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Knowledge frontiers and knowledge boundaries : Evidence from the UK micro-level data

Dr. Maksim Belitski

Associate Professor, Department of Leadership, Organisation and Behaviour, Henley Business School

BEROC , 27 December 2017

Reading – a centre of the Thames Valley

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Henley Business School, Greenlands Campus

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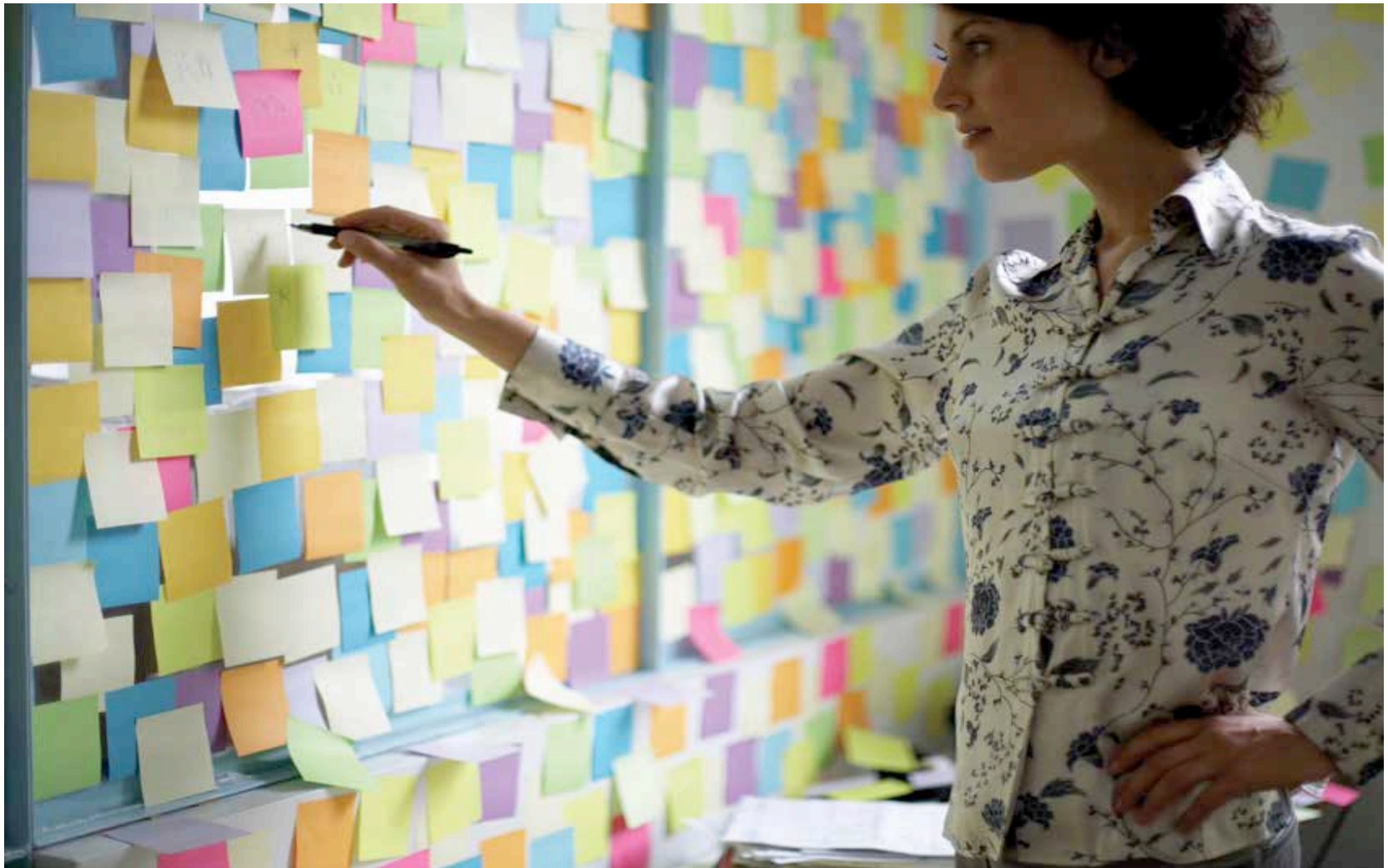

Whiteknights campus

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Outline

- Motivation
- Theory & Hypothesis
- Data
- Model and Method
- Major Findings
- Discussion
- Q&A

Warm up question……

How many friends do you have?

1, 2, 4, 9, 25 +?

Warm up question……

How many friends do you communicate in week days and days-off?

1, 2, 4, 9, 25 +?

Do you expect the people you approach, friends supply you with more ideas and knowledge?

Would firms follow a similar behaviour?

How do firms collaborate and why is it important?

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- Collaboration takes place within the industry (e.g. competitors, suppliers, within enterprise group) and across industries (e.g. competitors, suppliers, universities, government, consultants, etc.)
- Knowledge spillovers for product and process innovation Marshall (1890), Arrow (1962), and Romer (1986), Jacobs (1970)

What is a knowledge spillover?

- M-A-R suggest that knowledge spillovers arise among firms in the same industry, sharing very specific tacit knowledge.
- Jacobs (1970) believes that the most important knowledge spillovers develop across various functionalities and areas of expertise, usually clustered within industries and across different types of collaborative partners.
- Rule: Jacob's externalities are likely to increase with an increase in a number of collaboration partners across various functional areas and geographical proximities.
- Not so easy…….Positive and negative externalities

Theory & Hypothesis: what do we know and what we don't:

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- Jacobs diversification of knowledge: positive relationship between functional diversity of knowledge and innovation has been widely researched (Boschma, 2005; Lahiri, 2010; Spanjer and van Witteloostuijn, 2017)
- The interplay between functional and geographical boundaries of knowledge and its relationship with various innovation outcomes has not yet been studied and not using sufficient empirical data and not for developed country, and not to account for a multi-level effects of firm embeddedness on firm innovation (Delgado-Marquez et al. 2017) .

Ails and RQ

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- This study aims :
- First, theoretically discuss and empirically test the relationship between a functional diversity of knowledge and innovation performance across different geographical proximities.
- First, theoretically discuss and empirically test the effect of reverse spillover of knowledge across four major industries in the UK and explain its implications.
- In doing so we make a contribution to geography of innovation and regional economics, and knowledge management literatures.

Contribution

- First, we establish and test the inverted U-shape effect btw functional diversity and innovation.
- Second we do it across various geographical proximities (regional, national, Europe, international).
- Third we match various sources of external unique data over six waves of 2002-2014 and apply a multilevel generalised linear model to test our hypothesis.

H1:

- Diverse and inter-disciplinary knowledge enables firm to develop new associations and linkages in knowledge (Cohen and Levinthal, 1990), increasing the absorptive capacity of a firm and pushing the knowledge boundaries even further (George and Zahra, 2002).

- An increase in the number of external collaborators may dissipate knowledge, limit ability to use knowledge strategically, increase time for decision-making due to variety of alternative sources and types of solutions, result in leakage of knowledge and information to competitors within and across sectors, espionage, competition.

H1 *There is an inverted U-shape relationship between the functional diversity of knowledge (number of external collaborators) and product (process) innovation*

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- Combining the positive and negative relationship we argue that there is an optimum level of external cooperation a firm is able to manage using its learning cooperation and innovation skills, capabilities, financial, labour and technology resources.
- This will mean the existence of inverted U-shape relationship between innovation performance and a set of cooperation partners.
- An inverted U-shape relationship illustrates and may diagnose a “partnership trap” for firms where an increase in the number of partners may dissipate knowledge, trigger leakage of knowledge

H2:

- Why internationally? Maintaining predominantly local and national partners as sources of knowledge leads to a lock-in effect. Former significantly limits the development of firm's international capabilities and absorptive capacity, in particular for MNEs aiming at creation of foreign subsidiaries (Rugman and Verbeke, 2001).

- Why nationally? National boundaries is where the market knowledge is relevant for firms that target local and national markets, they build their expertise and skills, before going internationally; national markets are used as a test ground for new products and services before scaling up; in national markets the competition is less intense and protection of IP rights could be better enforced; national partners offer customised services and provide a firm with information and knowledge valid for national market

H2: *The inverted U-shape relationship between functional diversity of knowledge (number of external collaborators) and product (process) innovation is stable across different geographical proximities.*

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- The benefits of internationalization overweight the cost of it (Lahiri, 2010).
- Unlike the case of functional diversity, where we stated an optimum level of external collaboration, Boschma and Frenken (2010) in their study describe a “proximity paradox”, which poses that being too far and too close can reduce the scope of learning from a collaborator.

Reverse spillovers when collaborating

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- In case of knowledge intense firms collaboration becomes a necessary condition to learn management and innovation skills which further enable exploration of knowledge
- A focal firm will find it beneficial to engage in external cooperation to exploit the knowledge spillover as long as the benefits from cooperation overweight possible loss of the market due to the reverse spillover.
- In other words, knowledge sourcing, rather that knowledge spillover may occur simultaneously. The net effect is positive if the size of the knowledge spillover from external collaboration is greater than the size of reverse spillover and negative if vice versa

Reverse spillover channels

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- purchases and usage of knowledge which could be later decomposed, sourced and combined
- having a sufficient level of absorptive capacity, external partners will access and adapt advanced knowledge and prototyping ideas by interacting with a focal firm digital and technological leaders
- collaboration on the projects may facilitate labour mobility between partners. It may be true that the knowledge is not readily available to use and in particular in highly complex industries where reverse engineering is limited.
- formal and strategic protection of innovation could be applied.

Who is affected?

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- The reverse spillover occurs in firms and sectors where the scope of positive knowledge spillover to be perceived by collaborators as the highest in addition to low or no penalty on infringement.
- The reverse spillover is likely to be most apparent in sectors where firms have invested heavily in R&D, have achieved high absorptive capacity, high concentration of knowledge workers, innovation performance, but knowledge is still incomplete and easy to infringe with a little penalty of infringement.
- Knowledge intensive business services, high-tech manufacturing, ICT and creative sectors are likely to be most affected.

H3:

- It is more likely that firms in industries where knowledge is most novel, dynamic and incomplete will be most affected by the reverse spillover unlike other high-tech sectors, and in particular manufacturing where patenting is more common.

- ***H3a: Firm in the knowledge intense sectors (KIBS, ICT, high—tech manufacturing and creative) will experience the reverse spillover of collaboration with external partners.***
- ***H3b: The size of the reverse spillover of collaboration with external partners is likely to be the highest for firms in creative sectors.***

Do reverse spillovers vary with distance?

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- Given the importance of close proximity in knowledge creation and sourcing, reverse spillover are likely to be geographically bounded (Jaffe, 1989; Jaffe et al., 1993), but an issue is “the lock-in effect” (Boschma, 2005).
- With the advancement of technology and digital capabilities (LEAD, 2014; Li et al. 2016) it is not a localised network per se what matters for knowledge creation, but access to the localised networks.
- In a world, when access to information is personalised and secured, the geographical boundaries of collaboration are blurred and the local ecosystems of innovation may quickly become global. This brings the reverse spillover story from a local to global phenomenon.

Risks of international collaboration

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- Important distinction between the knowledge spillovers from within national boundaries as opposed to international boundaries is the ability to enforce regulation and protection of intellectual property.
- Legal differences in protection of intellectual property rights between countries, the benefits from collaboration could be easily ripped off and dissipated.
- On the demand side, there is higher uncertainty and lower transparency in market operations between the external partner and their customers when knowledge is modified and adapted to their markets.

H4: The size of the reverse spillover of collaboration with external partners increases with the geographical proximity from the source of knowledge

Data

- We used six pooled cross-sectional datasets Business Structure database known as Business Register, business Enterprise Research and Development survey and the UK Innovation Survey (UKIS) over 2002-2014.
- First, we collected and matched six consecutive UKIS waves
- Second, we used Business Structure database (BSD) and BERD data for years 2002, 2004, 2006, 2008, 2010 and 2012 were matched to a correspondent CIS survey waves.
- The UKIS data ; BSD data and BERD data (ONS, 2015).
- We work with two samples, 17,859 firms available for product innovation model and second sample of 19,850 firms available for process innovation model.

Dependent variables and derivative of IVs

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Label	Description of variables		Mean (Product innovation sample 19,510 obs.)	Std. Dev. (Product innovation sample 19,510 obs.)	Mean (Process innovation sample 23,070obs)	Std. Dev. (Process innovation sample 23,070obs)
Process innovation (DV2)	**Binary variable=1 if firm introduced any new or significantly improved processes for producing or supplying goods or services, , zero otherwise.**		0.305	0.46	0.305	0.46
Product innovation (DV1)	**% of firm's total turnover from goods and services that were new to the market (%), radical product innovation**		0.048	0.136	0.048	0.13
UK Regional	1 if business co-operated on any innovation activities with at least one of the following partners : within enterprise group, suppliers, clients or customers, competitors, consultants, commercial labs, universities, government	Regionally	0.167	0.37	0.192	0.39
UK National		Nationally	0.217	0.41	0.255	0.44
European Countries		Europe	0.106	0.30	0.119	0.32
Other Countries		World	0.092	0.28	0.104	0.31

Functional diversity (Independent variables) (UKIS)

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UK Regional	# partners firm cooperates on innovation regionally (enterprise group, suppliers, clients and customers, competitors, consultants and private R&D labs, universities, local and national government (0– no collaborators , max. 7 – collaboration with all seven groups)	0.399	1.108	0.442	1.142
UK National	# partners firm cooperates on innovation nationally(enterprise group, suppliers, clients and customers, competitors, consultants and private R&D labs, universities, local and national government (0– no collaborators , max. 7 – collaboration with all seven groups)	0.588	1.350	0.667	1.404
European Countries	# partners firm cooperates on innovation in Europe (enterprise group, suppliers, clients and customers, competitors, consultants and private R&D labs, universities, local and national government (0– no collaborators , max. 7 – collaboration with all seven groups)	0.220	0.771	0.238	0.791
Other Countries	# partners firm cooperates on innovation in other world (enterprise group, suppliers, clients and customers, competitors, consultants and private R&D labs, universities, local and national government (0– no collaborators , max. 7 – collaboration with all seven groups)	0.190	0.734	0.214	0.778

Four major sectors

Sectors (BSD)	High-tech Manufacturing	Binary variable equal one if firms belongs to one of the following SIC 2007 (2 digit): 19-22, 26-27, 29, 32, 33.20, zero otherwise	0.112	0.31	0.111	0.31
	ICT	Binary variable equal one if firms belongs to one of the following SIC 2007 (2 digit): 58-63, zero otherwise	0.072	0.25	0.076	0.26
	KIBS	Binary variable equal one if firms belongs to one of knowledge intensive business services sectors SIC 2007 (2 digit): 64-66, 69-71, 74.20, 74.30 and 74.90, zero otherwise	0.104	0.30	0.108	0.31
	Creative	Binary variable equal one if firms belongs to one of SIC2007 (2 digit): 70.21, 71.11, 71.20, 73.11, 73.12, 74.10, 74.20, 85, zero otherwise	0.043	0.20	0.049	0.22

Other control variables

- Firm size
- *Industry: high tech / medium and low tech*
- *Exploration activity : market development*
- *Exploration activity : Product range development*
- Factors constraining innovation
- Firm's legal status
- R&D intensity (BSD and UKIS)
- Foreign (course BSD)
- Scientist, % of FTE (UKIS)
- Firm age
- Exporter (UKIS)
- Part of a group (BSD)

Sample industrial distribution

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Description	2005	2007	2009	2011	2013	2015	Total
1 - Mining & Quarrying	144	<10	11	<10	<10	<10	
2 - Manufacturing basic	815	141	92	102	21	14	
3 - High-tech manufacturing	2,600	491	424	265	66	66	
4 - Electricity, gas and water supply	93	<10	16	26	<10	<10	
5 – Construction & Architect	1,617	91	74	124	<10	<10	
6 - Wholesale, retail trade	2,417	138	130	279	39	58	
7 - Transport, storage	918	36	31	53	<10	<10	
8 - Hotels & restaurants	794	29	46	120	17	<10	
9 - ICT	898	169	196	86	28	44	
10 - Financial intermediation	578	39	49	28	<10	<10	
11 - Real estate & business activities	1,701	169	199	262	63	86	
12 – Admin and support services, defence	1,519	84	98	185	18	15	
13 - Education	61	<10	11	<10	<10	<10	
16 - Other community, social activities	355	53	47	<10	<10	<10	
Total							19,510

Sample regional distribution

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Description	Sample of the regressions (DV: Product innovation)						
	2005	2007	2009	2011	2013	2015	Total
North East	830	93	85	61	<20	17	
North West	1341	129	117	174	32	23	
Yorkshire and The Humber	1,179	110	133	126	<20	17	
East Midlands	1178	145	121	121	<20	23	
West Midlands	1,285	146	122	143	21	19	
Eastern	1,252	143	128	159	25	34	
London	1,401	104	111	170	36	32	
South East	1543	162	157	203	48	45	
South West	1,196	127	141	128	27	18	
Wales	975	106	97	74	<20	19	
Scotland	1,115	116	122	104	<20	38	
Northern Ireland	1215	84	90	73	<20	22	
Total							19,510

Sample size distribution

Description	Sample of the regressions (DV: Product innovation)						
	2005	2007	2009	2011	2013	2015	Total
Micro and Small 1-49	6,380	513	558	912	184	178	
Medium 50-249	4,098	362	389	404	61	105	
Large >249	4,032	590	477	220	23	24	
Total							19,510

Description	Sample of the regressions (DV: Process innovation)						
	2005	2007	2009	2011	2013	2015	Total
Micro and Small 10-49	6,380	863	1,181	940	374	430	
Medium 50-249	4,098	615	907	417	148	251	
Large >249	4,034	948	1,087	233	74	90	
Total							23,070

What sector collaborates most

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- High tech manufacturing 19.7% - regional and 29.3% with national partners, while collaboration with European and international partners is 18.9% and 17.9%.
- ICT sector we 19.5% - regional and 33.5% with national partners. At the same time only 15.2% and 17.6% of firms in ICT have European and international partners.
- KIBS 16.9 and 23.4% of firms who collaborate within regional and national boundaries and 8.0 and 8.2% as Europe and international.
- Creative industries, 27.3% - regional and 40.7% firms national; while 26.1% and 23.3% with Europe and international partners.

Model

- We use a generalised linear three-level model with the fractional dependent variable $y\downarrow ijk$ and the independent variable $x\downarrow ijk$ such that:

$$g[E(y\downarrow ijk)]=\beta\downarrow 0+\beta\downarrow 1\ x\downarrow ijk+\beta\downarrow 2\ \tau\downarrow ijk+v\downarrow ijk \quad (1)$$

- where i is the firm level-1, j is the region level-2 and k serves to index the wave survey level-3. Dependent variable $y\downarrow ijk$ gathers radical product innovation (process innovation). The explanatory variables $x\downarrow ijk$. Finally, $\varepsilon\downarrow ijk$ is an error term, that in hierarchical model, consists of three components:

$$\varepsilon\downarrow ijk=\gamma\downarrow i\cdot\cdot+\mu\downarrow j\cdot+t\downarrow k\cdot+\nu\downarrow ijk \quad (2)$$

- Where $\gamma\downarrow i\cdot\cdot$ represents the omitted variables that vary across firms but not over regions and waves, $\mu\downarrow j\cdot$ denotes the omitted that vary over

Selection bias correction

- This bias is originated on the fact of willingness to report a share an information on collaboration with external partners in the UKIS.
- This response and collaboration per se may be conditional on applying various IPR protection mechanisms which while collaboration and knowledge transfer. Thus, observations on collaboration on innovation can be affected for those observations that adopt or not the IPR protection measures.
- Selection step: $Pr(D=1 \mid z_{ijk}) = \Phi(\alpha' z)$ (3)

p_{ijk} is a dependent variables measures degree of IPR protection, α is a vector of unknown parameters, and Φ is the cumulative distribution function of the standard normal distribution

Random-effects probit estimates (N=65, 162 obs)

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Two-step Heckman approach		Protection (D=1)		
		Coef.	SE	
Age of firm	Age, log	-0.005	0.001	***
Employment, in logs	Employment, log	0.238	0.011	***
Scientist, % of employments	Scientist	0.016	0.001	***
R&D intensity to sales	RD internal	4.439	0.300	***
Context for Innovation				
Increasing range of goods or services .	New product	0.331	0.016	***
Increasing market share	New market	0.241	0.016	***
Constant		-2.968	0.196	***
sigma u		1.024	0.050	
rho		0.512	0.024	
Sectoral dummies		Yes		
Regional dummies		Yes		
Likelihood ratio test Wald chi2		1353.8		

Note: *,** and * Significance at the 1%, 5% and 10% levels, respectively**

Predictive Margins with 95% CIs: Radical product innovation

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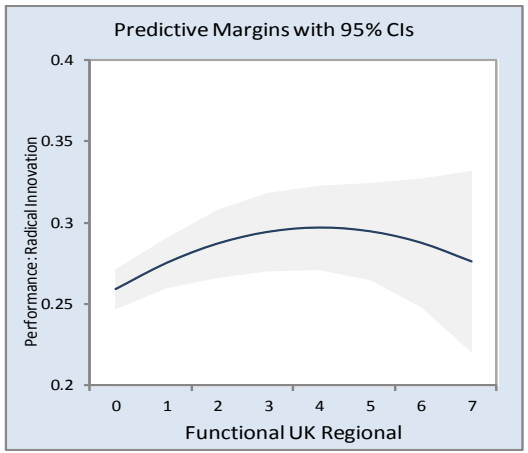

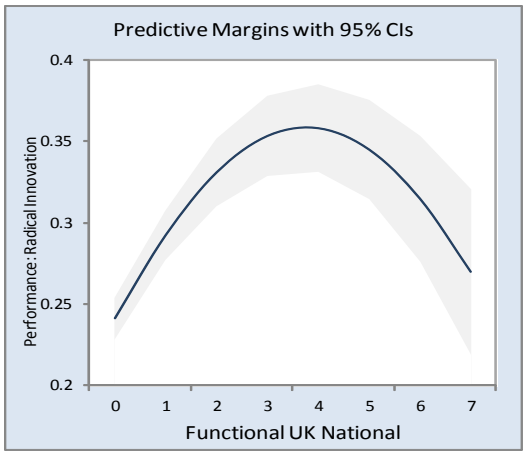

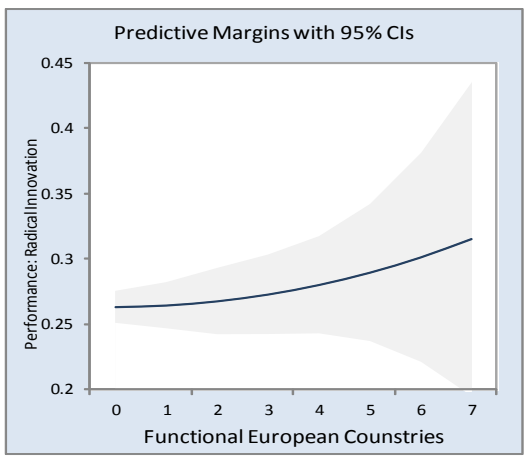

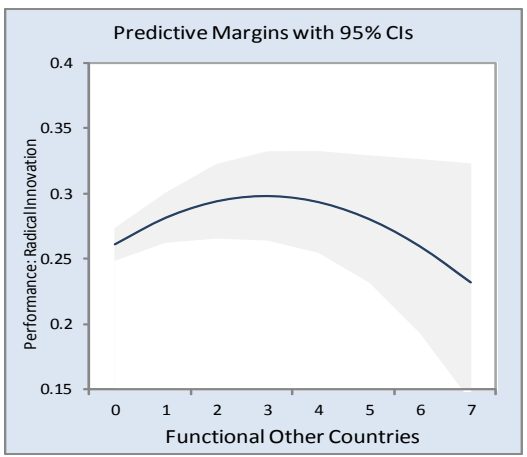

Predictive Margins with 95% CIs: Process innovation

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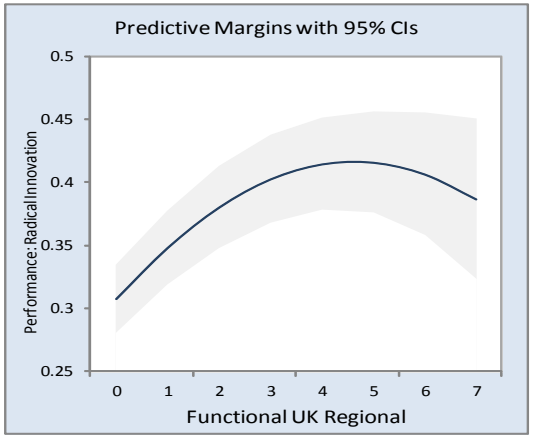

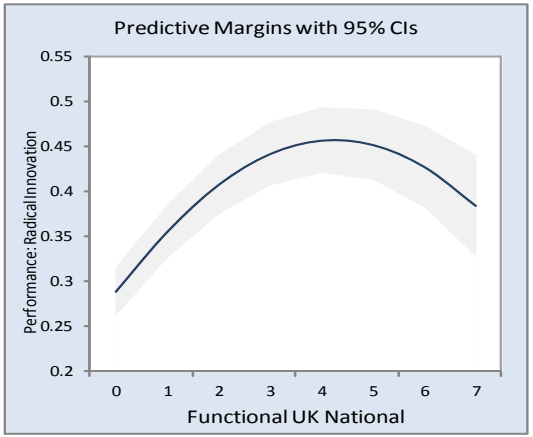

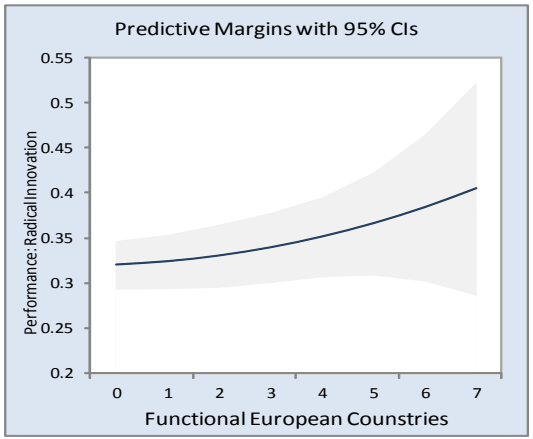

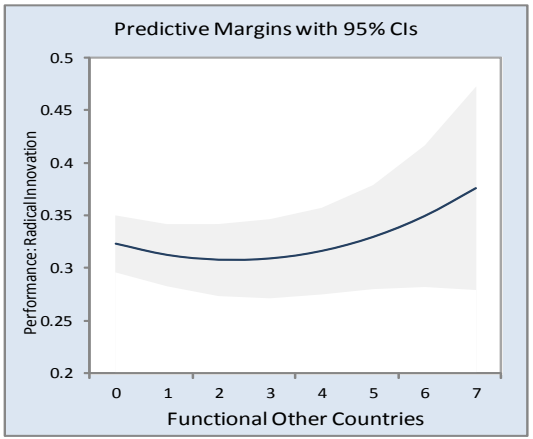

Test for U-shape relationship based on estimation

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Dependent variable: Product Innovation

	Regional scope		National scope		Europe scope		World scope	
Bounds	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Interval	0	7	0	7	0	7	0	7
Slope	0.158	-0.131	0.386	-0.339	-0.037	0.147	0.154	-0.264
t-value	3.252	-1.536	8.618	-4.547	-0.518	0.930	2.114	-1.792
P>|t|	0.001	0.062	0.000	0.000	0.302	0.176	0.017	0.037
Extremun point:	3.83		3.73		n.a.		2.57	
95% Confidence	[2.31	, 5.35]	[3.21	, 4.24]			[1.41	, 3.73]
Overall test of:	Inverse U-shape		Inverse U-shape		Inverse U-shape		Inverse U-shape	
t-value	1.54		4.55		0.52		1.79	
P>|t|	0.06		0.00		0.30		0.04	

Dependent variable: Process Innovation

	Regional scope		National scope		Europe scope		World scope	
Bounds	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Interval	0	7	0	7	0	7	0	7
Slope	0.250	-0.130	0.402	-0.258	0.015	0.118	-0.083	0.164
t-value	7.017	-2.007	12.114	-4.689	0.288	0.976	-1.565	1.581
P>|t|	0.000	0.022	0.000	0.000	0.386	0.164	0.059	0.057
Extremun point:	4.61		4.27		n.a.		2.36	
95% Confidence	[3.39	, 5.83]	[3.75	, 4.78]			[1.03	, 3.68]
Overall test of:	Inverse U-shape		Inverse U-shape		Inverse U-shape		Inverse U-shape	

Mixed GLM results other (weighted)

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	Radical Product Innovation						Process Innovation					
	Base model			Full model			Base model			Full model		
	Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE	
small				Reference						Reference		
medium				-0.290	0.054	***				-0.078	0.024	***
large				-0.516	0.123	***				-0.049	0.030	*
Technological intensity												
High-tech manufacturers				0.954	0.365	***				-0.231	0.144	
Med-tech manufacturers				0.235	0.125	*				0.053	0.102	
Low-tech manufacturers				0.741	0.172					0.009	0.134	
High/Med-tech services				0.197	0.116	*				-0.145	0.055	***
Exploration												
R&D				0.879	0.054	***				0.237	0.028	***
Development work				0.025	0.044					0.084	0.026	***
R&D intensity to sales				2.318	0.538	***				-0.696	0.191	***
Foreign firm				-0.171	0.061	***				-0.089	0.016	***
Scientist, % of employments				0.001	0.001					-0.003	0.001	***
Exporter firm				0.631	0.062	***				0.135	0.030	***
Part of a group				0.533	0.037	***				0.119	0.025	***
Age of firm				0.003	0.003					0.001	0.001	
Mill's ratio												
Protection selection	-1.255	0.048	***	-0.884	0.079	***	-0.559	0.018	***	-0.516	0.025	***
Number of obs	19510			19510			23070			23070		

Reverse spillovers estimation

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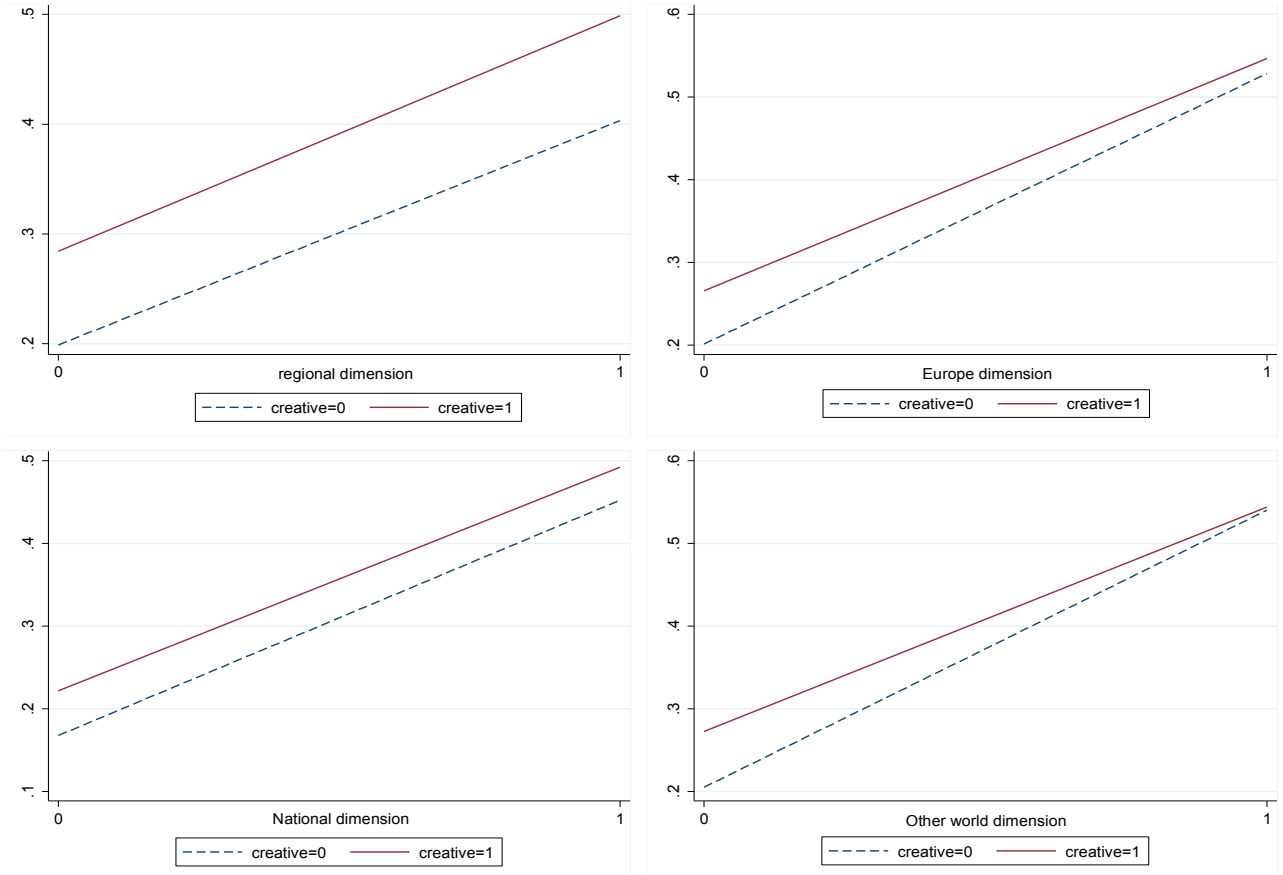
	Model 1			Model 2			Model 3			Model 4		
	Coef.	SE		Coef.	SE		Coef.	SE		Coef.	SE	
UK Regional	0.052	0.023	**	0.065	0.020	***	0.065	0.020	***	0.063	0.020	***
× High-tech	0.004	0.059										
× ICT	0.075	0.077										
× KIBS	0.044	0.054										
× Creative	0.025	0.068										
UK National	0.144	0.019	***	0.159	0.022	***	0.145	0.019	***	0.144	0.019	***
× High-tech				0.019	0.042							
× ICT				0.018	0.055							
× KIBS				-0.046	0.047							
× Creative				-0.137	0.049	***						
European Countries	0.019	0.033		0.025	0.033		0.055	0.041		0.028	0.033	
× High-tech							-0.033	0.069				
× ICT							0.010	0.098				
× KIBS							-0.080	0.087				
× Creative							-0.163	0.076	**			
Other Countries	0.016	0.034		0.019	0.034		0.026	0.034		0.032	0.047	
× High-tech										0.075	0.075	
× ICT										-0.040	0.086	
× KIBS										0.053	0.089	
× Creative										-0.211	0.081	***
Firm size												

Difference in Difference Analysis for the reverse knowledge spill ver in creative sector (predicted values)



Discussion

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- Functional diversity of knowledge (regionally, nationally and internationally) is related to product and process innovation and is inverted U-shaped. This means both +-ve and –ve externalities.
- This study gives an answer on prior mixed findings whether or not the effect of functional diversity on innovation (Delgado et al. 2017) changes across geographical proximities (Lundvall, 1998).
- Interesting finding for European collaborators and product innovation with no results found. This could means sourcing of European knowledge takes place within the UK boundaries.
- Interesting finding for process innovation demonstrates a weak u-shape relationship between functional diversity of knowledge sourced internationally and process innovation

Discussion

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- To be effective in increasing innovation performance firms should facilitate the range of products and services, aim to enter new markets, invest in in-house R&D and aim to sell internationally.
- Strong support to localised diversity of knowledge for both process and product innovators, expanding our understanding of knowledge frontiers and boundaries in regional economics and innovation clustering literature.
- Contribution to the knowledge spillover of entrepreneurship theory (Acs et al. 2013) by estimating the positive and negative effect of knowledge externalities on innovation performance and within different spatial proximities.
- Implications for policy, firms and further research

Discussion (reverse spillovers)

- Both firms in creative and non-creative sectors benefit from collaboration with external partners, significantly increasing their product innovation.
- At the same time the benefits of such collaboration are not equally distributed between creative and non-creative sectors.
- In creative sector we detected and measured the size of the reverse knowledge spillover.
- Measures to protecting creative sector firms when collaborating internationally should be developed by government (formal and strategic protection).

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Thanks for listening!

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