Public Support for R&D and Innovation: Are Grants and Tax Credits Complements or Substitutes?

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Motivation

- Innovation is vital for transitioning to a clean energy system at low cost
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- Various policies can provide incentives for environmentally-friendly innovation
  - Pricing natural capital and induced innovation, early-stage deployment subsidies, etc.

Schematic of the Innovation System (IEA, 2008)
Motivation

• Innovation is vital for transitioning to a clean energy system at low cost

• Various policies can provide incentives for environmentally-friendly innovation
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Schematic of the Innovation System (IEA, 2008)
Overview

• **Today’s focus**: public funding for research and development (R&D), and spending such resources *wisely*

• Economic justification for clean energy public R&D funding, and optimal R&D spending for clean energy

• **An empirical example:**
  • How do R&D support schemes in the UK impact innovation of private firms?
  • Preview of results: it depends
Economic Justification for Public R&D Support

- Knowledge (technological) spillovers
  - Firms innovate, and then other firms can acquire that information without paying for it
  - Spillovers are the non-appropriable parts of knowledge that are produced by a firm’s innovation

- Large wedge between social and private benefits of innovation

- Competitive markets under-incentivize private investment in innovation

- Public expenditures to support innovation should be equal to the size of knowledge spillovers (Goulder and Schneider, 1999)
Economic Justification for Public R&D Support

Low-carbon tech spillovers versus other emerging fields

Note: The y-axis is the percentage difference in intensity of knowledge spillovers relative to the average, so a value of 0.2 means that the tech induced 20% more knowledge spillovers than the avg. patented technology.

Source: Dechezlepretre et al. (2014).
Economic Justification for Public R&D Support

Low-carbon tech spillovers versus other emerging fields

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- R&D is currently massively under funded
  - “Mission Innovation” commitment to double public R&D spending on clean energy 2021—this is still not quite enough
  - Evidence suggests support should increase by at least fivefold (Nemet and Kammen, 2007; Pless et al., in preparation)
  - Environmental externalities justify even more spending
More funding doesn’t necessarily mean more innovation

Source: Pless et al. (in preparation)
Understanding What Works and Why

I used to think correlation implied causation.

Then I took a statistics class. Now I don't.

Sounds like the class helped. Well, maybe.
Challenges Measuring Innovation Policy Effectiveness

1. Measuring Innovation Outcomes

2. Estimating Causal Effects

3. Understanding Policy Interactions

4. Accounting for Response Timing Lags
Evidence so far in the literature

- Large literature on input additionality
  - Bloom et al. (2002), Duguet (2010), Lokshin and Mohnen (2012), others
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  - Closest to this study is Dechezleprêtre et al. (2016) who find large effects of the UK's R&D tax scheme on patenting
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- No empirical studies that convincingly disentangle the effects of grants and tax credits to study the two simultaneously
First, how does R&D grant generosity impact innovation outcomes?

- Quasi-experimental research design based upon firm size thresholds
- Importantly, some of these thresholds do not coincide with the thresholds for tax credit generosity
Research Question and Contribution

• First, how does R&D grant generosity impact innovation outcomes?
  • Quasi-experimental research design based upon firm size thresholds
  • Importantly, some of these thresholds do not coincide with the thresholds for tax credit generosity

• Then, how does tax credit generosity impact the grant effect?
  • Exogenous shocks to generosity based upon changes in tax credit generosity and SME threshold
  • Difference-in-discontinuities approach
• First, how does R&D grant generosity impact innovation outcomes?
  • Quasi-experimental research design based upon firm size thresholds
  • Importantly, some of these thresholds do not coincide with the thresholds for tax credit generosity

• Then, how does tax credit generosity impact the grant effect?
  • Exogenous shocks to generosity based upon changes in tax credit generosity and SME threshold
  • Difference-in-discontinuities approach

- First quasi-experimental study that disentangles indirect and direct R&D funding impacts
- Focus on small firms
Institutional Details

- **UK State Aid (direct grants) for R&D**
  - Since 2003, thresholds based upon firm size determine grant generosity
  - Natural treatment group of firms just below the thresholds
  - Firm size thresholds are as good as randomly assigned at the cutoffs so long as firms cannot precisely manipulate firm size

<table>
<thead>
<tr>
<th>Applicant Business Size</th>
<th>Fundamental Research</th>
<th>Feasibility Studies</th>
<th>Industrial Research</th>
<th>Experimental Development</th>
</tr>
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<tbody>
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<td>100%</td>
<td>70%</td>
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<td>45%</td>
</tr>
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</tr>
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- **Grant Generosity for State Aid in the UK**

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- **UK R&D Tax Relief for Corporation Tax**
  - Reduces corporate tax liabilities based upon R&D expenditures
  - Large public expenditure—in 2013, the policy cost the UK government 1.4bn GBP (Fowkes et al., 2015)
  - Substantial changes to tax credit generosity were made in 2008—enhanced deductions of 50% until 2008, then 75% from 2008, 100% from 2011, and 125% from 2012
Overview of Data

- Firm-level surveys and business microdatasets from UK Office of National Statistics from 2004 to 2014

- UK Innovation Survey
  - Data from large sample of businesses about innovation related activities
  - Various industrial sectors and regions in UK

- Business Structure Database
  - Covers nearly all businesses in the UK
  - Importantly, provides enterprise-level employment data
### Innovation Outcomes Around Grant Generosity Threshold, Small Firms

<table>
<thead>
<tr>
<th></th>
<th>Means</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-2008</td>
<td>Post-2008</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>A. Firms with 25 to 49 Employees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Products innovation</td>
<td>0.417</td>
<td>0.531</td>
</tr>
<tr>
<td>Services innovation</td>
<td>0.350</td>
<td>0.541</td>
</tr>
<tr>
<td>Processes innovation</td>
<td>0.343</td>
<td>0.411</td>
</tr>
<tr>
<td><strong>B. Firms with 50 to 75 Employees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Products innovation</td>
<td>0.405</td>
<td>0.495</td>
</tr>
<tr>
<td>Services innovation</td>
<td>0.385</td>
<td>0.433</td>
</tr>
<tr>
<td>Processes innovation</td>
<td>0.319</td>
<td>0.414</td>
</tr>
</tbody>
</table>

**Notes:** Innovation outcomes are averaged by group based upon binary survey responses, where a 1 is indicated if innovated and a 0 otherwise. Descriptive statistics are provided based upon sub-samples around the firm employment threshold of 50. Asterisks denote *p < 0.10, **p < 0.05, ***p < 0.01.
Graphical Evidence

Average Goods & Services Innovation of Small Firms, 2006-2014

Source: Created by author using data from the UK Community Innovation Survey and Business Structure Databases, Department for Business, Innovation and Skills, Office for National Statistics
Graphical Evidence

Average Innovation of Small Firms, Goods Only, 2006-2014

Source: Created by author using data from the UK Community Innovation Survey and Business Structure Databases, Department for Business, Innovation and Skills, Office for National Statistics
Graphical Evidence

Average Innovation of Small Firms, Services Only, 2006-2014

Source: Created by author using data from the UK Community Innovation Survey and Business Structure Databases, Department for Business, Innovation and Skills, Office for National Statistics
Econometric Framework—Grant Generosity Effects

\[ \text{Innovation}_i = \alpha + \beta_1 J_i + \gamma_0 P_i^* + \gamma_1 J_i P_i^* + \varepsilon_i \]  

- Innovation is whether firm had new or significantly improved products, services, or processes
- \( J \): threshold treatment (equal to 1 if firm is under threshold)
- \( P_i^* = P_i - P_c \)
- Only use data from a narrow window around the thresholds
- Coefficient of interest is \( \beta_1 \), which captures treatment effect
  - Estimates the causal effect of the difference in grant generosity
- Identification is guaranteed when firms cannot manipulate the running variable
Econometric Framework—Policy Interaction Effects

\[ I_i = \alpha_0 + \alpha_1 P^*_i + J_i(\gamma_0 + \gamma_1 P^*_i) + T_t[\alpha_0 + \alpha_1 P^*_i + J_i(\beta_0 + \beta_1 P^*_i)] + \epsilon_i \]  

(2)

- \( \beta_0 \) is the difference-in-discontinuities estimator
  - Estimates the causal effect of the tax credit policy on grant generosity effectiveness
- \( J \): threshold treatment (equal to 1 if firm is under threshold)
- \( T \): time of tax credit policy change (equal to 1 if post-2008)
- \( P^*_i = P_i - P_c \)
- Only use data from a narrow window around the thresholds
- Identification is guaranteed when firms cannot manipulate the running variable
No Evidence of Firm Size Manipulation

Density of Firms Around 50 Employee Threshold, 2006-2014

Source: Created by author using data from the UK Community Innovation Survey and Business Structure Databases, Department for Business, Innovation and Skills, Office for National Statistics
No Evidence of Firm Size Manipulation

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## Main Results

**Innovation Outcomes for Small Firms, Marginal Effects, 2006-2014**

<table>
<thead>
<tr>
<th></th>
<th>Goods</th>
<th>Services</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Grant Generosity Only</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1[employment &lt; 50]</td>
<td>0.020</td>
<td>-0.024</td>
<td>-0.081</td>
</tr>
<tr>
<td></td>
<td>(0.088)</td>
<td>(0.085)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>3,765</td>
<td>3,761</td>
<td>3,761</td>
</tr>
<tr>
<td><strong>B. Difference-in-Discontinuities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1[year = post 2008] * 1[employment &lt; 50]</td>
<td>0.070</td>
<td>0.176***</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.065)</td>
<td>(0.062)</td>
</tr>
<tr>
<td>1[year = post 2008] * 1[employment &lt; 50] * $P_i^*$</td>
<td>-0.001</td>
<td>-0.002</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>3,765</td>
<td>3,761</td>
<td>3,761</td>
</tr>
</tbody>
</table>

**Notes:** Dependent variable is dummy indicator if firm introduced a new or significantly improved good, service, or process. Controls for first order polynomials of the (centered) running variable (employment) are included separately for each side of the threshold. Specifications also include dummies for size threshold, size threshold by centered employment, treatment year (equal to one if the year is post-2008), and treatment year by centered employment. Standard errors are clustered at the industry level. Asterisks denote *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.**
## Innovation Outcomes for Small Firms, Marginal Effects, 2006-2014

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<tr>
<td><strong>A. Firms with &lt;100 Employees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1[employment &lt;50]</td>
<td>0.046</td>
<td>0.217***</td>
<td>-0.016</td>
</tr>
<tr>
<td></td>
<td>(0.051)</td>
<td>(0.044)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>9,712</td>
<td>9,705</td>
<td>9,709</td>
</tr>
<tr>
<td><strong>B. Firms with 40 to 60 Employees</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1[year = post 2008] * 1[employment &lt;50]</td>
<td>0.036</td>
<td>0.181*</td>
<td>-0.011</td>
</tr>
<tr>
<td></td>
<td>(0.110)</td>
<td>(0.097)</td>
<td>(0.093)</td>
</tr>
<tr>
<td>1[year = post 2008] * 1[employment &lt;50] * $P_i$</td>
<td>-0.008</td>
<td>-0.019</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.016)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>1,424</td>
<td>1,421</td>
<td>1,420</td>
</tr>
</tbody>
</table>

**Notes:** Dependent variable is dummy indicator if firm introduced a new or significantly improved good, service, or process. Controls for first order polynomials of the (centered) running variable (employment) are included separately for each side of the threshold. Specifications also include dummies for size threshold, size threshold by centered employment, treatment year (equal to one if the year is post-2008), and treatment year by centered employment. Standard errors are clustered at the industry level. Asterisks denote *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.}
Accounting for Timing Lags: Tax Credits Only, Medium-Sized Firms

### Innovation Outcomes for Medium-Sized Firms, Marginal Effects, 2008-2014

<table>
<thead>
<tr>
<th>Panel A: Impact on Different Types of Innovation</th>
<th>Goods</th>
<th>Services</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1[employment &lt;500]</td>
<td>0.045</td>
<td>-0.011</td>
<td>-0.051</td>
</tr>
<tr>
<td></td>
<td>(0.070)</td>
<td>(0.067)</td>
<td>(0.074)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Impact on Goods Innovations by Year</th>
<th>Goods</th>
<th>Services</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1[employment &lt;500]</td>
<td>0.032</td>
<td>-0.103</td>
<td>0.215***</td>
</tr>
<tr>
<td></td>
<td>(0.131)</td>
<td>(0.098)</td>
<td>(0.109)</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>345</td>
<td>372</td>
<td>421</td>
</tr>
</tbody>
</table>

Notes: Dependent variable is dummy indicator if firm introduced a new or significantly improved good, service, or process. Firms with 250 to 750 employees are included. Controls for first order polynomials of the (centered) running variable (employment) are included separately for each side of the threshold. Standard errors are clustered at the industry level. Asterisks denote * \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \).
Conclusions & Continued Work

- Economic theory justifies substantial research subsidies—important to know whether to allocate funds to more generous grants or tax credits

- For small firms, generosity of grants and tax credits appear to be complementary for some types of innovations (services) but not others

- It’s also important to account for timing lags when examining innovation policy impact

- Continued work:
  - Investigate explanations for why grants and tax credits are complementary in certain settings but not others
  - Explore other measures of innovation and impacts on firms, including behavioural additionality
  - Examine joint impacts on spillovers
Back-up