The impact of R&D tax Credits on Innovation and spillovers: A Regression Discontinuity Design

Abstract

We will study the causal impact of research and development (R&D) tax incentives on innovation using a RD Design. We exploit a change in the asset-based size thresholds for eligibility for R&D tax subsidies using administrative tax data on UK firms matched to information on patents and citations. In particular, we will examine in detail technological spillovers of the induced R&D on the innovations of technologically related firms. The paper will extend our preliminary work in Dechezlepretre et al (2016) by (i) focusing on the spillover effects and (ii) including an extra four years of data (through 2015).

1. Overview of the research question

Innovation is recognized as the major source of growth in modern economies. But because of knowledge externalities, private returns on research and development (R&D) are lower than their social returns, hence the need for some public subsidy.[1] Consequently, not only does every country treat R&D investments more generously than capital investment, but the majority of OECD countries also have additional fiscal incentives for R&D. Over the last two decades, these tax incentives have grown more popular compared to more direct R&D subsidies to firms.[2] One reason for this shift is that subsidizing R&D through the tax system rather than direct grants reduces administrative burden and mitigates the risk of "picking losers" (e.g. choosing firms with low private and social returns due to political connections).

[1] Typical results find marginal social rates of return to R&D between 30% and 50% compared to private returns between from 7% to 15% (Hall, Mairesse and Mohnen, 2010). Endogenous growth theories (Romer 1990, Aghion and Howitt 1992) provide several reasons why private innovative activities do not take into account externalities over producers and consumers, and produce sub-optimal levels of R&D. For evidence showing R&D externalities, see for example Bloom, Schankerman and Van Reenen (2013). There is also evidence that these spillovers are partially localized geographically, so the country where the R&D is performed obtains a disproportionate share of the productivity benefits, at least initially (e.g. Jaffe, Trajtenberg and Henderson, 1993).

[2] Over the period 2001-2011, R&D tax incentives were expanded in 19 out of 27 OECD countries (OECD 2014).

But do R&D tax incentives actually work? The existing literature has several serious shortcomings that we seek to address in this study. First, researchers have mainly focused on the effects of taxes on R&D whereas the point of the policy is to try and stimulate innovation.[3] The tax incentive could increase observed R&D without having much effect on innovation if, for example, firms re-labeled existing activities as R&D to take advantage of the tax credits or only expanded very low quality R&D projects.

A second problem with the literature is that it has proven difficult to come up with compelling causal designs to evaluate the impact of R&D tax policies. Evaluations at the macro-economic level (e.g. Bloom, Griffith and Van Reenen, 2002; Corrado et al., 2015) or state level (e.g. Wilson, 2009; Moretti and Wilson, 2015) face the problem that changes of policies are likely to be coincident with many unobserved factors that may influence R&D. On the other hand, variation at the firm level is often limited as the tax rules apply to all firms and the heterogeneity in tax prices that does exist are at least partially driven by endogenous firm choices (e.g. R&D spending, tax exhaustion, etc.).

A third problem with the literature is that data limitations have generally meant a focus on large firms. Since R&D is concentrated, aggregated data will also be effectively dominated by large firms. Accounting regulations in most countries only require larger (usually public listed) firms to report R&D. As a consequence, there has been a particular focus on US publicly listed firms.[4] But since at least Arrow (1962) it has been recognized that financial markets may under-supply credit for R&D and these problems are likely to be particularly acute for SMEs.[5] Hence, extrapolating from the innovation response of large firms to policy changes may be misleading.

In addition to the direct effect of tax incentives on innovation outputs, a comprehensive evaluation should also address the technological externalities that R&D induced by tax incentives cause on other related firms. In presence of such externalities, the social returns to tax incentives can be estimated at a higher level than private returns enjoyed by innovating firms, which implies the efficiency benefits of tax incentives.

[3] There is a large literature on the effects of public R&D grants on firm and industry outcomes such as Einiö (2014), González, Jamandreu and Pazó (2005), Goodridge et al. (2015), Jaffe and Le (2015), Lach (2002), Moretti, Steinwender and Van Reenen (2016) and Takalo, Tanayama, Toivanen (2013). The earlier literature is surveyed in David, Hall and Toole (2000).

[4] An exception is Agrawal, Rosell and Simcoe (2014) look at the tax effect on investment for small private Canadian firms.

[5] Since R&D costs are mainly people such as scientists, it is hard to post collateral to borrow against R&D projects. Furthermore, asking outsiders for finance may reveal the innovation and so undermine its value.

2. Overview of the proposed methodology

In this study, we plan to address these three issues with novel data and methods. We address the first issue of measurement by analyzing the effect of R&D tax incentives not only on R&D expenditures but also on patenting activity (and other firm performance measures such as productivity and size). We also look at the quality of these additional innovations through various commonly used measures of patent value.

To address the second problem regarding identification, we exploit a policy reform in the UK which raised the size threshold under which firms can access the more generous tax regime for small- and medium-sized enterprises (SME). Importantly, the new tax threshold introduced was unique to the R&D tax policy so it did not overlap with access to other programs or taxes. Prior to the major change in 2008 the threshold was based on the European Commission definition of an SME. Given this change in tax thresholds, we can implement a Regression Discontinuity (RD) Design (e.g. Lee and Lemieux 2010) looking at differences in R&D and innovation around the new SME threshold, which was based on accounting data pre-dating the policy change.

For the third problem regarding generalization and selected sample, we use a new merged dataset containing the universe of UK firms. This combines confidential HMRC data (the UK equivalent of the US IRS) on R&D levels, company accounts from the population of public and private firms, and patents from 60 patent offices around the world. The data is available before and after the R&D tax change.

To further evaluate spillovers of R&D induced by tax incentives, we extend the RD Design to estimate the impact of tax incentives on nontreated firms that are technologically close to treated firms. We propose two different empirical methods to estimate this spillover effect.

3. Institutional setting of the research

We now summarize the most important features of the institutional setting and tax policies in this section. From the early 1980s the UK business R&D to GDP ratio fell, whereas it rose in most other OECD countries. In 2000, an R&D Tax Relief Scheme was introduced for small and medium enterprises (SMEs). It was extended to cover large companies in 2002, but SMEs continued to enjoy more generous R&D tax relief. The policy costs the UK government £1.4bn in 2013 alone (Fowkes, Sousa and Duncan, 2015).

The tax policy is based on the total amount of R&D, i.e. it is volume-based rather than calculated as an increment over past spending like the US R&D tax credit. It works mostly through

enhanced deduction of R&D from taxable income, thus reducing corporate tax liabilities.[6] At the time of its introduction, the scheme allowed SMEs to deduct an additional *enhancement rate* of 50% of qualifying R&D expenditure from taxable profits (on top of the 100% deduction that applies to any form of current expenditure). If an SME was not making profits, it could surrender enhanced losses in return for a payable *tax credit*[7] amounting to 16% of enhanced R&D.[8] This design feature was aimed at dealing with the problem that smaller companies may not be making enough profits to benefit from the enhancement rate. The refundable aspect of the scheme is particularly beneficial to firms who are liquidity constrained. Large companies had a less generous deduction rate of 25% of their R&D and could not claim the refundable tax credits in the case of losses (Finance Act, 2002).

The aggregate UK business R&D to GDP ratio stabilized after the introduction of this R&D tax policy and Bond and Guceri (2012) suggest that these are causally connected. Guceri (2015) uses a difference-in-differences method across firm size classes to look at the effect of the introduction of the program and argues that the policy raised R&D by a fifth in the affected firms. Fowkes et al. (2015) calculate the firm-specific user cost and instrument this with lagged values, also finding positive effects on R&D. While suggestive, the assumptions to identify causal effects underlying these papers are strong (e.g. the absence of group-specific trends and/or serial correlation).

The policy used the definition of an SME recommended by the European Commission (EC) throughout most of the 2000s. This definition was based on employment, total assets, and sales[9] from the last two accounting years. It also takes into consideration company ownership structure and constrains variation in the SME status over time by requiring that in order to change its SME status, a company must fall in the new category two consecutive years.

We will focus on the major change to the scheme that commenced from August 2008. The SME assets threshold was increased from €43m to €86m, the employment threshold from 249 to

[6] Only current R&D expenditures, such as labor and materials, qualify for the scheme, but since capital only accounts for about 10% of total R&D, this is less important (e.g. Cameron, 1996).
[7] Throughout we will use "tax credit" to refer to this refundable element of the scheme as distinct from the "enhancement" element.
[8] Or equivalently, 24% (=16% x 150%) of total R&D expenditure. See Finance Act 2000 (Chapter 17, Schedule 20).
[9] We use the terms "sales", "turnover" and "revenue" interchangeably in the text, except when more precise definitions are needed.

499 and the sales threshold from €50m to €100m.[10] As a result of these changes, a substantial proportion of companies that were eligible only for the large company rate according to the old definition became eligible for the SME rate. In addition to the change in SME definition, the UK government also increased the enhancement rate for both SMEs and large companies in the same year. The SME enhancement rate increased from 50% to 75%.[11] For large companies, the rate changed from 25% to 30%. The policy change implies a reduction in the tax-adjusted user cost of R&D from 0.19 to 0.15 for the newly-eligible SMEs whereas the user cost for large companies was basically unchanged.

We will examine the impact of this jump from 2008 onwards in tax-adjusted user cost of R&D at the new SME thresholds. There are several advantages of employing this reform instead of the earlier changes. First, unlike the previous thresholds based on the EU definition, which were extensively used in many other support programs targeting SMEs, the thresholds introduced in 2008 were specific to the R&D Tax Relief Scheme. This allows us to recover the effects of the R&D Tax Relief Scheme without confounding them with the impact of other SME schemes. Second, identifying the impacts around newly introduced thresholds mitigates biases arising from tax planning which may cause endogenous bunching of firms around the thresholds.

Specifically, we will focus on 2007 value of assets as our key running variables, as this will matter for SME tax status in 2009 due to the two-year rule as discussed above. Besides checking whether the covariates were all balanced at the cutoff, we will also examine whether there was any bunching around the threshold in 2007 (or earlier). This is important as although the policy was not completely detailed until July 2008 (and implemented in August 2008), aspects of the policy were understood in 2007 so firms may in principle have responded in advance. Information frictions, adjustment costs and policy uncertainty mean that this adjustment is likely to be sluggish, especially for the SMEs we study.[12] Finally, we chose to focus on assets as, unlike employment and sales, it does not suffer from missing values in the available datasets.[13]

[10] The other criteria laid down in the EC 2003 recommendation (e.g. two-year rule) were maintained in the new provision in Finance Act 2007 (Chapter 11). This act did not appoint a date on which new ceilings became effective. The date was appointed in the Finance Act 2007, Section 50 (Appointed Day) Order 2008 of July 16th 2008.

[11] In parallel, the SME payable tax credit rate was cut slightly to 14% (from 16%) of enhanced R&D expenditure (i.e. 24.5% of R&D expenditure) to ensure that R&D tax credit falls below the 25% limit for state aid.

[12] Sluggish adjustment to policy announcements is consistent with many papers in the public finance literature (e.g. Kleven and Waseem, 2013).

[13] The fact that we use only one of the three SME criteria for determining eligibility does not violate the assumptions for RD Design, it may just reduce the efficiency of our estimates. For robustness checks, we will also experiment with using employment and sales, and measures in other years for the running variable.

4. Data sources

Our data comes from three main sources: (1) HMRC Corporate Tax returns (CT600) and its extension, the Research and Development Tax Credits (RDTC) dataset, which provide data on the universe of UK firms and importantly includes firm's R&D expenditures as claimed under the R&D Tax Relief Scheme, (2) Bureau Van Dijk's FAME dataset which provides data on the accounts of the universe of UK incorporated firms, and (3) PATSTAT which has patent information on all patents filed by UK companies in the main 60 patent offices across the world.

CT600 is a confidential administrative panel dataset provided by HMRC Datalab which consists of tax assessments made from the returns for all UK companies liable for corporation tax. The original dataset covers financial years 2000-01 to 2011-12[14], with close to 16 million firm by year observations, and contains all information provided by firms in their annual corporate tax returns. This dataset has very recently in April 2017 been expanded to include financial years up to 2014-2015. We are specifically interested in the RDTC dataset, which consists of all information related to the R&D Tax Relief Scheme including the amount of qualifying R&D expenditure each firm has in a year and the scheme under which it makes the claim (SME vs. Large Company Scheme).

We only observe total R&D when firms seek to claim R&D tax relief. All firms performing R&D are in principle eligible for tax breaks which as we have discussed are generous. Further, all firms must submit tax returns each year and claiming tax relief is a simple part of this process. Hence we believe we have reasonably comprehensive coverage of current R&D spending. Statistics provided by internal HMRC analysis indicate that qualifying R&D expenditure amounts to 70% of total business R&D (BERD).[15] Note that the other outcomes (like patents) are observed for all firms, regardless of R&D status.

CT600 makes it possible to determine the SME status of firms who claim the R&D tax relief, but not the SME status of firms who are *not* claiming (the vast majority of firms). Employment and total assets are not available because such information is not directly required on corporate tax forms. Furthermore, only tax-accounting sales is reported in CT600, while the SME definition is based on financial-accounting sales as reported in company accounts.[16]

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[14] The UK fiscal year runs from April 1st to March 31st so 2001-02 refers to data between April 1st 2001 and March 31st 2002. In the text we refer to the financial years by their first year, so 2011-2012 is denoted "2011".

[15] There are various reasons for this difference, including the fact that BERD includes R&D spending on capital investment whereas qualified R&D does not (only current expenses are liable). It is also the case that HMRC defines R&D more narrowly for tax purposes that BERD which is based on the Frascati definition.

[16] Tax-accounting sales turnover is calculated using the cash-based method, which focuses on actual cash receipts rather than their related sale transactions. Financial-accounting turnover is calculated using the accrual method, which records sale revenues when they are earned, regardless of whether cash from sales has been collected.

Consequently, we turn to a second dataset, FAME, which contains all UK company accounts from the mid-1980s to 2015. FAME has close to full coverage of total assets, since all firms are required to report their assets in company accounts. However, reporting of sales and employment is mandatory only for larger firms. In addition, FAME provides industry, location, capital investment, profits, remuneration, etc., though coverage differs across variables. The dataset therefore allows us to compute various performance measures such as productivity and growth and examine the impact of R&D tax incentives on these measures.

The third dataset we exploit is PATSTAT, a database curated by the European Patent Office (EPO). PATSTAT is the largest available international patent database and covers close to the population of all worldwide patents from 1900 to 2015. It brings together over 70 million patent documents from over 60 patent offices, including all of the major offices such as the European Patent Office, the United States Patent and Trademark office (USPTO) and the Japan Patent Office (JPO). Patents filed with the UK Intellectual Property Office (UK IPO) are also included. To assign patents to UK-based companies we use the matching between PATSTAT and FAME implemented by Bureau Van Dijk and available from the ORBIS database. Our dataset contains comprehensive information from the patent record, including application date, citations, and technology class. Importantly, PATSTAT includes information on patent families, which are sets of patents protecting the same invention across several jurisdictions. This allows us to identify all patent applications filed worldwide by UK-based companies and to avoid double-counting inventions that are protected in several countries.[17] This comprehensive family-level patent count is our key outcome variable of interest. In addition, to tackle the problem that the value of individual patents is highly heterogeneous, we will also (i) consider separately EPO patents vs. UK patents, (ii) use data on the number of countries that IP protection is sought, (iii) look only at granted patents instead of all applications, (iv) consider different technology classes, and (v) weight patents by future citations.[18]

5. Details of the empirical method

We start with a simple R&D equation of the form:

$$rd_{i,t} = \alpha_{1,t} + \beta_{FS,t} E_{i,2007} + f_{1,t}(z_{i,2007}) + \varepsilon_{1i,t} \quad (1)$$

where t = 2009, 2010, 2011 following the 2008 policy change and $\varepsilon_{1i,t}$ is an error term. $rd_{i,t}$ is

[17] This means that thanks to patent family information our dataset includes patents filed by foreign affiliates of UK companies overseas that relate to an invention filed by the UK-based mother company. However, patents filed independently by foreign affiliates of UK companies overseas are not included.

[18] Variations of these quality measures have been used by *inter alia* Lanjouw et al. (1998), Harhoff et al. (2003) and Hall et al. (2005).

R&D the expenditure of firm *i* in year *t* and $E_{i,2007} = I\{ z_{i,2007} \leq \tilde{z} \}$ is a binary indicator equal to one if assets in 2007 ($z_{i,2007}$) are equal to or less than the corresponding new SME threshold, $\tilde{z}$. The coefficient of interest β_{FS} ("FS" for First Stage) estimates the effect of the difference in tax relief schemes between SMEs and large firms on R&D spending. In an RD Design framework, the identification assumption requires that the distribution of all predetermined variables is smooth around the threshold, which is testable on observables. The identification is guaranteed when firms cannot manipulate their running variable, $z_{i,2007}$ (Lee, 2008). Under this assumption, eligibility, $E_{i,2007}$, is as good as randomly assigned at the cutoff. We will consider year by year regressions of equation (1) as well as averaging over post-policy years (from 3 to 7 post-policy years). We also estimate equivalent regressions in the pre-policy years to assess the validity of the RD Design. Equation (1) can be derived from the static first order condition of a firm with an R&D augmented CES production function.

As is standard in RD Designs, we control for separate polynomials of the running variable on both sides of the asset threshold of €86m. As noted above, because of the two-year rule, a firm's SME status in 2009 is partly based on its financials in 2007. These are unlikely to be manipulated by firms for tax planning purpose since the start date of the new SME definition (August 1st 2008) was only announced on July 16th 2008.[19] Using total assets in 2007 as our primary running variable thus mitigates the concern that there may have been endogenous sorting of firms across the threshold.

Notice that the "new SMEs", i.e. those who became SMEs only under the new definition, could only obtain the higher tax deduction rates on R&D performed after August 2008. Hence, to the extent that firms could predict the change in thresholds in early 2008 (or they could manipulate the reported timing of within year R&D), such companies would have an incentive to *reduce* 2008 R&D expenditures before August and increase them afterwards. To avoid these complexities with the transition year of 2008, we focus on 2009 and afterwards as full post-policy years.

In terms of innovation outputs we consider the following patent equation analogous to the R&D equation (1):

$$pat_{i,t} = \alpha_{2,t} + \beta_{RF,t} E_{i,2007} + f_{2,t}(z_{i,2007}) + \varepsilon_{2i,t} \quad (2)$$

where the dependent variable is the number of patent families, $pat_{i,t}$. Under the same identification assumptions discussed above, β_{RF} ("RF" for Reduced Form) estimates the causal effect of the

[19] Finance Act 2007, Section 50 (Appointed Day) Order 2008 of July 16th 2008.

policy on patents.

Finally we consider the "structural" patents equation:

$$pat_{i,t} = \alpha_{3,t} + \gamma_{3,t} rd_{i,t} + f_{3,t}(z_{i,2007}) + \varepsilon_{3i,t} \quad (3)$$

which can interpreted as a "knowledge production function" as in Griliches (1979). Equations (1) and (3) correspond to a fuzzy RD model identifying the impact of additional R&D spending induced by the difference in tax relief schemes on firms' innovation output, using $E_{i,2007}$ as the instrument for R&D. With homogenous treatment effects, IV delivers the causal effect of R&D on patents under the exclusion restriction that the threshold indicator $E_{i,2007}$ does not affect innovation outputs through any other channel.[20]

Estimation of R&D spillovers. The main economic rationale given for more generous tax treatment of R&D is that there are technological externalities, so the social return to R&D exceeds the private return. Our design allows us to estimate the causal impact of tax policies on R&D spillovers, i.e. the innovation of *other* firms. Following the work of Jaffe (1986) we calculate the knowledge spillover pool available to firm *i* as $SpilltechRD_{i,09\text{-}11} = \sum_{j \neq i} \omega_{ij} rd_{j,09-11}$ where $rd_{j,09\text{-}11}$ is the average R&D of firm *j* over 2009-11 and ω_{ij} is measure of technological "proximity" between firms *i* and *j* as indicated by which technology classes a firm patents in (e.g. if two firms have identical distributions of patent classes then proximity is 1 and if they are in entirely different patent classes the proximity is zero).[21] We follow our earlier approach of using $E_{j,2007}$ as instrument for $rd_{j,09\text{-}11}$ where $E_{j,2007}$ is the below-asset-threshold dummy in 2007 for firm *j*. Consequently, we construct $SpilltechSME_{i,09\text{-}11} = \sum_{j \neq i} \omega_{ij} E_{j,2007}$ as instrument for $SpilltechRD_{i,09\text{-}11}$. The exclusion restriction requires that the discontinuity-induced random fluctuations in firm *j's* eligibility would only affect connected firm *i*'s R&D and innovation outputs through R&D spillovers.

Our spillover IV regression estimates the impact of $SpilltechRD_{i,09\text{-}11}$ on firm *i*'s innovation,

[20] With heterogeneous treatment effects, IV requires a monotonicity assumption that moving a firm's size slightly below the threshold always increases R&D. In this case, γ_3 is the Average Causal Response (Angrist and Imbens 1995), a generalization of the Local Average Treatment Effect that averages (with weights) over firms' causal responses of innovation outputs to small changes in R&D spending due to the IV.

[21] Following Jaffe (1986) we define proximity as the uncentered angular correlation between the vectors of the proportion of patents taken out in each technology class $\omega_{ij} = \frac{F_i F_j'}{(F_i F_i')^{\frac{1}{2}} (F_j F_j')^{\frac{1}{2}}}$. $F_i = (F_{i1}, \ldots, F_{i\Upsilon})$ is a $1 \times \Upsilon$ vector where $F_{i\tau} = \frac{n_{i\tau}}{n_i}$ is firm i's number of patents in technology field τ as a share of firm i's total number of patents.

$pat_{i,09\text{-}11}$, controlling for firm i's own R&D using $E_{i,2007}$ as an instrument:

$$pat_{i,09-11} = \alpha_4 + \delta spilltechRD_{i,09-11} + G_i(z_{2007}) + \theta E_{i,2007} + f_4(z_{i,2007}) + \lambda techconnect_i + \varepsilon_{4i} \quad (4)$$

where $G_i(\boldsymbol{z}_{2007}) = \sum_{j \neq i} \omega_{ij} g(z_{j,2007})$ and $\boldsymbol{z}_{2007}$ is a vector comprising of the 2007 assets for all firms; $f_4(z_{i,2007})$ and $g(z_{j,2007})$ are polynomials of firms i and j's total assets in 2007; and $techconnect_i = \sum_{j \neq i} \omega_{ij}$.[22] We instrument $spilltechRD_{i,09-11}$ with $spilltechSME_{i,2007}$. $G_i(\boldsymbol{z}_{2007})$ and $f_4(z_{i,2007})$ are polynomial controls for $spilltechSME_{i,2007}$ and $E_{i,2007}$ respectively while $techconnect_i$ additionally controls for firm i's level of "connectivity" in technology space.

In addition to equation (4), we also plan to examine an alternative "dyadic" specification to estimate R&D spillovers on innovations:

$$pat_{i,09-11} = \alpha_5 + \kappa E_{j,2007} + g_5(z_{j,2007}) + \mu z_{i,2007} + \varepsilon_{5ij} \quad (5)$$

where each observation is a pair of technologically-connected firm i and firm j that share the same main technology field (the technology field in which the firm files the most patents) or have high enough Jaffe technological proximity (as described earlier). In this specification, we are interested in the spillover effect of firm j's R&D instrument $E_{j,2007}$ on firm i's patents, controlling for firm i's own 2007 total assets. Focusing on more closely connected dyads should improve precision which can be an issue in RD Design approaches to estimating peer effects (see Dahl, Loken and Mogstad, 2014 or Angrist, 2014). Furthermore, this approach allows us to more directly test the hypothesis that spillovers are stronger among smaller and tighter firm networks (as measured by the number of and proximity between firms in networks of technologically-connected firms).

Besides spillovers in technology space, there may be some negative R&D spillovers through business stealing effects among firms in similar product markets. To address this concern, we will follow Bloom et al. (2013) and construct $spillsicRD_{i,09-11} = \sum_{j \neq i} \phi_{ij} rd_{j,09-11}$ that captures the

[22] Given an RD Design equation for firm j's R&D as $rd_{j,09-11} = \alpha + \beta_{FS} E_{j,2007} + g(z_{j,2007}) + \varepsilon_j$, aggregating across all connected firm j's around the SME asset threshold and using ω_{ij} as weights gives $\sum_{j \neq i} \omega_{ij} rd_{j,09-11} = \alpha \sum_{j \neq i} \omega_{ij} + \beta_{FS} \sum_{j \neq i} \omega_{ij} E_{j,2007} + \sum_{j \neq i} \omega_{ij} g(z_{j,2007}) + \sum_{j \neq i} \omega_{ij} \varepsilon_j$. Rewritten as $spilltechRD_{i,09-11} = \alpha \sum_{j \neq i} \omega_{ij} + \beta_{FS} spilltechSME_{i,2007} + G_i(\boldsymbol{z}_{2007}) + \eta_i$, this equation shows that $G_i(\boldsymbol{z}_{2007})$ is the appropriate polynomial control when using $spilltechSME_{i,2007}$ as instrument for $spilltechRD_{i,2007}$. The key condition that $\eta_i = \sum_{j \neq i} \omega_{ij} \varepsilon_j$ is mean independent of $spilltechSME_{i,2007}$ conditional on $G_i(\boldsymbol{z}_{2007})$ follows from RD Design results. To address non-trivial serial correlation among the error term $\eta_i = \sum_{j \neq i} \omega_{ij} \varepsilon_j$, we bootstrap the standard errors.

R&D spillovers in product market space, where ϕ_{ij} is a measure of product market distance between firms i and j.[23] We also construct $spillsicSME_{i,2007} = \sum_{j \neq i} \phi_{ij} E_{i,2007}$ as instrument for $spillsicRD_{i,09-11}$.

6. Related literature

In terms of the existing literature, some papers have examined the causal impact of other types of innovation policy on R&D and other outcomes. Rao (2016) is also closely related as she uses administrative tax data and looks at the impact of US tax credits on R&D (but not other firm outcomes). In her approach she uses the changes in the Federal tax rules interacted with lagged firm characteristics to generate instrumental variables for the firm-specific user cost of R&D. A few papers have used ratings given to grant applications as a way of generating exogenous variation around funding thresholds. Jacob and Lefgren (2010) and Azoulay et al. (2014) examine NIH grants; Ganguli (2017) at grants for Russian scientists and Bronzini and Iachini (2014) and Bronzini and Piselli (2014) study firm R&D subsidies in Italy.[24] Probably closest to our study is Howell (2017) who uses the ranking of US SBIR proposals for energy R&D grants. She finds significant effects of R&D grants on future venture capital funding and patents. None of these papers have examined tax incentives. Other papers have looked at the impact of R&D tax credits on non-R&D outcomes without an RD Design. For example, Bøler, Moxnes and Ulltveit-Moe (2015) employ a difference-in-differences strategy to investigate how the introduction of R&D tax credit in Norway affects profits, intermediate imports and R&D.[25]

Our paper also contributes to the literature on the effects of R&D on innovation (e.g. Hall, Mairesse and Mohnen, 2010; Doraszelski, and Jaumandreu, 2013). More broadly, we provide evidence on the role of tax on a particular kind of investment (Hall and Jorgenson, 1967; Hassett and Hubbard, 2002).

[23] For example, $\phi_{ij} = 1$ if firm i operates in the same industry as firm j and $\phi_{ij} = 0$ otherwise. These data are available from FAME.

[24] The authors look at the impacts of R&D subsidies on investment and patents in Northern Italy in an RD Design (they do not have R&D data). In their setting the running variable is determined on the basis of scoring the project applications by a committee of experts. They observe a discontinuity in the score distribution around the eligibility cut-off, which they interpret as a sign of program managers being able to assign higher scores for projects just below the cut-off to avoid appeals.

[25] See also Czarnitki, Hanel, and Rosa (2011), Cappelen, Raknerud, and Rybalka (2012) and Bérubé and Mohnen (2009) who look at the effects of R&D tax credits on patents and/or new products. Branstetter and Sakakibara (2002) examine Research Joint Ventures and patents.

7. Potential value of the research

Fiscal incentives for R&D have become an increasingly popular policy of supporting innovation across the world. But little is known about whether these costly tax breaks causally raise innovation. This study has the potential to uncover strong evidence that such a policy can cause an economically and statistically significant increase in R&D and patenting (even after quality-adjusting), so R&D tax policies are not simply devices for relabeling existing spending. We can further calculate the elasticity of R&D with respect to changes in its (tax adjusted) user cost, and compare it with measures from the extant literature. Finally, it is important to estimate the size of technology spillovers due to the tax policies to fully evaluate their impacts.

8. Planned activities

The funds are requested to support Trang Nguyen who is the junior graduate student on the research to visit MIT January to July 2018 to work on the project.

9. Track record of investigators

Van Reenen is one of the world's leading researchers on innovation and productivity. Trang Nguyen is a PhD researcher at LSE, but has already proven herself to be a rising star, having already published important work.

10. Budget plan

The cost of supporting Trang Nguyen includes monthly living expenses, health and other employer costs and MIT registration fee for spring 2018 semester. In addition there are travelling and moving costs. These will be around $28,000. We request $20,000 from the grant with the rest being made up from Van Reenen's personal research account funds.

11. References

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