University-Industry interactions

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Outline of the talk

PART I: University-Industry interactions in context

- Definition and historical trends
- Motivation and barriers
- Some literature on U-I interactions

PART II: University-Industry collaboration and impact on firms' R&D activities

- Literature: relation between U-I collaboration and firms' performance
- Focus: UK publicly-funded collaborations
- Hypotheses: impact on R&D expenditure and R&D employment
- Data: research council data + anonymized firm-level data
- Methodology: the evaluation problem and possible solution
- Results
- Conclusion

PART I

University-Industry interactions in context

Definition

U-I interactions refers to a broad concept identifying a wide set of interactions between firms and universities, aimed at *the exchange of knowledge related to research, science and technology* (OECD, 1998, 2002; Agrawal, 2001)

Examples (see e.g. Geuna and Rossi, 2013; Rossi and Rosli, 2013):

- temporary personnel exchanges between U and I or recruitment of graduates (employment channels)
- patent ownership agreement and licensing (IPR-related interactions)
- U-I collaborative R&D projects, partnerships, consultancy projects and consortia (research collaborations)
- publications, conferences and informal meetings (informal contacts).

History

Nineteenth/early twentieth centuries:

- in Germany, UK, US, Japan there were U-I linkages in the form of industrial labs
- collab with 'land grant' universities, government technology programmes, ...

Aftermath of II WW:

- industry relied heavily on univ for the provision of skilled graduates
- companies supported public research through endowments and gifts

From 1980s onwards:

- globalisation, competition, emphasis on innovation brought about radical changes in U-I relationship
- universities become engaged actors in the economy; public policies provide incentives for both U and I
- declining profits and increasing research costs lead firms to seek support from U

Motivations for U-I interactions

Industry:

- Response to market failures preventing firms from conducting socially optimal level of R&D (appropriability issues and spillovers...)

  (Dasgupta and David, 1994; Martin and Scott, 2000; Salter and Martin, 2001)

- Motivations: **access to research infrastructure and expertise, recruiting opportunities, expanding contacts for labs, reducing/sharing research costs**

  (Hagedoorn, 1993; Steurs, 1995; Cassiman and Veugelers, 2002; Lopez, 2008; Bruneel et al., 2009)

University:

- Pushed by government budgetary constraints leading to decreasing public funding, and higher costs of research

  (Geuna and Muscio, 2009)

- Motivations: **financial support, broadening study/research experience of students/faculty, identifying research problems, employment opportunities, contributing to local economic development**

  (Larsen, 2011; Geuna and Rossi, 2013; Perkmann et al., 2013)

Barriers to U-I interactions

Different **institutional norms** govern science in U and I (Dasgupta and David, 1994)

- goal of U is the creation of public knowledge for the society (**open system**)
- creation of knowledge in I is directed at commercial exploitation and protection from others' potential use (**closed system**)

Diverging **research agenda, timing, incentive structures and disclosure policy** (Bruneel et al., 2010)

- U is traditionally more on basic research; I is oriented towards applied research
- U research agenda is not constrained to short term objectives; I must deliver results within the short term
- Academics' rewards are based on publications, prizes, etc; reward structure of R&D staff in I is not directly linked to results achieved
- U system builds upon the concept of public knowledge and disinterested research; I has a fully non-disclosure policy

Academic research on U-I interactions

FIRMS

- determinants of firms' engagement with U: demographics, internal organisation, resource allocation, research effort

  (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998; Ziedonis, 1999; Audretsch, 2000; Zucker et al., 2000)

- impact of interaction on firms' research and innovation activities and economic performance

  (Becker, 2003; Fritsch and Franke, 2004; Faems et al, 2005, Arvanitis et al., 2008; Lööf & Broström, 2008)

UNIVERSITIES

- determinants of U engagement with I: research quality, univ IPR policies, TTO licensing strategies, charact of inventor/professor

  (Feldman et al., 2002; Thursby and Thursby, 2002; Di Gregorio and Shane, 2003)

- impact on academic research, academic patenting, teaching

  (Henderson et al., 1998; Larsen, 2011)

Academic research on U-I interactions

GEOGRAPHY OF INTERACTIONS

- localised knowledge spillovers: on the spatial relationship bw U and I and knowledge transfer success

  (Jaffe, 1989; Jaffe et al., 1993; Audretsch and Feldman, 1996; Zucker et al., 1998)

- role of geographical proximity for interactions, location decision from public and private perspectives

  (Arundel and Geuna, 2004; Abramovsky et al. 2007; Fritsch and Slavtchev, 2007; D'Este and Iammarino, 2010)

CHANNELS OF KNOWLEDGE TRANSFER

- relative importance of various transfer channels: publications, patents, consulting, employment, research contracts, informal contacts

  Cohen et al., 1998, 2002; Agrawal and Henderson, 2002; Colyvas et al., 2002; Shane, 2002; D'Este and Patel, 2007; D'Este and Perkmann, 2011)

PART II

University-Industry collaboration and firms' R&D effort

Introduction

Research question
What is the impact of U-I collaboration on firms' R&D activities?

Aim
To investigate the impact of collaborative projects funded by the UK Engineering and Physical Sciences Research Council (EPSRC) on:

- *R&D expenditure per employee*
- *share of R&D employment*

Motivation
UK policy makers' emphasis on U-I collaboration; mixed empirical evidence on impact; lack of evidence on EPSRC case

Contribution
New evidence on impact of U-I knowledge exchange on firms; new data on U-I collab + firm data; propensity score matching combined with OLS regression to address selection bias

Literature

On the impact of U-I collaboration on firms:

- **R&D coop., knowledge spillovers** and firm performance: firms collaboration with external actors
- positive impact on innovative output, mixed evidence on productivity
  (Barajas et al, 2011; Benfratello & Sembenelli, 2002; Cincera et al, 2003; Criscuolo & Haskel, 2003; Faems et al, 2005; Monjon & Waelbroek, 2003)

- **U-I knowledge transfer activities**: determinants, characteristics and recently, impact of U-I interactions
- positive impact on R&D input & output
  (Becker, 2003; Belderbos et al, 2004; Arvanitis et al, 2005; 2008; Lööf & Broström, 2008; Medda et al, 2006)

→ No clear effect on R&D input

EPSRC U-I collaboration

- Partnerships aimed at **upstream research**, excluding contract research having well-defined outcome
- Intended **benefits for companies**: financial support for the project, developing relationships with the science base, opportunities for recruiting appropriately trained staff
- Policy issues tackled: systematic **under-investment in knowledge creation** in the society and imbalance between graduates skills and **skills required by business**
- Empirical studies on determinants, types of collaboration and barriers; little on impact on firms
  (D'Este and Fontana, 2007; Bruneel et al., 2009, 2010; D'Este et al, 2012)

Hypotheses

Hp 1: U-I partnerships have a positive effect on R&D expenditure per employee of participating firms

- R&D expenditure is a firm-specific determinant of firms' innovative behaviour (Becker & Dietz, 2004)
- R&D exp per empl takes into account both capital and labour input factors

Hp 2: U-I partnerships have a positive effect on the share of R&D employment in participating firms

- R&D employment share provides concrete measurement of R&D resources (OECD, 2002)
- R&D personnel mirrors the human capital component of R&D that is usually more permanent (Busom, 2000).

Data

Data sources:

- EPSRC U-I projects 1997-2007: 4,990 projects involving 3,331 UK firms
- UK Business Structure Database (BSD): industry, region, employment, turnover
- UK Business Expenditure on R&D survey (BERD): R&D exp., R&D employment

Dataset creation:

- String matching to link firms in EPSRC dataset to unique identifier in BSD (48% matched)
- Match on a yearly basis with firm-level data from BSD and BERD
- Final raw dataset made up of **434 treated firms** and raw sample of 171,769 untreated firms (sample representativeness)

Method: PSM+OLS

Select control group on the basis of pre-treatment characteristics (t-1) via propensity score matching (PSM), then compare performance of treated and untreated firms via OLS reg at t+3 and t+5

- PSM: estimate prob that firms participate to U-I projects in year t (*pscore*), given pre-treatment characteristics at t-1
- with *pscore*, treated firms are matched with non-treated ones: 1:1 and Kernel matching
- pooled cross sectional dataset where a given firm is observed at year t-1, t, t + 3 and t + 5
- OLS: dep vars are **R&D expenditure per employee** and **share of R&D employment**, treatment variable is dummy 1/0 indicating participation to U-I collab

Propensity score estimation: probit model

Table 2
Probit estimations.

Prob. of treatment in year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Employment	0.0012**	0.0004	0.0006***	0.0005***	0.0016***	0.0002**	0.0006**	0.0012***	0.0011*	0.0003	0.0004*
	(0.0005)	(0.0003)	(0.0001)	(0.0001)	(0.0004)	(8.14e−05)	(0.0003)	(0.0003)	(0.0005)	(0.0002)	(0.0002)
Empl squared	−4.46e−07*	−1.26e−07	−5.23e−08**	−3.54e−08*	−6.81e−07**	−4.26e−09*	−8.50e−08	−2.59e−07**	−2.17e−07	−2.44e−08	−2.51e−08
	(2.48e−07)	(1.44e−07)	(2.34e−08)	(1.83e−08)	(2.79e−07)	(2.37e−09)	(7.22e−08)	(1.05e−07)	(1.99e−07)	(3.32e−08)	(1.96e−08)
Lab product	−3.96e−05	−0.0001	5.71e−05	−0.0001	6.34e−05	5.29e−08	1.26e−05	−0.0001	−3.02e−05	1.33e−05	4.58e−05
	(0.0001)	(0.0004)	(6.84e−05)	(0.0002)	(5.19e−05)	(2.38e−06)	(9.79e−05)	(0.0003)	(0.0003)	(1.47e−05)	(0.0001)
Market share	0.733	1.755*	−1.197	0.420	−0.556	1.617*	1.062	0.419	−1.345	0.589	−0.406
	(1.034)	(0.958)	(1.396)	(0.878)	(1.544)	(0.917)	(1.349)	(0.947)	(1.806)	(0.958)	(1.471)
Single plant	−0.0893	−0.0594	−0.267*	−0.137	−0.0634	−0.266*	−0.323**	−0.0606	−0.0136	−0.187	−0.300
	(0.176)	(0.162)	(0.151)	(0.128)	(0.124)	(0.144)	(0.162)	(0.166)	(0.224)	(0.139)	(0.204)
Foreign link	0.432**	0.287	−0.0670	0.154	0.115	0.244	−0.141	0.253*	0.0193	0.288**	0.169
	(0.183)	(0.188)	(0.208)	(0.151)	(0.145)	(0.169)	(0.204)	(0.135)	(0.178)	(0.130)	(0.185)
R&D	0.253*	0.479***	0.225*	0.310***	0.184*	0.234*	0.247*	0.234*	0.367**	0.217*	0.547***
	(0.148)	(0.132)	(0.131)	(0.105)	(0.0968)	(0.128)	(0.137)	(0.122)	(0.171)	(0.124)	(0.210)
Constant	−1.272*	−2.700***	−2.003***	−1.956***	−2.011***	−1.454**	−2.115***	−2.065***	−3.181***	−2.967***	−3.329***
	(0.668)	(0.434)	(0.585)	(0.381)	(0.547)	(0.612)	(0.598)	(0.604)	(0.528)	(0.565)	(0.582)
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6027	7024	6549	9421	11,045	9856	7869	10,887	5440	10,079	6407
ll	−177.8	−214.9	−212.5	−362.7	−416.2	−239.7	−214.6	−277.2	−146.0	−268.2	−129.7
χ^2	84.90	83.97	72.81	139.3	105.5	73.74	73.21	105.2	58.95	72.70	45.54

Outcome variables

Final samples (at t+3):

- 1:1 matching: 434 treated firms + 434 untreated firms = 868
- kernel matching: 434 treated firms + 68,936 untreated firms = 69,370

Table 3
Descriptive statistics of the outcome variables in 1:1 and Kernel matched samples, at $t+3$ and $t+5$.

Outcome variable	Obs.	Mean	St. dev.
1:1 matching			
ln R&D per $empl_{t+3}$	868	1.2495	1.5394
share R&D $empl_{t+3}$	868	0.1387	0.2049
ln R&D per $empl_{t+5}$	747	1.2188	1.5895
share R&D $empl_{t+5}$	747	0.1410	0.1928
Kernel matching			
ln R&D per $empl_{t+3}$	69,370	0.9306	1.4697
share R&D $empl_{t+3}$	69,370	0.1080	0.1445
ln R&D per $empl_{t+5}$	53,552	0.9670	1.3944
share R&D $empl_{t+5}$	53,781	0.1180	0.1543

[a] Minima and maxima have been rounded off or suppressed to comply with ONS confidentiality.

Evaluating the PSM procedure

PSM is satisfactory if mean values or pre-treatment vars across treated and untreated firms do not differ significantly after matching

Test via t-test of pre-treatment vars (mean treated - mean untreated)

⇒ **Only 1:1 sample achieves good matching**

Table 6
Mean comparison and *t*-test after 1:1 (Panel A) and Kernel (Panel B) matching.

Variable	Panel A: 1:1			Panel B: Kernel		
	(1) Mean treated (N = 434)	(2) Mean untreated (N = 434)	(3) Difference	(4) Mean treated (N = 433)	(5) Mean untreated (N = 68, 937)	(6) Difference
R&D	0.6866	0.7442	−0.0576	0.6859	0.4895	0.1964***
Employment	402.2396	392.8963	9.3433	367.86	97.07	270.78***
Empl squared	1,493,846	895,594.5	598,251.5	992,306.4	187,415.1	804,891.3
Lab product	171.01	249.88	−78.87	170.94	241.02	−70.08
Market share	0.0289	0.0308	−0.0018	0.0289	0.0064	0.0224***
Single plant	0.6290	0.6290	0.0000	0.6305	0.8234	−0.1928***
Foreign link	0.3272	0.3433	−0.0161	0.3256	0.1904	0.1351***

Results: 1:1 matching, t+3

Table 4
OLS results on 1:1 matched sample at $t+3$ (Panel A) and $t+5$ (Panel B).

Variables	Panel A: $t+3$			
	(1) ln *R&D* $perempl_{t+3}$	(2) ln *R&D* $perempl_{t+3}$	(3) *shareR&D* $empl_{t+3}$	(4) *shareR&D* $empl_{t+3}$
Treatment	0.164	0.163*	0.0186	0.0149
	(0.104)	(0.0870)	(0.0131)	(0.0114)
$R\&D_{t-1}$		0.392***		0.0309**
		(0.114)		(0.0138)
$Employment_{t-1}$		8.19e−05		1.51e−05
		(0.0001)		(1.79e−05)
$Emplsquared_{t-1}$		−2.72e−09		−1.73e−10
		(9.67e−09)		(1.27e−09)
$Labproduct_{t-1}$		1.03e−06		−8.43e−07
		(3.00e−05)		(2.68e−06)
$Mktshare_{t-1}$		1.722**		0.0713
		(0.841)		(0.123)
$Singleplant_{t-1}$		0.432***		0.0196
		(0.124)		(0.0153)
$Foreignlink_{t-1}$		0.305**		0.0282*
		(0.138)		(0.0171)
Constant	0.809***	1.142	0.144***	0.0859
	(0.246)	(0.708)	(0.0307)	(0.129)
Observations	868	868	868	868
Year dummies	Yes	Yes	Yes	Yes
Birth year dummies	–	Yes	–	Yes
Industry dummies	–	Yes	–	Yes
Region dummies	–	Yes	–	Yes
Adj-R^2	0.003	0.338	−0.0026	0.219

+17%

Results: 1:1 matching, t+5

Table 4
OLS results on 1:1 matched

Variables	Panel B: $t+5$			
	(5) ln *R&D* $perempl_{t+5}$	(6) ln *R&D* $perempl_{t+5}$	(7) *shareR&D* $empl_{t+5}$	(8) *shareR&D* $empl_{t+5}$
Treatment	0.243**	0.216**	0.0384**	0.0324**
	(0.116)	(0.101)	(0.0149)	(0.0136)
$R\&D_{t-1}$		0.202*		0.0145
		(0.121)		(0.0158)
$Employment_{t-1}$		7.66e−05		3.26e−05
		(0.0001)		(2.61e−05)
$Emplsquared_{t-1}$		−1.11e−08		−2.02e−09
		(1.21e−08)		(1.70e−09)
$Labproduct_{t-1}$		−5.07e−05*		−4.59e−06
		(2.99e−05)		(3.13e−06)
$Mktshare_{t-1}$		2.031		0.188
		(1.334)		(0.193)
$Singleplant_{t-1}$		0.117		0.000561
		(0.138)		(0.0171)
$Foreignlink_{t-1}$		0.223*		0.0359*
		(0.135)		(0.0204)
Constant	0.902***	−1.931	0.108***	0.376***
	(0.243)	(1.229)	(0.0270)	(0.0766)
Observations	747	747	747	747
Year dummies	Yes	Yes	Yes	Yes
Birth year dummies	–	Yes	–	Yes
Industry dummies	–	Yes	–	Yes
Region dummies	–	Yes	–	Yes
Adj-R^2	0.0016	0.329	−0.0026	0.242

+24%

+3%

Conclusion (1)

- Positive and significant impact on firms' R&D exp per empl at the end of projects (t+3) and two years later (t+5): increase of $\approx$ £5,000
- Positive and significant effect on the share of R&D employment at t+5 only: increase of 1 worker
- Results are confirmed by a robustness check where lagged dep vars are included in OLS regressions
- Results in line with previous empirical findings, see e.g. Veugelers (1997), Becker and Dietz (2004) and Schmiedeberg (2008)

Conclusion (2)

- These findings particularly confirm the achievement of the second objective of EPSRC partnerships: **increasing employment opportunities while improving skills' matching**
- They support the argument that universities are an integral part of the supply chain to firms to support both business growth and economic prosperity (Lawton Smith and Bagchi-Sen, 2006; Wilson, 2012)
- Policy implication: create/strengthen mechanisms that support the use of university research as a mean for recruiting appropriately skilled staff (more useful than focusing on research or recruitment alone) (Bruneel et al., 2009)

Thank you!

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Sample representativeness

Table 8
Sample representativeness on the basis of project characteristics.

Variable	(a) Mean full sample $N = 3558$	(b) Mean unmatched $N = 1671$	(c) Mean matched $N = 1887$	(d) Mean final sample $N = 434$	(e) Diff (b)–(c)	(f) Diff (a)–(c)	(g) Diff (a)–(d)	(h) Diff (c)–(d)
Num of projects	2.3333	2.4566	2.2242	2.2637	0.2324**	0.1092	0.0697	−0.0395
Length of projects, dd	990.81	997.77	984.65	1005.45	13.12	6.1628	−14.64	−20.80
Length of projects, mm	33.03	33.26	32.82	33.52	0.4374	0.2054	−0.4880	−0.6934
Length of projects, yy	2.7523	2.7716	2.7351	2.7929	0.0365	0.0171	−0.0407	−0.0578
Size of Univ dept.	42.51	43.17	41.93	43.53	1.2397	0.5788	−1.0125	−1.5913
Funds per firm (ln)	12.15	12.16	12.14	12.19	0.0255	0.0120	−0.0452	−0.0572

*Significance level: $p < 0.1$.
** Significance level: $p < 0.05$.
***Significance level: $p < 0.01$.

Descriptive stats pre-treatment variables

Table 1
Descriptive statistics and mean comparison of pre-treatment characteristics between treated ($N = 434$) and untreated (raw sample: $N = 171,769$) firms. Total $N = 172,203$.

Variable ($t-1$)	Mean	Standard deviation	Min[a]	Max[a]	Mean treated	Mean untreat.	Diff.
R&D	0.3718	0.4833	0	1	0.6146	0.3711	0.2435***
Employment	111.38	699.71	1	–	425.8004	110.45	315.35***
Lab product	249.05	14,345.74	0	–	182.45	249.25	−66.80***
Market share	0.0065	0.0357	0	1	0.0307	0.0065	0.0242***
Single plant	0.8124	0.3904	0	1	0.6206	0.8130	−0.1924***
Foreign link	0.1953	0.3964	0	1	0.3063	0.1950	0.1113***
Birth year	1987.97	9.18	1973	2006	1986.91	1987.98	−1.065***
Channel Island	0.0092	0.0954	0	1	0.0138	0.0092	0.0047
East Midlands	0.0804	0.2718	0	1	0.0988	0.0803	0.0185
East of England	0.1083	0.3108	0	1	0.1304	0.1082	0.0222*
London	0.1049	0.3064	0	1	0.0711	0.1050	−0.0338***
North East	0.0401	0.1963	0	1	0.0553	0.0401	0.0153*
North West	0.0879	0.2832	0	1	0.0692	0.0880	−0.0188
Northern Ireland	0.0288	0.1672	0	1	0.0316	0.0288	0.0029
Scotland	0.0979	0.2972	0	1	0.0968	0.0979	−0.0011
South East	0.1536	0.3606	0	1	0.1917	0.1535	0.0382***
South West	0.0791	0.2698	0	1	0.0731	0.0791	−0.0060
Wales	0.0544	0.2268	0	1	0.0613	0.0544	0.0069
West Midlands	0.0866	0.2812	0	1	0.0613	0.0866	−0.0254***
Yorkshire and Humber	0.0688	0.2532	0	1	0.0455	0.0689	−0.0235***

[a] Minima and maxima have been rounded off or suppressed to comply with ONS confidentiality.
* Significance level: $p < 0.1$.
** Significance level: $p < 0.05$.
*** Significance level: $p < 0.01$.