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

Rachel Griffith (Institute for Fiscal Studies and UCL)

Rupert Harrison (Institute for Fiscal Studies and UCL)

John Van Reenen (Centre for Economic Performance and LSE)

1

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)

2

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

3

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…

4

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
- *"Technology sourcing":* evidence from patent citations, e.g. Bransetter (2004) on US affiliates of Japanese firms.
- We look at citations *and* firm-level productivity outcomes

5

A Simple Model

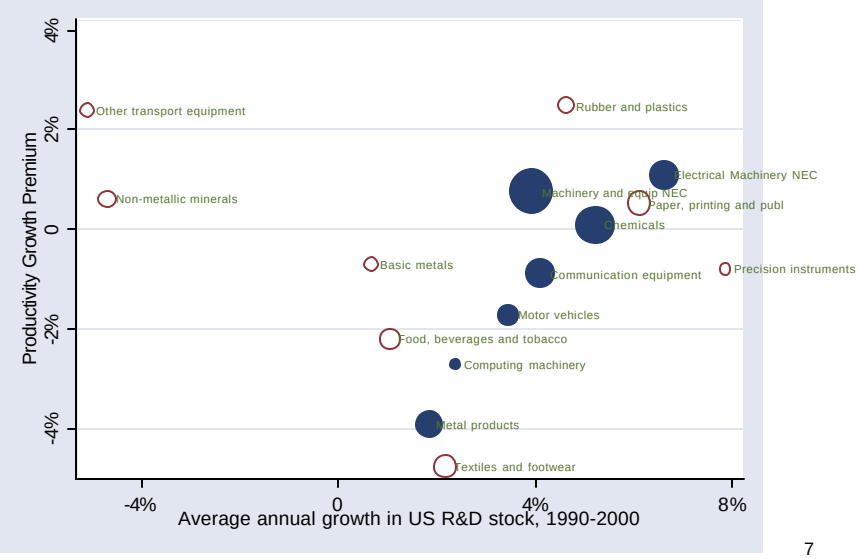
- A firm's stock of "knowledge" is a key determinant of its productivity (Griliches, 1979, 1998)
- *Internal* stock of knowledge (e.g. from own R&D) and *external* pools of available knowledge (e.g. from other firms' R&D)

TFP = F("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?

6

A Simple Graphical Illustration



7

Econometric Specification

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

$$y_{it} = a_l l_{it} + a_k k_{it} + b r_{it} + q_1 domestic_{jt} + f_1 foreign_{jt}$$
$$+ q_2 (W_{i0}^{UK} * domestic_{jt}) + f_2 (W_{i0}^{US} * foreign_{jt})$$
$$+ q_3 W_{i0}^{UK} + f_3 W_{i0}^{US} + u_{it}$$

- 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

8

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*

9

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_i^{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

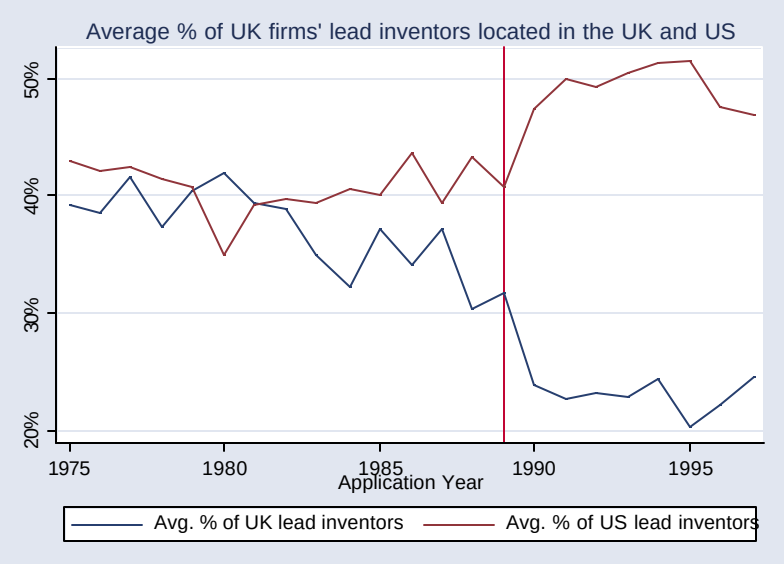
10

Location of Lead Inventors

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

11

Location of Lead Inventors



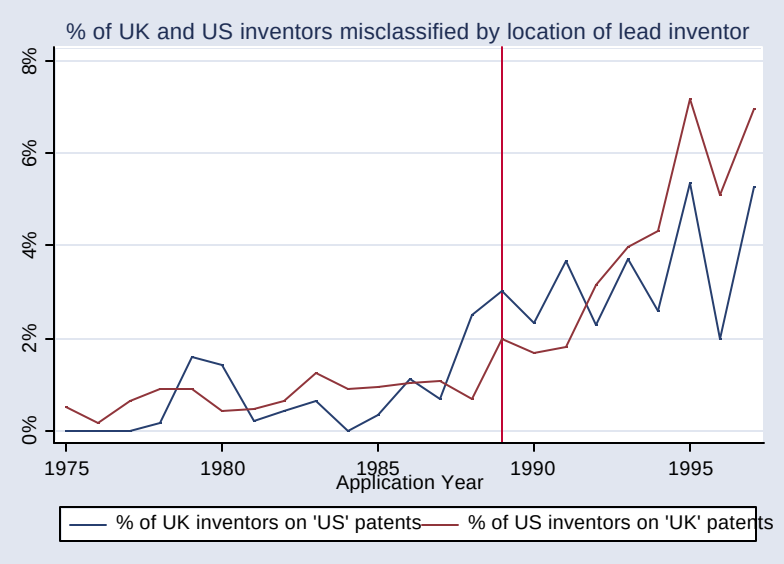
12

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?

13

Other Inventors?



14

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

15

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

16

UK Firms: Production Function Results (Table 3)

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation Method	**OLS**	**OLS**	**GMM**	**GMM**	**GMM**	**Olley-Pakes**
Dependent variable	**ln (Y) $_{it}$**	**ln (Y/K) $_{it}$**	**ln (Y/K) $_{it}$**	**ln (Y/K) $_{it}$**	**ln (Y/K) $_{it}$**	**ln (Y) $_{it}$**
Location Weight, W	-	Location	Location	Location & Citation	Location & Citation within 3 years	Location & Citation within 3 years
ln (L/K) $_{it}$	-	0.657 (0.046)	0.648 (0.065)	0.647 (0.065)	0.642 (0.067)	-
ln (L) $_{it}$	0.620 (0.057)	-	-	-	-	0.555 (0.039)
Ln(K) $_{it}$	0.343 (0.042)	-	-	-	-	0.385 (0.041)
ln (R&D) $_{it,}$	0.029 (0.008)	0.012 (0.007)	0.026 (0.011)	0.025 (0.010)	0.022 (0.010)	0.015 (0.005)
W^{US}* ln (US R&D) $_{jt}$	-	**0.076 (0.024)**	**0.066 (0.035)**	**0.084 (0.031)**	**0.173 (0.054)**	**0.165 (0.062)**
W^{UK}* ln (UK R&D) $_{jt}$	-	0.035 (0.022)	0.026 (0.028)	0.092 (0.095)	0.400 (0.291)	-0.488 (0.557)
ln (US R&D) $_{jt}$	-	0.050 (0.118)	0.065 (0.067)	0.059 (0.065)	0.063 (0.066)	-0.054 (0.038)
ln (UK R&D) $_{jt}$	-	0.273 (0.165)	0.221 (0.101)	0.219 (0.101)	0.206 (0.096)	0.250 (0.083)

17

Economic Magnitudes

- The increase in the US R&D stock over 1990-2000 is associated with on 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

18

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

19

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

20