How Special is the Special Relationship?  
Using the impact of US R&D spillovers on UK firms 
as a test of “Technology Sourcing”

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Introduction

• International technology transfer is at the centre of global 
economic growth, but micro-econometric evidence on how it 
occurs is thin

• We test the “technology sourcing” hypothesis: firms gain access 
to international technology spillovers by locating their R&D labs 
close to leading edge research

• Crucial role of patent statistics matched to firm-level data: 
  – The geographical distribution of firms’ innovation activities 
    (using the location of inventors)
  – The nature of firms’ foreign innovation activities 
    (using citation information)
Research Strategy

• The question: to what extent does locating their research labs in the US enable UK firms to access spillovers from US R&D?

• The “experiment”: did the productivity of UK firms with a higher share of inventors in the US (by 1990) respond more strongly to the 1990-2000 growth in US R&D in their industry?

• The UK is a good test case for “technology sourcing”:
  – Behind the technological frontier (40% lower labour productivity than the US) so ‘lots to learn’
  – Strong historical linkages with the US – lots of cross-firm variation in FDI into the US

• Symmetrical test for US firms with inventors in the UK

Summary of Results

• Find strong evidence that UK firms benefit far more from US R&D spillovers if they have inventors located in the US

• UK manufacturing productivity (TFP) would be 5% lower in 2000 without 1990s growth in US R&D

• The benefits of “technology sourcing” are larger where the investing firm has ‘more to learn’:
  – Effects are stronger in UK industries that have a larger productivity gap with the US
  – Effects are much weaker for US firms with inventors in the UK (i.e. statistical and economic significance is low)

• Policy relevance?
  – No such thing as a completely free lunch…
  – EU Lisbon 3% target for R&D intensity…
Literature on international spillover mechanisms

- **Geographical proximity**: Evidence from patent citations (e.g. Jaffe et al, 1993; Jaffe and Trajtenberg, 2002) but little evidence within firms across countries.

- **International trade**: Learning from importing (e.g. Coe and Helpman, 1995) or exporting (e.g. MacGavie, 2004)

- **Foreign Direct Investment**: Mainly inward FDI (e.g. Keller and Yeaple, 2003) - we look at “outward” FDI of a specific kind


- We look at citations and firm-level productivity outcomes

A Simple Model

- A firm’s stock of “knowledge” is a key determinant of its productivity (Griliches, 1979, 1998)

- **Internal** stock of knowledge (e.g. from own R&D) and **external** pools of available knowledge (e.g. from other firms’ R&D)

\[
\text{TFP} = F(\text{“internal”, “domestic external”, “foreign external”})
\]

- **International spillovers**: Is the impact of the “foreign external” pool of available knowledge positive and significant?

- **“Technology sourcing”**: Is the impact of the “foreign external” pool of available knowledge a function of the geographical location (and type) of the firm’s innovation activity?
Econometric Specification

- Augmented Cobb-Douglas production function for a panel of UK firms (1990-2000):

\[ y_{it} = \alpha_i l_{it} + \alpha_k k_{it} + \beta r_{it} + \theta_1 \text{domestic}_{jt} + \phi_1 \text{foreign}_{jt} \]

\[ + \theta_2 (W_{i0}^\text{UK} \ast \text{domestic}_{jt}) + \phi_2 (W_{i0}^\text{US} \ast \text{foreign}_{jt}) \]

\[ + \theta_3 W_{i0}^\text{UK} + \phi_3 W_{i0}^\text{US} + u_{it} \]

- Test for technology sourcing: does US R&D have a larger effect when the firm has a higher proportion of its innovation activity in the US?

- Symmetrical estimation for a panel of US firms
Patent Data

- Patent data provides the crucial information on the location and nature of firms’ innovation activity

- USPTO data manually matched to a panel of 188 firms listed on the London Stock Exchange

- Use “Who Owns Whom” in 1985 to match patent assignees to parent firms

- Use information on country location of inventors (UK and US) and citations

Location of Lead Inventors

- Our basic measure of the location of firms’ innovative activity is based on the country of the lead inventor

- For example $W_j^{US}$ is measured as the proportion of the firm’s total pre-sample (1975-1989) patents where the lead inventor is located in the US

- Using pre-sample information ensures that the location measures are not affected by shocks that affect firm-level outcomes during the sample period (1990-2000)

- But at a cost – location information likely to be more noisy
### Location of Lead Inventors

<table>
<thead>
<tr>
<th>Country of Lead Inventor</th>
<th>Patents matched to our UK firms</th>
<th>% of patents matched to our UK firms</th>
<th>% of patents matched to our US firms</th>
<th>% of all USPTO patents</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>14,058</td>
<td>36.8</td>
<td>1.1</td>
<td>3.0</td>
</tr>
<tr>
<td>USA</td>
<td>14,856</td>
<td>38.9</td>
<td>92.3</td>
<td>55.7</td>
</tr>
<tr>
<td>Japan</td>
<td>2,886</td>
<td>7.6</td>
<td>1.5</td>
<td>18.8</td>
</tr>
<tr>
<td>Germany</td>
<td>1,647</td>
<td>4.3</td>
<td>1.3</td>
<td>7.9</td>
</tr>
<tr>
<td>France</td>
<td>1,117</td>
<td>2.9</td>
<td>0.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Other</td>
<td>3,596</td>
<td>9.4</td>
<td>2.9</td>
<td>11.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38,160</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

#### Diagram: Average % of UK firms' lead inventors located in the UK and US

- **Avg. % of UK lead inventors**
- **Avg. % of US lead inventors**
Other Inventors?

- Question: does the geographical distribution of lead inventors of a firm’s patents give an accurate measure of the location of its innovation activity?

- In particular, what about other inventors, i.e. inventors from different countries listed on the *same patent*?

- Are we missing an important aspect of international collaboration by not using *all* inventors?
The *nature* of foreign innovation activity

- The literature distinguishes (at least) two motivations for locating R&D abroad:
  - “Technology Sourcing”
  - Adapting existing products to new foreign markets

- We use information in *citations* to refine our location measures so that they reflect “technology sourcing” innovation

- We assume that a patent owned by a UK firm but invented by an inventor located in the USA is more likely to be associated with “technology sourcing” behaviour if it *cites* other patents that were
  - not owned by the same firm (i.e. not self citations),
  - invented in the USA,
  - and (possibly) invented recently – more likely to be tacit

Increasingly refined location measures

- **(1) Basic location weight**: the proportion of a firm’s total (pre-sample) patents where the lead inventor was located in the US

- **(2) Location and citation**: the proportion of the firm’s total (pre-sample) patents where:
  - the lead inventor was located in the US
  - the patent cites at least one other patent whose lead inventor was located in the USA and which is not owned by the same parent firm

- **(3) Location and citation within 3 years**: the proportion of the firm’s total (pre-sample) patents where:
  - the lead inventor was located in the US
  - the patent cites at least one other patent *that was applied for within the last three years*, whose lead inventor was located in the USA, and which is not owned by the same parent firm
UK Firms: Production Function Results (Table 3)

<table>
<thead>
<tr>
<th>Estimation Method</th>
<th>OLS</th>
<th>OLS</th>
<th>GMM</th>
<th>GMM</th>
<th>GMM</th>
<th>Olley-Pakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>ln (Y)</td>
<td>ln (Y/K)</td>
<td>ln (Y/K)</td>
<td>ln (Y/K)</td>
<td>ln (Y/K)</td>
<td>ln (Y)</td>
</tr>
<tr>
<td>Location Weight, W</td>
<td>-</td>
<td>Location</td>
<td>Location</td>
<td>Location &amp; Citation</td>
<td>Location &amp; Citation</td>
<td>Location &amp; Citation</td>
</tr>
<tr>
<td>ln (UK R&amp;D)</td>
<td>0.657</td>
<td>0.648</td>
<td>0.647</td>
<td>0.642</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(0.046)</td>
<td>(0.065)</td>
<td>(0.065)</td>
<td>(0.067)</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln (US R&amp;D)</td>
<td>0.620</td>
<td>0.343</td>
<td>0.029</td>
<td>0.076</td>
<td>0.066</td>
<td>0.084</td>
</tr>
<tr>
<td>(0.057)</td>
<td>(0.042)</td>
<td>(0.008)</td>
<td>(0.007)</td>
<td>(0.011)</td>
<td>(0.01)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>ln (R&amp;D)</td>
<td>0.343</td>
<td>0.312</td>
<td>0.026</td>
<td>0.035</td>
<td>0.026</td>
<td>0.092</td>
</tr>
<tr>
<td>(0.042)</td>
<td>(0.007)</td>
<td>(0.011)</td>
<td>(0.022)</td>
<td>(0.028)</td>
<td>(0.095)</td>
<td>(0.291)</td>
</tr>
<tr>
<td>ln (US R&amp;D)</td>
<td>0.026</td>
<td>0.059</td>
<td>0.063</td>
<td>0.005</td>
<td>0.005</td>
<td>0.273</td>
</tr>
<tr>
<td>(0.065)</td>
<td>(0.065)</td>
<td>(0.066)</td>
<td>(0.038)</td>
<td>(0.165)</td>
<td>(0.101)</td>
<td>(0.101)</td>
</tr>
</tbody>
</table>

Economic Magnitudes

- The increase in the US R&D stock over 1990-2000 is associated with an average 5% higher productivity (TFP) in our UK firms by 2000, with larger gains in industries further behind the frontier.

- This compares with an average 6.5% higher level of TFP associated with the increase in their own internal R&D stocks.

- Shifting 10% of a firm’s innovation activity (as measured by successful patent applications) from the UK to the US while keeping its overall R&D stock the same is associated with an increase in its level of TFP of about 4%.

- For US firms there is evidence of domestic spillovers, but no statistical evidence of “technology sourcing” from the UK.
Further Investigations

- We investigate whether these results are robust to a number of measurement and specification issues

- In particular: is it possible that our measures of the location of innovation activity are acting as proxies for other (unobservable) firm-level characteristics?

- For example: “absorptive capacity”, “technological proximity”

- We test for this by constructing various measures of “absorptive capacity” and “technological proximity” and including them in the same way as our location measures

- We also use citation behaviour to corroborate our main results

Conclusions

- First evidence for “technology sourcing” effects on firm-level productivity outcomes – a potentially important channel for international technology diffusion and economic growth

- Patent data provide key information on the geographical distribution and nature of firms’ innovation activity

- Policy implications
  - No such thing as a completely free lunch…
  - EU Lisbon 3% target for R&D intensity…

- Possible extensions:
  - Other countries, EPO data etc…
  - Modeling and testing the determinants of R&D location decisions