supply chains); and £12.3bn in induced effects related to employee spending[14]. In consultations with LE, life sciences sector stakeholders emphasized that firms tend to build supply networks *in the country where they are located.* Amongst others, service suppliers include contract development and manufacturing organisations (CDMOs); contract research organisations (CROs); and contract diagnostic organisations (CDOs). This high-tech service sector's demand is underpinned by biotech and pharmaceuticals firms whose purchasing power is driven partly by the R&D tax relief. Stakeholders pointed out that "life science parks" which have been established in several UK towns are an illustration of the wider economic benefits that attracting life sciences firms brings the UK.

In a similar vein, a 2022 report by the UK Government's Office for Life Sciences (OLS) estimated that the life sciences sector and its supply chains employed 282,000 people in the UK in 2021[15]. Sector stakeholders argue that, by attracting life sciences firms to the UK, R&D tax credits may help attract and retain highly-skilled, high-earning workers. Supporting this hypothesis, Moretti & Wilson (2017)

[13] Dechezleprêtre, Antoine, et al. "Do Tax Incentives Increase Firm Innovation? An RD Design for R&D, Patents, and Spillovers." American Economic Journal: Economic Policy 15.4 (2023): 486-521.

[14] "Life Sciences Superpower Report", available at https://www.abpi.org.uk/publications/abpi-life-sciences-superpower-report/

[15] "Bioscience and health technology sector statistics 2021", available at https://www.gov.uk/government/statistics/bioscience-and-health-technology-sector-statistics-2021

find that the location decisions of "star scientists" in the US are responsive to interstate differentials in business tax rates[16].

If R&D tax relief does in fact affect the UK economy in the ways described above, this could have implications for exchequer revenues from both business taxes and personal income taxes, particularly from relatively high-earning life sciences employees. Estimates of the additionality of the tax relief which account only for exchequer revenues lost due to the policy and not for revenues potentially gained risk underestimating the true additionality ratio.

3.2 Intensive margin effects

Other possible effects of the R&D tax relief at the *intensive* margin also merit consideration. These include direct effects on existing firms' R&D spending as well as indirect effects including, but not limited to, those on supply chain spending and job creation. It is likely that the size of these effects varies between different sectors meaning that sector-specific analysis is valuable.

Direct effects – more R&D spending by firms

Box 3 Hypothesis 3

R&D tax relief enables firms in sectors such as the life sciences to initiate more R&D projects in the present, which can mean that more R&D projects are ongoing even *several years in the future.*

Whereas the 2019 Report focused on understanding the effect of the R&D tax relief on *contemporaneous* R&D spending by firms, it is also possible that the *present* rate of relief affects firms' *future* R&D spending. In sectors such as the life sciences, where R&D projects can often last up to 15 years, greater capacity for a firm to initiate R&D projects *today* can mean that a larger number of promising R&D projects are developed that can continue for several years in the future. Spending on life sciences R&D projects typically increases exponentially as projects progress along the pipeline. So, the present rate of relief affects *aggregate* R&D spending by firms over the next several years.

During consultations, life sciences stakeholders emphasised the inherently risky nature of life sciences R&D projects, with a relatively low probability of any given project progressing beyond its early stages or, ultimately, resulting in success. In this context, stakeholders expressed the view that the R&D tax relief allows firms to "take more shots at goal" in the hope of landing upon a "winning" project which progresses beyond its early stages and receives R&D investment for several years.

Indirect effects on firms of more R&D spending

Box 4 Hypothesis 4

R&D tax relief enables firms in sectors such as the life sciences to finish R&D projects faster; achieve more new product approvals and commercialisations; and raise more equity.

The literature on assessing R&D performance identifies various firm-level outcomes, beyond those considered in the 2019 Report, which may be affected by the R&D tax relief via R&D spending

[16] Moretti, Enrico, and Daniel J. Wilson. "The effect of state taxes on the geographical location of top earners: Evidence from star scientists." American Economic Review 107.7 (2017): 1858-1903.

(Schumann et al., 1995[17]; Werner & Souder, 1997[18]; Bilderbeek, 1999[19]; Salimi & Rezaei, 2018[20]). Effects of the relief on these outcomes represent (potential) indirect effects of the relief which would not have been captured in the 2019 Report. Consideration of these potential indirect effects is necessary for building a full understanding of the effects of the relief. This is particularly the case in the context of sectors such as the life sciences where indicators previously used to capture indirect effects of the relief are not appropriate. Studying indirect effects using firm turnover as an outcome, for example, is inappropriate in the context of life sciences firms because many of these firms are unlikely to reach commercialisation or generate revenues for several years.

Instead, there are likely to be some benefits of R&D tax relief for firms to be captured by indicators such as number and breadth of R&D projects undertaken; average completion speed of projects; probability of a given R&D project succeeding; high-skilled full-time employees (FTEs) (working on R&D); and number of product approvals sought and obtained, as well as number of new product commercialisations. For the reasons discussed previously, the relief may also increase firms' equity fundraising amounts; valuations between funding rounds; and the speed at which they are able to attract their next round of funding.

The next two sections discuss the design of a study that would facilitate the collection and analysis of data to investigate the effects hypothesised above.

4 Challenges using secondary data and natural experiments

Designing a study to rigorously investigate the wider effects of the R&D tax relief is a challenging task. This section explains why the methodology for the proposed study a) involves use of a survey, rather than relying on secondary data and b) does not centre on a natural experiment. Secondary data allows the researcher to understand how firms have *actually* responded to policy changes and natural experiments represent a robust source of evidence about the causal effects of policy changes. Explaining why the proposed study makes limited use of these approaches despite their advantages justifies the methodology presented in the next section.

The discussion below considers how secondary data and natural experiments might be used to study hypotheses about the effects of the R&D tax relief at the intensive and extensive margins. In each case, issues around data availability and constructing appropriate counterfactual groups to identify causal effects mean that approaches based on secondary data and natural experiments do not sufficiently capture the breadth of impacts and the differences across sectors.

4.1 Intensive margin effects

Firm-level effects of the tax relief can be (and have been) studied using administrative data and natural experiment designs exploiting exogenous variation in the R&D tax relief. Although such

[17] Schumann Jr, Paul A., Derek L. Ransley, and Donna CL Prestwood. "Measuring R&D Performance." Research-Technology Management 38.3 (1995): 45-54.

[18] Werner, Bjorn M., and William E. Souder. "Measuring R&D performance—state of the art." Research-Technology Management 40.2 (1997): 34-42.

[19] Kerssens-van Drongelen, Inge C., and Jan Bilderbeek. "R&D performance measurement: more than choosing a set of metrics." R&D Management 29.1 (1999): 35-46.

[20] Salimi, Negin, and Jafar Rezaei. "Evaluating firms' R&D performance using best worst method." Evaluation and program planning 66 (2018): 147-155.

studies represent a robust source of evidence about *some* effects, the administrative datasets they rely on do not capture the full range of outcomes which may be affected by the tax relief. Constructing appropriate counterfactuals to capture treatment effects of interest is also a hurdle.

4.1.1 Secondary data

Approaches

Several administrative datasets were considered and determined to be insufficient for the full objectives of this study. The analysis conducted by the 2019 Report is instructive as to the types of firm outcomes which can and cannot be studied using administrative data. This report used HMRC data on claims for the R&D tax relief to obtain firms' R&D spending amounts; data from the Office for National Statistics (ONS) Business Structure Database (BSD) to obtain firms' turnover; and data from the Intellectual Property Office (IPO) to capture firms' patent filings.

The Business Enterprise Research and Development Survey (BERD) also collects relevant data on R&D from an annual sample of UK firms, including R&D spending and FTEs working on R&D.

Limitations

Administrative data on firms is, by its nature, limited in scope. Except, perhaps, for firm employment information, which is available in the BSD, the administrative datasets considered contain few indicators which are useful for studying the effects of interest. Given that the proposed study aims to assess the effect of the R&D tax relief on outcomes which preceding evaluations have not been able to study, primary data collection (i.e., via a survey) is, almost by definition, a necessity. It is not possible to obtain information from the administrative data on, for example, the speed at which firms complete R&D projects or their access to equity funding.

Although BERD captures some relevant variables, it has the disadvantage that it does not include data for the same firms over multiple years. To identify the effects of the R&D tax relief, the researcher would ideally be able to observe how the *same* firms respond to different R&D tax relief policies, which cannot be done using a "point-in-time" dataset such as BERD.

As discussed in the next section, primary data-collection also offers the researcher the opportunity to identify the causal effects of interest by asking firms to respond to hypothetical scenarios and to self-assess effects. These approaches would not be possible if the study were constrained to using existing datasets such as those discussed above.

4.1.2 Natural experiments

Approaches

Several natural experiment designs were considered and rejected for the proposed study as a result of the limitations discussed subsequently. These designs, some of which have been implemented in the literature, were:

- Difference-in-differences designs exploiting policy changes affecting some firms but not others – e.g., change in R&D tax relief for SMEs, but not large firms. (Bøler, Moxnes, and Ulltveit-Moe, 2015[21]; Guceri & Liu, 2019[22]).
- Regression discontinuity (RD) designs based on firm size thresholds for different rates of R&D tax relief – typically thresholds based on firm asset holdings or number of employees. (Chen et al., 2021[23]; Dechezleprêtre et al., 2023).
- Comparing subsequent outcomes for firms whose applications for the top rate of the R&D tax credit have been (narrowly) rejected versus approved under new requirements introduced as of April 2023. (Not attempted in the literature)

Limitations

A natural research design is not a useful approach here for several reasons. Firstly, constructing counterfactuals is challenging. The ideal counterfactual group to identify the effects of the R&D tax relief would be a group of firms *not receiving relief* (or receiving less of it) who are identical in every other way to firms who do receive relief. These counterfactuals are rare. Firms are not *randomly* excluded from the UK tax relief; rather, firms claiming R&D tax relief likely differ systematically from other firms in various ways. Although overseas firms receiving different levels of R&D tax relief represent a possible counterfactual cohort for UK firms, overseas firms differ from UK firms in various other ways and may be subject to different treatments, such as their national regulatory environments. Constructing appropriate counterfactuals is even more difficult when seeking to study effects within a specific sector, such as the life sciences sector. R&D is one of the core activities of firms in the life sciences sector, which means that it is unlikely to identify similar firms in the life sciences sector that do not conduct R&D.

Secondly, natural experiment studies tend to exploit opportunities presented by specific historical policy changes to identify effects, which can mean that the external validity of results, i.e., scope for making inferences about the effects of other policy changes, may be limited. For example, Dechezleprêtre et al. (2023) identified effects of the UK R&D tax relief using a 2008 change in the asset ownership threshold for different rates of relief. Effects estimated in this context are not necessarily informative about the effects of other, present-day changes to the relief policy.

4.2 Extensive margin effects

Various approaches were considered to study how the R&D tax relief may affect the number of firms conducting R&D in the UK. The literature on this topic consists of two main methodologies. “Macroeconomic outcome” studies compare macroeconomic indicators across countries with different R&D tax relief policies. “MNE decision” studies consider how international investment decisions by multi-national entities (MNEs) respond to changes in countries’ relief policies, to draw inferences about how countries’ R&D tax relief policies affect firms’ willingness to operate there.

Both types of study offer findings of general international relevance, but lacking specificity to the UK context. These studies also suffer from limited ability to identify *causal* effects, as is discussed

[21] Bøler, Esther Ann, Andreas Moxnes, and Karen Helene Ulltveit-Moe. "R&D, international sourcing, and the joint impact on firm performance." American Economic Review 105.12 (2015): 3704-3739.

[22] Guceri, Irem, and Li Liu. "Effectiveness of fiscal incentives for R&D: Quasi-experimental evidence." American Economic Journal: Economic Policy 11.1 (2019): 266-291.

[23] Chen, Zhao, et al. "Notching R&D investment with corporate income tax cuts in China." American Economic Review 111.7 (2021): 2065-2100.

further below. As before, this subsection first discusses limitations in the secondary data and then limitations of potential econometric approaches.

4.2.1 Secondary data

Approaches

Country-level macroeconomic data can provide outcome indicators relevant to understanding the effects of R&D tax relief, such as gross domestic expenditure on R&D (GERD). Several cross-country panel datasets on such indicators are available, constructed by collating statistics published by governments and/or estimating these independently. These include the OECD's Research and Development Statistics (RDS)[24] and the UNESCO Statistical Institute's R&D dataset[25].

MNE investment data has, in at least one study, been obtained from historical survey data. Athukorala & Kohpaiboon (2010) construct a panel dataset of international R&D spending by US MNEs from 1990 to 2004 using data from the Annual Survey of US Investment Abroad conducted by the Bureau of Economic Analysis at the Department of Commerce[26]. Other studies have constructed similar panel datasets, using (publicly available) annual patent filings by an MNE in each country as a proxy for annual R&D investment by that MNE in that country (Knoll et al., 2021).

Limitations

Although relevant country-level macroeconomic data is readily available, it is of limited utility in the context of the proposed study. As discussed below, issues with identifying causal effects in cross-country studies, mean that using country-level data to study the effects of taxation policy has become an outdated approach.

Similar methodological concerns apply to using MNE investment data, as discussed below. This type of data is unlikely to be of value for identifying causal effects unless it exists in panel form (i.e., tracking investments by many MNEs *over many years*), but few such datasets are available. National administrative data rarely captures the full international distribution of firms' R&D investments and survey data on this topic is limited. Athukorala & Kohpaiboon (2010) highlight the challenges of using this type of (panel) data, stating that "to the best of our knowledge, ours is the first attempt to examine patterns and determinants of overseas R&D activity using panel-data econometrics."

4.2.2 Econometric approaches

Approaches

One approach in the literature on the effects of taxation policy on the macroeconomy is to consider the relationship between taxation policy and macroeconomic indicators across countries (Engen & Skinner, 1996; Lee & Gordon, 2005). This approach has been applied to studying R&D tax relief policy by Griffith (2000). Typically, such studies include country and time fixed effects to improve causal interpretability. Country fixed effects ensure that countries are being compared "to themselves" under different taxation policies over time, while time fixed effects help ensure that the estimated

[24] https://www.oecd.org/sti/inno/researchanddevelopmentstatisticsrds.htm

[25] http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en

[26] Athukorala, Prema-chandra, and Archanun Kohpaiboon. "Globalization of R&D by US-based multinational enterprises." Research Policy 39.10 (2010): 1335-1347.

"effects" are not in fact being driven by the dependent and independent variable changing in the same direction over time due to some omitted third factor.

Other studies have used cross-country panel datasets capturing MNEs' international R&D spending to study how these decisions are affected by changes in countries' R&D tax relief policies (Athukorala & Kohpaiboon, 2010; Knoll et al., 2021). These studies use different units of analysis to country outcome studies – MNEs instead of countries – but they are fundamentally similar in that they rely on drawing of comparisons between country-level R&D taxation policies (i.e., measuring the implications of differences between, say, the US and the UK's policies).

Limitations

These approaches are not useful in this context for two main reasons. First, as with studying the effects of the R&D tax relief on firms, the construction of counterfactuals proves challenging. In an ideal design, the researcher would have the opportunity to observe groups of countries assigned *randomly* to different R&D tax relief regimes. In reality, countries' R&D tax relief policies are not random. R&D tax relief may be associated with country characteristics, such as skill-level of the workforce and other business taxes, which are also associated with macroeconomic indicators and with MNEs' willingness to invest in a country. This creates endogeneity in the approaches discussed above. While there may occasionally be random variation in the exposure of *firms* to R&D tax relief, these natural experiment scenarios are rare, or non-existent, at the level of *national* policy. This makes it difficult to identify *causal* effects of policy differences between countries.

Second, by their nature, cross-country studies lack specificity to the UK. Such studies estimate an *average* effect of R&D tax relief which draws upon data from all countries included in the sample. These approaches are of most value when the research objective is to draw internationally generalisable insights about the effects of R&D tax relief. They are of limited value when the research is concerned with a specific country's R&D tax relief scheme, as is the case here.

5 Proposed methodology: survey-based approach

This section sets out the methodology which has been developed by London Economics for the proposed study, consisting of a **large-scale survey of UK firms across a range different sectors** and an accompanying survey of a representative sample of VC investors in the UK and abroad. The proposed methodology has several advantages relative to those discussed above. Firstly, primary data collection offers the opportunity to collect data from firms on a wider range of outcomes of interest than are available in existing datasets. Secondly, survey questions offer additional tools for identifying causal effects of the R&D tax relief beyond just natural experiments – for example, asking respondents to respond to hypothetical policy scenarios or to self-assess effects. Thirdly, survey questions offer the researcher the opportunity to investigate the precise effects of interest. For example, questions may be designed to study the effects of marginal changes to the rate of the R&D tax relief or, alternatively, to compare hypothetical versions of the policy which differ according to several parameters, such as the rate of relief and the filing requirements for claiming relief.

LE recommend that **stakeholder consultations** be undertaken, during study design, with a sample of 10 to 20 firms and industry representatives from a range of different sectors. The purpose of this scoping exercise would be to ensure that the survey covers relevant outcome indicators for a range of different sectors. The proposed methodology presented in the following sections has largely been informed by inputs from *life sciences* stakeholders only.

The methodology proposed here consists of **three main analytical approaches** for studying the effects of the R&D tax relief, each of which will use data from a separate group of questions within the survey:

- Firstly, respondents will be asked to make hypothetical decisions about certain variables of interest under different **hypothetical policy scenarios**. In this approach, firms can be *randomly* assigned to different (hypothetical) policy scenarios. So, differences in average outcomes between firms assigned to different policy scenarios can be interpreted as causal effects of different policies.
- Secondly, respondents will be asked to ***self-assess* the effects** that the R&D tax relief has had on their firms. Self-assessed effects represent a simple and direct means of gauging the effects of interest, including effects on the extensive and intensive margin – e.g., whether to invest in R&D in the UK and if so, how much. Collecting data on firm-specific effects from each firm in the sample will also facilitate analysis of the *distribution* of heterogeneous effects in the population of firms, including whether effects are larger for firms with certain characteristics (e.g., life sciences firms or firm/sectors with a high R&D intensity).
- Finally, respondents will be asked to **report historical values** for several variables for the past five years. To the extent that respondents report data accurately, this should enable the construction of a panel dataset which allows the researcher to observe how the same firms have behaved under different rates of the R&D tax relief. This data will allow for comparisons to be drawn between historical outcomes of firms claiming and not claiming R&D tax relief, and for analysis of whether firm outcomes and behaviour have changed in response to changes in relief policy.

In addition to the main firm survey, the proposed methodology would include a **survey of *investors***, such as VC firms. As discussed in Section 3.1, changes in the UK's R&D tax relief may affect the extent to which UK firms are able to access the capital they require to conduct R&D and carry out their other operations. This survey would seek to understand how the R&D tax relief affects investors' willingness to invest in (established and new) UK firms. The results of this survey should complement those of the main firm survey to elucidate the relationship between R&D tax relief; VC funding for startups; and R&D expenditure in the UK economy.

This section sets out a sampling methodology for the main survey and describes the topics the survey would cover and the analysis each topic would facilitate. This is followed by some discussion of the proposed investor survey. More detailed aspects, such as the survey questionnaire, depend on the ultimate scope, budget and inputs from the scoping interviews.

5.1 Sampling

This section discusses the sampling strategy for the proposed study. The precise composition of any sample should be informed by the purpose and objective of the research. The discussion of the life sciences context has revealed that the effect of R&D tax relief is likely to vary across sectors and across firms' levels of R&D intensity. The review of the literature has also revealed that there is a limited understanding of heterogeneous effects in the effects of R&D tax relief. To facilitate an analysis that would fill this gap in the literature, the sample should a) focus on companies that conduct R&D, b) allow for a comparison across sectors and other firm characteristics, such as R&D intensity, and c) be large enough to provide robust results when comparing the effect across sub-samples.

Focus on R&D conducting firms

The proposed analysis is aimed at understanding differences in the effect of R&D tax relief across different sectors (and other firm characteristics). Due to the limitations outlined in Section 4, the analysis is based on comparing R&D conducting firms across different sectors rather than comparing R&D conducting firms to non-R&D conducting firms. (The proposed analysis is presented in more detail in Section 5.2.) For this reason, it is not necessary to sample firms that do not conduct R&D.

It would also be possible to narrow the sample further to firms conducting R&D that is eligible for the R&D tax relief. As a result, the study would analyse differences across companies that are currently claiming and benefitting from the tax relief. In the life sciences sector, for example, firms in the "core biopharmaceuticals" sector[27] are eligible for R&D tax relief, while life sciences *service-providers*, such as contract research organisations (CROs), are not. The exclusion of service-providers from the life sciences sector sample would also preclude the risk of double-counting benefits of the R&D tax relief which will already have been accounted for through analysis of firms' supply-chain spending.

Broad range of sectors (and other firm characteristics)

To analyse differences in the effect of R&D tax relief, it is important to include firms with different characteristics in the sample. The discussion of the life sciences sector suggests that there are likely to be differences across sectors (and based on R&D intensity). For this reason, the sample should include firms from a broad range of sectors. While a representative sample would ensure a broad range of sectors, budgetary constraints may mean that a representative sample would not include sufficient firms to enable a statistically robust analysis by sector. Since the comparison across sectors is essential for the analysis, it would be preferred to limit the number of sectors in order to include sufficient firms per sector. Within each sector, firms should be selected randomly to ensure that they are representative of the sector (i.e., in terms of R&D intensity and firm size). This approach is also known as stratified sampling.

The selection of sectors to be included in the sample should be based on the sectors' (average) R&D intensity. The identification of differences in the effect of R&D tax relief will depend on the overall composition of the sample. For this reason, it is important for the sample to be balanced and to include sectors with low, medium and high R&D intensity. To ensure that R&D tax relief is sufficiently relevant for firms within the selected sectors, all sectors should meet a minimum threshold of R&D intensity. The (average) R&D intensity of each sector can be determined based on HMRC's data on R&D tax relief claimants (if the analysis is aimed at R&D eligible for the tax relief) or on the ONS Business Enterprise Research and Development Survey (BERD) (if the analysis is aimed at all R&D).

Based on the discussion of the life sciences sector in Section 3 and the likely benefits that have not been sufficiently reflected in previous studies, the life sciences sector is an important sector to be included in the study.

Sample size

[27] This sector is defined by the Office for Life Sciences as "all businesses involved in developing and/or producing their own pharmaceutical products - from small, research and development (R&D) focused bio-techs to multinational Big Pharma." Bioscience and health technology sector statistics 2021: background quality and user guide", available at https://www.gov.uk/government/statistics/bioscience-and-health-technology-sector-statistics-2021/bioscience-and-health-technology-sector-statistics-2021-background-quality-and-user-guide#statistical-presentation – sub-section 2.5

To enable a robust and statistically powerful analysis, the sample needs to include sufficient observations for each sector. Assuming the analysis to include six different sectors (i.e., two sectors with low, two with medium and two with high R&D intensity), responses from at least 184 firms would be necessary for each sector to identify a difference in the survey results of 10 percentage points (or more) with a 10% significance level and power of 80% when comparing a percentage figure from one sector to the average of at least five other sectors.[28][29]

It should be noted that a difference of 10 percentage points is relatively large. It would, thus, be advisable to sample a larger number of firms per sector. Larger sample sizes will yield more robust evidence and will enable the analysis to identify smaller differences. Furthermore, it would be beneficial for the analysis to include more than six sectors. Differences in the effect of R&D will - by design - depend on the sectors that are part of the sample. Potential biases become smaller, the more sectors form part of the sample.

The sample size should be considered carefully as the study progresses towards implementation. It should be based on the minimum effect size that the analysis is meant to identify and the desired power for the study.

5.2 Survey Topics and Analysis

This subsection provides detail on the three survey topics and corresponding analytical approaches of the proposed methodology: hypothetical scenarios; self-assessed effects; and historical data. For each approach, a brief overview is provided, followed by discussion of the data to be collected; analysis; and any caveats.

5.2.1 Hypothetical scenarios

In the hypothetical scenarios approach the researcher will observe the decisions that firms make under different hypothetical R&D tax relief policies. This data will be used to draw inferences about the causal effects of the tax relief. Crucially, in the hypothetical scenarios approach, the researcher can ensure, *by design*, that counterfactuals are *ceteris paribus*. Put differently, by ensuring that the only differences between hypothetical scenarios relate to the R&D tax relief policy, the researcher can ensure that any differences in firm decisions between hypothetical scenarios are *driven by differences in the relief policy.* The hypothetical scenarios will be assessed in the form of a vignette study.

Box 5 Vignette studies

"Vignette studies use short descriptions of situations or persons (vignettes) that are usually shown to respondents within surveys in order to elicit their judgments about these scenarios." (Atzmüller & Steiner, 2010)[30]

[28] To be able to detect a difference of five percentage points (or more), 740 firms would be required for each sub-group.

[29] The significance level refers to the likelihood of concluding that there is a significant difference when there is none. The power refers to the likelihood of concluding that there is a significant difference when there is one.

[30] Atzmüller, Christiane, and Peter M. Steiner. "Experimental vignette studies in survey research." Methodology (2010).

Survey questions

Respondents will be presented with hypothetical policy scenarios in the form of vignettes, each describing a different hypothetical amendment to the R&D tax relief policy to be implemented in the coming year. They will be asked to project their decisions about outcomes of interest in each hypothetical scenario (assuming all other factors that may affect their decisions, such as the wider economic climate, are as they currently expect them to be).

Respondents may be asked to respond to just one vignette, or to several. In the latter case, care must be taken to avoid bias arising from *order effects* – a behavioural phenomenon in which respondents provide different answers depending on the order in which vignettes are displayed to them (for example, because they anchor on the first vignette and judge all other scenarios relative to that).[31] This risk can be partly mitigated by randomising the order in which vignettes are displayed. This ensures that there is no common order in which respondents see the vignettes, so there is no opportunity for particular order effects to manifest across the sample. Vignettes will feature versions of the policy which differ according to some or all of the parameters below, or other parameters of interest to HMT. It will be emphasized to respondents that these policy differences represent the *only* difference between these hypothetical scenarios.

- Rate of R&D tax relief
- Differences in the rate of R&D tax relief by firm R&D intensity
- Eligibility criteria
- Administrative requirements to claim relief (e.g., necessary forms to submit)
- Clarity of claim criteria (e.g., what is and is not eligible R&D spending)
- Timeliness of payment of credits

Different combinations of these parameters represent different "treatments" which may be applied to respondents to observe their (hypothetical) decisions. The precise treatments to be applied will be those which are of most interest to HMT. For example, if focus is on understanding how marginal changes in the rate of relief affect decisions, respondents could be treated with a continuum of different rates of relief. Alternatively, an amended version of the policy could be compared to the status quo, with a "treatment group" of respondents being shown the amended policy while a "control group" are presented with no policy change. As discussed further on, different types of treatments would facilitate different types of analyses.

The decisions respondents will be asked to project will be ones which they can reasonably be expected to project for the following year (or two to three years, in the case of some variables, where specified). Table 1 shows potential variables to be asked about in hypothetical scenarios.

Table 1 Decision variables for hypothetical scenarios (firm survey)

Variable	Description
R&D expenditure	Firm's projected R&D expenditure.
R&D programs	Projected number of R&D programs firm will undertake.
Breadth of R&D programs	Projected (average) number of studies within each R&D program.
R&D program capital	Projected (average) capital available to R&D programs

[31] Auspurg, Katrin, and Annette Jäckle. "First equals most important? Order effects in vignette-based measurement." Sociological Methods & Research 46.3 (2017): 490-539.

Variable	Description
R&D FTEs	Projected number of FTEs firm will employ working on R&D as their main activity.
FTEs	Projected total number of FTEs firm will employ.
Subcontracting expenditure	Projected % of R&D labour costs spent on third parties as opposed to own employees
Clinical trials	Projected number of clinical trials.
Firm stops operating in UK	Is it likely (probability above 0.5) that firm will stop operating in the UK in the next two to three years?
Firm needs equity funding	Is it likely (probability above 0.5) that firm will need further funding to *survive* the next two to three years?
R&D abroad	Is it likely (probability above 0.5) that firm will conduct R&D in a country other than the UK next two to three years?

Analysis

As long as respondents are assigned randomly to different hypothetical policy scenarios (i.e., independently of their characteristics), the setup here is analogous to a randomised control trial (RCT) in which participants are randomly assigned to different R&D tax policies. Differences in mean outcomes between groups of respondents assigned to different treatments can be interpreted as causal effects of these treatments relative to one another. A "no policy change" control group's outcomes could provide a useful counterfactual against which to assess the outcomes of firms exposed to amended versions of the policy.

Descriptive statistics and statistical analysis can be used to compare the results from one sector to all other sectors. As such, it would allow inference on whether the effect in a particular sector is different from all other sectors (in the sample). The magnitude of the differences that can be detected depends on the sample size (see example sample and effect size in Section 5.1). A comparison of one sector to another sector is likely not to yield statistically significant results due to small sample sizes. In addition to the comparison by sectors, differences in the effect size should be explored for other firm characteristics, such as R&D intensity and firm size.

To analyse the results' robustness and sensitivity, simple econometric models can also be used to estimate the effect of changing certain policy parameters while holding others constant. For example, by presenting different respondents with different combinations of values for the rate of relief and administrative requirements parameters, the researcher can seek to understand the effect of raising the rate of relief while keeping administrative requirements constant and vice versa. An econometric approach allows the researcher to apply many different combinations of policy parameters to the sample and then disentangle the effects of changing different parameters. This could be valuable for building policymakers' understanding of the *relative* effects of adjusting different policy parameters.

Econometric models can be adapted to study whether firms with different characteristics (e.g., firms in the life sciences sector versus other sectors; firms with different levels of R&D intensity; or firms of different sizes) respond differently to changes in the R&D tax relief. As discussed in Sub-section 5.1, the size of the overall sample should be sufficiently large to allow for entirely separate models to be fitted to subsets of the data, such as firms from a particular sector. Effect estimates can then be compared between subset models. Alternatively, using the whole sample, inclusion of interaction terms between policy parameters and characteristic dummies can be used to understand, say, whether outcomes of life sciences firms are more responsive to changes in the rate of relief than outcomes of other firms. As discussed further on, this type of benchmarking of effects between

sectors (and other firm characteristics) could help to understand *relative* effects on firms with different characteristics even in the presence of over-reporting of effects.

Certain hypothetical decisions could be particularly informative about extensive margin effects of the R&D tax relief. Understanding how the relief affects firms' shutdown decisions, need for funding, and decision to conduct R&D outside of the UK is relevant for understanding the effect on the total number of firms conducting R&D in the UK. Data on the proportions of firms reporting that they are likely to stop operating in the UK under certain policies could be combined with data on the typical economic contribution (e.g., average number of FTEs) of these firms to understand the wider implications for the UK economy of potentially losing these firms.

Limitations

Some limitations of the hypothetical scenarios approach are worth noting, although, overall, the approach remains valuable. Foremost among these limitations is the possibility of over-reporting bias; firms have an incentive to over-report the benefits of R&D tax relief, as this may bring about more generous relief policies. Even in the presence of overreporting bias, reports from different sectors can be *benchmarked* against one another. Assuming that the size of overreporting bias is the same in all sectors, even in the presence of overreporting bias the data should allow for conclusions to be drawn about the effects in certain sectors (e.g., the life sciences) *relative to* other sectors.

Another limitation is that even if respondents do not intentionally overreport effects, they may struggle to accurately project how they would respond in hypothetical scenarios. However, given that firms are accustomed to responding to changes in business taxes, we may also expect respondents to be capable of accurately assessing hypothetical scenarios, so long as the hypothetical scenarios are sufficiently realistic. Crucially, so long as there are not *systematic* biases in reporting, estimates for *average* effects of policy changes will remain unbiased.

5.2.2 Self-assessed effects

Respondents will be asked to *self-assess* the effect that the R&D tax relief has had on their firm in recent years. This offers a direct and simple means of investigating various effects of the relief, including effects which cannot be assessed using other means, for example, because relevant indicators are not available in secondary datasets.

Survey questions

Respondents will first be asked to select which of their firm outcomes, from a list of outcomes of interest, they believe the R&D tax relief has affected. Outcomes of interest are presented in Table 2. These include some outcomes considered in the hypothetical scenarios and historical data approaches, such as R&D expenditure, but also outcomes, particularly at the extensive margin, which are challenging to study using other approaches, such as the firm decision to locate R&D operations in the UK.

Table 2 Outcome variables for self-assessed effects (firm survey)

Variable	Description (… in last three years)
R&D expenditure	Firm's total R&D expenditure
R&D programs	Number of R&D programs firm undertook
Breadth of R&D programs	(Average) number of studies within each R&D program firm undertook
R&D program capital	(Average) capital available to R&D programs

Variable	Description (… in last three years)
R&D FTEs	Total number of FTE working hours firm has used from FTEs whose main activity is R&D
FTEs	Total number of FTE working hours firm has used from FTEs whose main activity is R&D
Subcontracting expenditure	% of R&D labour costs spent on third parties as opposed to own employees
R&D asset development speed	Average speed of development of R&D assets
R&D research speed	Average speed of completion of key research phases
Patent filings	Total number of patents filed
New product approvals sought	Total number of new product approvals sought
New product approvals obtained	Total number of new product approvals obtained
New commercialisations	Total number of new products commercialised
Equity funding amount	Total value of equity funding raised
Equity funding frequency	Time between equity funding rounds
Valuation	Firm valuation
Grant funding[32]	Total value of grant funding raised.
Supplier contracts	Total spending on contracts with suppliers
Turnover	Total revenues
Firm shutdown decision	Whether or not firm shut down (i.e., self-assessment of how R&D tax relief affected firm decision to not shut down)
Firm location decision	Whether or not firm conducted R&D in another location *instead of* UK (i.e., self-assessment of how R&D tax relief affected firm decision to conduct R&D in the UK instead of other locations)
Firm establishment decision	Whether or not firm was established (i.e., self-assessment of how R&D tax relief affected firm decision to be established)

For outcomes which respondents report were affected by the R&D tax relief, follow-up questions will gather data on the magnitude of the effect. The magnitude of the effect on continuous numerical outcome variables, such as patent filings or equity funding, will be gauged by asking respondents to estimate what percentage of its realised value the variable *would have been* in the absence of *any* R&D tax relief. For binary variables (firm shutdown decision; location decision; and establishment decision) firms will be asked to report how important the R&D tax relief was relative *other* potentially relevant factors (such as market demand in the UK).

Analysis

Analysis of self-assessed effects would consist of descriptive statistics and statistical analysis to establish if the differences between firms with different characteristics are statistically significant.

As noted earlier, the self-assessed effects approach is also valuable for considering *heterogeneous* effects. Because this approach estimates a firm-specific effect for each firm in the sample, the data can be used to study the distribution of (self-assessed) effect sizes in the population of firms, for example, by plotting this effect size distribution. This will facilitate understanding of whether the effects of R&D tax relief accrue relatively equally to all firms or, alternatively, are experienced strongly by some firms and weakly by others.

Continuing in this vein, the data also provides opportunities to explore the relationship between effect sizes and *firm characteristics*. Statistical analysis could be used to compare the average effect

[32] The availability of R&D tax relief may affect the amount of grant funding firms seek and/or obtain. Understanding the effect of the R&D tax relief on the amount of grant funding firms receive is important for understanding the relief's effect on firms' *overall* access to funding.

size, for example, in one sector to the average across all other sectors. As such, it would allow inferences on whether the effect in a particular sector is different from all other sectors (in the sample). The magnitude of the differences that can be detected depends on the sample size (see example sample and effect size in Section 5.1). A comparison of one sector to another sector is likely not to yield statistically significant results due to small sample sizes. In addition to the comparison by sectors, differences in the effect size should be explored for other firm characteristics, such as R&D intensity and firm size.

Furthermore, the effect size itself could be expressed as the outcome variable in an econometric model with firm characteristics as explanatory variables. This analysis would allow to control for confounding factors and could be explored as a robustness / sensitivity analysis.

Limitations

Self-assessed effects are likely to suffer from the same over-reporting bias discussed previously. However, assuming the size of overreporting bias is not associated with firm characteristics, this bias will not hamper the opportunity to study the relationship between firm characteristics and effect sizes. The *relative* differences between average self-assessed effects for groups of firms with different characteristics will still give unbiased estimates of the differences in *true* effects between these groups of firms.

There is also a risk that, even if they want to, respondents may not be able to accurately assess the effect of the R&D tax relief on their firm. However, as noted previously, in the absence of systematic estimation errors in a particular direction, this issue will not bias *averages* computed using the data.

5.2.3 Historical data

Respondents will be asked to provide historical data on variables of interest to retrospectively construct a panel dataset. Respondents will be asked to provide data for the previous five years. Analysis of historical data collected via survey can be supported by matching of respondent firms to administrative data from sources such as HMRC filings and the BSD. This analysis can also be supported by collation of variables describing wider market dynamics in the years of interest (e.g., interest rates, inflation, and rate of corporation tax). Historical data, so far as it is accurately reported, enables the researcher to observe how firms have *really* behaved in response to historical variation in the R&D tax relief.

Survey questions

Respondents will be asked to provide annual data on historical variables of interest for as many of the past five years as they are able to. These variables will be such that respondents can be reasonably expected to recall or estimate their values or to obtain these values from firm records. The historical dataset will most likely take the form of an unbalanced panel (with some firms reporting data for all five years, others fewer). Variables of interest are shown in Table 3.

These variables include several which are useful primarily for determining the rate of R&D tax relief a given firm was eligible for in a given year, which are marked with an asterix in the table below. These variables also include the predictability and timeliness of relief; asking firms about these provides an opportunity to understand how historical policy changes have affected specific aspects of firms' experience of the relief, possibly shedding light on causal channels between changes to policy parameters and effects on firm behaviour.

Table 3 Historical variables of interest (firm survey)

Variable	Description (annually)
R&D expenditure	Firm's total R&D expenditure.
R&D programs	Number of R&D programs firm undertook.
Breadth of R&D programs	(Average) number of studies within each R&D program firm undertook
R&D program capital	(Average) capital available to R&D programs
Number of R&D FTEs	Number of FTEs in average month in the year whose main activity is R&D.
Number of FTEs in total	Number of FTEs in average month in the year.
Subcontracting expenditure	% of R&D labour costs spent on third parties as opposed to own employees
R&D asset development speed	Average speed of development of R&D assets
R&D research speed	Average speed of completion of key research phases
Patent filings	Total number of patents filed.
New product approvals sought	Total number of new product approvals sought.
New product approvals sought	Total number of new product approvals obtained.
New commercialisations	Total number of new products commercialised.
Equity funding	Total value of equity funding raised.
Equity funding amount	Total value of equity funding raised
Equity funding frequency	Time between equity funding rounds
Grant funding	Total value of grant funding raised.
Supplier contracts	Total spending on contracts with suppliers.
Turnover	Total revenues.
Firm shutdown decision	Whether or not firm shut down.
Firm location decision	Whether or not firm conducted R&D in another location *instead of* UK.
Timeliness of relief	Length of time between filing for and receiving relief.
Predictability of relief	Perceived predictability of relief decision scored from 1-10.
R&D intensiveness*	R&D costs as a proportion of total costs.
R&D relief rate*	Amount of each £1 of R&D spending recovered in the form of a credit or deduction from corporation tax liability.

* Used to determine rate of R&D tax relief firm was eligible for.

Data on firms from administrative datasets can be matched to the survey data using company registration numbers (CRNs). HMRC filings (in particular, CT600 forms) provide data on firms' R&D expenditure in years in which they applied for the relief. The BSD provides data on firms' sector; number of FTEs; and turnover.

A timespan of five years for the panel should be sufficiently large that data is captured on how the same firms behave under different rates of R&D tax relief. This period allows an analysis of changes to rates of R&D tax relief in 2023. At the same time, the data request from firms is not excessively large.

Analysis and limitations

The historical data can be used to inform the analysis of hypothetical scenarios and self-assessed effects. For example, it might be possible to identify patterns in the hypothetical scenarios and self-assessed effects based on past R&D investments or company performance.

As in the 2019 Report, descriptive statistics on outcomes can also be computed and compared for firms who do and do not claim R&D tax relief. However, the sample of firms that conduct R&D and do not claim R&D tax relief is likely to be very small and insufficient for a robust analysis. Furthermore, causal interpretability here is highly limited given that firms claiming and not claiming

R&D tax relief likely differ systematically according to other characteristics (i.e., are in other sectors). It should also be noted that in contrast to the 2019 Report, the survey would not collect data on companies that do not conduct R&D. As such, the historical data could only be compared across firms with different firm characteristics.

5.3 Investor survey

Alongside the main firm survey, the proposed study includes a survey of VC investors. The objective of this survey is to provide additional information about the extensive margin effects of the UK's R&D tax relief. As discussed in Section 3.1, the R&D tax relief may affect the willingness of investors to found and fund UK start-ups and to fund R&D spending by UK firms, particularly post Brexit. More generally, the willingness of VC investors to direct internationally mobile capital towards the UK may serve as a useful measure of the overall attractiveness of the UK as a place for firms to operate. Understanding how VC investors respond to changes in the R&D tax relief is important in and of itself but is also informative as to the effect of the R&D tax relief on the UK business environment more broadly. To obtain a global picture, which is relevant due to the international mobility of capital, the survey should include VC investors that are both based in the UK and outside of the UK (e.g., in the US and EU).

Primary data-collection on the role that R&D tax relief policies play in VC investors' decision-making would represent a valuable addition to the evidence base on such policies. Like the firm survey, the VC survey would consist of three topics: hypothetical scenarios; self-assessed effects; and historical data. The analysis of data from each survey topic, and the limitations of this analysis, mirror the analysis and limitations of these approaches as set out above in the context of the main firm survey. The specific variables to be collected, however, differ from the main firm survey. The discussion below outlines some of the variables relevant for investors.

5.3.1 Topics and analysis

Hypothetical scenarios

As in the main firm survey, VC respondents can be randomly assigned to different hypothetical policy scenarios and asked to indicate how they would respond to the different policy scenarios. In particular, the objective is to elucidate whether and how the R&D tax relief affects VC decisions about the *magnitude* of investments to make in the UK and the *distribution* of these investments amongst UK firms (e.g., favouring more R&D-intensive firms). It may also be interesting to consider whether changes to the UK R&D tax relief affect VC investments in *other* countries, which could indicate that the UK is indeed competing with other countries to attract these investments and that the R&D tax relief plays a role in this competition.

Accordingly, variables of interest are shown in Table 4. It should be noted that if VC respondents are unwilling to disclose commercially sensitive information on the levels of their investments in particular sectors or in firms with particular characteristics, any of the variables in Table 4 can be expressed as *changes*. For example, respondents could be asked by what percentage they expect the value of a given variable to *change* relative to the status quo in a given policy scenario. In fact, asking respondents to report changes rather than levels may make the question easier to answer for respondents.

Table 4 Decision variables for hypothetical scenarios (VC survey)

Variable	Description (over the year)
UK investment value	Total value of investor investments in UK.
UK investment firms	Total number of UK firms invested in.
UK investment value – R&D intensive	Total value of investor investments in UK R&D-intensive firms.
UK investment firms – R&D intensive	Total number of UK R&D-intensive firms invested in.
UK investment value – non-R&D-intensive	Total value of investor investments in UK non-R&D-intensive firms.
UK investment firms – non-R&D intensive	Total number of UK non-R&D-intensive firms invested in.
UK investment value – life sciences	Total value of investor investments in UK life sciences firms.
UK investment firms – life sciences	Total number of UK life sciences firms invested in.
UK investment value – non-life sciences	Total value of investor investments in UK non-life sciences firms.
UK investment firms – non-life sciences	Total number of UK non-life sciences firms invested in.
Investment abroad	Is it likely (probability above 0.5) that investor will increase investment in countries other than the UK next year?

Self-assessed effects

Respondents would also be asked to self-assess the effect of the R&D tax relief policy on the variables shown in Table 4, with analysis proceeding mostly as per the analysis of self-assessed effects in the main firm survey.

A key addition in the investor survey relative to the main firm survey is that investors would be asked to self-assess whether the influence of the R&D tax relief on their decisions has changed *post-Brexit*. This should allow for consideration of whether the R&D tax relief has taken on additional importance in influencing the decision of EU VCs to invest in the UK given the UK is now subject to caps on the proportion of funds being invested outside the EU, as discussed in sub-section 3.1.

Historical data

VC respondents will also be asked to report data for the past five years on historical variables of interest which they can reasonably be expected to recall, estimate, or obtain the values of. Rather than attempting to construct an infeasibly large panel dataset of investment by VC respondents in different countries over time, historical data here is limited to a select few variables to be plotted and analysed using descriptive statistics. These are shown in Table 5.

By dividing the study period into pre-Brexit and post-Brexit years, analysis here could seek to elucidate the interaction between the effect of the R&D tax relief on investors' decisions and Brexit.

Table 5 Decision variables for hypothetical scenarios (VC survey)

Variable	Description (over the year)
UK investment value	Total value of investor investments in UK.
UK investment firms	Total number of UK firms invested in.
Investment value abroad	Total value of investor investments other than the UK.
Investment firms abroad	Total number of non-UK firms invested in.