The division of labour between academia and industry for the generation of radical inventions

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Introduction

- Technology tends to evolve along predictable trajectories, characterized sometimes by discontinuities brought about by paradigm shifts (Dosi, 1982).
  - long-run economic growth (Ollson, 2000)
  - new industries formation (Arthur, 2007).
- Radical inventions are the base of these discontinuities

- Given this pivotal role, two main questions arise:
  - How do we identify radical inventions?
  - What are the sources of radical inventions?

Defining radical inventions

- Radical inventions are rare events and only a few develop successfully into viable innovation
- New technology that “depart[s] in some deep sense from what went before” (Arthur, 2007, p. 274)
- Differ from incremental inventions in the capability to promote the development of subsequent inventions (Ahuja and Lampert, 2001)

How do we identify radical inventions?

- Two approaches to identify radicalness:
  - Ex ante approach: radicalness conceptualized as a recombination process (Schumpeter, 1934)
  - Ex post approach: conceptualised for its impact on future technology development (Schoenmakers and Duysters, 2010)
- As Verhoeven et al. (2016, p. 708) note however, adopting an ex post assessment of radicalness overlooks unsuccessful short-term inventions
  - Especially true in empirical studies based on patent data
- We adopt an ex ante approach to identify radicalness

Ex ante approach

- Approach theoretically built on the conceptualization of inventive activity as a recombination process
- A radical invention needs to show some form of novelty: to emerge from a different recombination process from that characterizing the majority of inventions
- Most measures of radicalness tend to capture novelty in terms of the distance between new and old combinations
- A recent approach requires the invention to encompass some form of novel combination never observed before (Fleming, 2001; 2007; Verhoeven et al., 2016).
  - Fleming (2001): degree of radicalness as a function of the rareness of the combination of the same components prior to the focal invention

Recombination processes

- Inventive activity can emerge from two distinct, but non-exclusive, forms of recombination (e.g. Arthur, 2007; Fleming, 2001; Carnabuci and Operti, 2013).
  - Novelty in recombination: the generation of a new combination of components that gives rise to a new method of doing things
  - Novelty in technological origins: novel application of a phenomenon to some combinations of components

What are the sources of radical inventions?

- Investigating the sources of radical invention requires exploring the “innovative division of labour” (Arora and Gambardella, 1994) between public and private research (Trajtenberg et al., 1997; Popp, 2016)
  – Various radical inventions generated by public research (Rosenberg and Nelson, 1994; Rosenberg, 2004)

- RQ: While the relationship between technological development and public R&D has been largely investigated and proved, the link between public research and radical invention has not been examined

Public research and technological change

- Positive relationship (Jaffe, 1989; Mansfield, 1991; Salter & Martin, 2001)
- Mechanisms for the transfer of public science to industry have become increasingly complex (Gibbons et al., 1994)
  - Policies incentivised more direct and codified technology transfer activities (Henderson et al., 1998; Mowery et al., 2001; Geuna, 2001).
- Public research, even if patented, tend to be more basic, more general and less appropriable (Trajtenberg et al., 1997)

Public research and technological change (2)

- Heterogeneity of relationship across scientific or technological sectors.
  - Biomedicine and chemistry: patents developed by public research important share of the sector's overall patenting activity (Mowery et al., 2001).
    - Most studies focus on these sectors
  - Applied science fields: the share of academic patents is much smaller (David, 1997)

- Codified public research usually proxied by two indicators in the literature: academic patenting and scientific literature in patent references

Empirical framework

- Patent data analysis based on the UK
- EPO patents in which at least one assignee based in UK
  - Focus only on public and private patents: sample of 113,910 patents (90% of total UK EPO population)
- Grouping patents into families (to avoid counting same invention more than once)
- Final dataset of 103,697 patent families
  - 6,710 include at least one public research institute as an assignee, corresponding to 6.5% of the sample.
- Relationship we investigate

$$Radicalness_{ijt} = \alpha + \beta PublicR\&D_{ijt} + \delta \boldsymbol{X}_{ijt} + \gamma_j + \tau_t + \varepsilon_{ijt}$$

Dependent variables: radical inventions

- Novelty in recombination (Nr): new-to-the-world combination of knowledge components
  - Nr takes the value 1 if the focal patent includes at least one IPC code combination that is novel in relation to the PATSTAT population of patents in the years before the year of the focal patent, and 0 otherwise.
- Novelty in technological origins (Nto): novelty in the knowledge sources from which the focal patent's components and principles are drawn
  - Nto takes the value 1 if the focal patent combines at least one own 8 digit IPC code and an 8 digit IPC code from its referenced patents that have not been combined previously in a patent, and 0 otherwise

Dependent variables: radical inventions

Table 1
Illustration of construction of the indicators based on the Oncomouse patent family. Column 1 indicates the IPC groups the oncomouse patent family is assigned to. Column 2 provides the patent/scientific references of the oncomouse patent family. Column 3 provides the IPC groups/WOS Subject Categories of these references. Column 4 displays the class combinations that are considered for calculating the indicators. The last two columns indicate whether the combination is assessed as a new combination and shows the score on the dichotomous indicator variables.

The Oncomouse patent family: US4736866, EP169672, CA1341442, DE3586020, JP5048093, JP61081743, JP2058915

IPC groups (Exhaustive)			(Examples of) combinations	First occurrence?	Indicator
A01K 67			A61D 19 – C07H 21	Yes	
A61D 7			A01K 67 – C07H 21	Yes	
A61D 19			A61D 7 – C07H 21	Yes	
C07H 21			A61D 19 – C07K 14	Yes	NR = 1
C07K 14			A01K 67 – A61D 7	No	
C12N 5			A01K 67 – A61D 19	No	
C12N 15			A01 K 67 – C07H 21	No	
G01N 33			. . .	No	
			Total Number of Positives = 4		
	References	**Classification of References**			
	Patents	**IPC groups**			
	US4579821	C12 N 15	A01K 67 – C12N 15	Yes	
			A61D 7 – C12N 15	Yes	
			A61D 19 – C12N 15	No	
	US4535058	C12P 21	A01K 67 – C12P 21	No	
		A61K 39	A01K 67 – A61K 39	No	NTO = 1
		C12Q 1	A01K 67 – C12Q 1	Yes	
		C07K 19	. . .		
		C12N 15	A61D 7 – C12P 21	Yes	
		C07K 14	A61D 7 – A61K 39	No	
		C07K 16	A61D 7 – C12Q 1	Yes	
		G01N 33	. . .	. . .	
			Total number of positives = 10		

Source: Verhoeven et al., 2016: 712

Independent variables

- Public: Dummy variable taking the value of 1 if the patent displays at least one public research institute as assignee, and 0 otherwise (only private companies)
- Npl: Dummy variable taking the value of 1 if at least one non-patent literature document is reported in the references of the patent, 0 otherwise
- Controls:
  - Bwd_pat: Number of patents referenced by the focal patent
  - N_ipc: Number of 8digit IPC codes of the patent
  - N_inv: Number of inventors of the patent
  - Time, technological field and geographical dummies

Method

- Logit regressions, due to the dichotomous nature of our dependent variables
  - Investigation of the relationship between a one-unit change in the predictor of interest, keeping the other predictors fixed, and the change in the log of odds ratio of the outcome, invention radicalness.

Frequencies and contingency tables

	Nr	*Nto*
Observed frequency	5,691	9,744
Percentage	5.49	9.4

	Nr=1 & Public=1	*Nto=1 & Public=1*	*Nr=1 & Npl=1*	*Nto=1 & Npl=1*
Observed frequency	430	596	2,135	3,591
Ratio between observed and expected frequency	1.16	0.94	1.03	1.01
Chi2(1)	10.92**	2.67	3.51	1.16

Logit regression, full sample

	Nr	*Nto*
Public	0.305**	0.126**
	[0.057]	[0.048]
Npl	0.184**	0.274**
	[0.034]	[0.027]
Bwd_pat	0.009**	0.089**
	[0.003]	[0.004]
N_ipc	0.163**	0.109**
	[0.005]	[0.004]
N_inv	-0.055**	-0.030**
	[0.012]	[0.009]
chi2	2875.76	4768.69
N	103,697	103,697

Robust standard errors in parentheses.
Time, technological field and geographical dummies included.
* p<0.05, ** p<0.01

Logit regression, full sample

	Nr		*Nto*
Public	1.2% higher probs of being Nr if the patent is Public (3.6% vs 4.8%)	>	+ 0.7%
Npl	+ 0.5%	<	+ 1.8%
Bwd_pat	0.009**		0.089**
	[0.003]		[0.004]
N_ipc	0.163**		0.109**
	[0.005]		[0.004]
N_inv	-0.055**		-0.030**
	[0.012]		[0.009]
chi2	2875.76		4768.69
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Robust standard errors in parentheses.
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* p<0.05, ** p<0.01

Radicalness in different sectors

Sector	Obs	Radicalness	Frequencies	Percentage
Electrical Engineering	19,355	*Nr*	589	3.03
		Nto	866	4.47
Instruments	16,654	*Nr*	715	4.29
		Nto	1,176	7.06
Chemistry	34,266	*Nr*	2,302	6.72
		Nto	3,617	10.55
Mechanical Engineering	25,384	*Nr*	1,745	6.87
		Nto	3,278	12.91

Technological sectors are identified by PATSTAT and associated to patents by Squicciarini et al., 2013

Logit regression, different sectors

	Electrical Engineering		Instruments		Chemistry		Mechanical Engineering	
	Nr	*Nto*	*Nr*	*Nto*	*Nr*	*Nto*	*Nr*	*Nto*
Public	0.059	0.152	0.101	-0.216	0.341**	0.138	0.206	0.252*
	[0.209]	[0.171]	[0.134]	[0.117]	[0.081]	[0.071]	[0.146]	[0.108]
Npl	-0.255**	0.001	-0.001	0.106	0.217**	0.327**	0.103	0.225**
	[0.098]	[0.080]	[0.094]	[0.073]	[0.051]	[0.041]	[0.074]	[0.053]
Bwd_pat	0.017	0.147**	0.004	0.141**	0.006	0.061**	-0.004	0.157**
	[0.015]	[0.011]	[0.010]	[0.015]	[0.004]	[0.004]	[0.008]	[0.006]
N_ipc	0.366**	0.205**	0.468**	0.321**	0.097**	0.069**	0.358**	0.213**
	[0.020]	[0.015]	[0.017]	[0.013]	[0.004]	[0.003]	[0.012]	[0.008]
N_inv	-0.029	-0.030	-0.043	-0.036	-0.052**	-0.022	-0.026	-0.008
	[0.038]	[0.030]	[0.034]	[0.024]	[0.015]	[0.012]	[0.025]	[0.018]
chi2	565.7	703.4	947.5	1075.6	1278.9	1815.7	1287.5	1884.8
N	19,355	19,355	16,654	16,654	34,266	34,266	25,384	25,384

Logit regression, different sectors

	Electrical Engineering		Instruments		Chemistry		Mechanical Engineering	
	Nr	*Nto*	*Nr*	*Nto*	*Nr*	*Nto*	*Nr*	*Nto*
Public	0.059	0.152	0.101	-0.[illegible]	[illegible]	[illegible]	0.206	[illegible]
	[0.209]	[0.171]	[0.134]	[0.[illegible]	[illegible]	[illegible]	[0.146]	[illegible]
Npl	-0.255**	0.001	-0.001	0.106	[illegible]	[illegible]	0.103	[illegible]
	[0.098]	[0.080]	[0.094]	[0.073]	[illegible]	[illegible]	[0.074]	[illegible]
Bwd_pat	0.017	0.147**	0.004	0.141**	0.006	0.061**	-0.004	0.157**
	[0.015]	[0.011]	[0.010]	[0.015]	[0.004]	[0.004]	[0.008]	[0.006]
N_ipc	0.366**	0.205**	0.468**	0.321**	0.097**	0.069**	0.358**	0.213**
	[0.020]	[0.015]	[0.017]	[0.013]	[0.004]	[0.003]	[0.012]	[0.008]
N_inv	-0.029	-0.030	-0.043	-0.036	-0.052**	-0.022	-0.026	-0.008
	[0.038]	[0.030]	[0.034]	[0.024]	[0.015]	[0.012]	[0.025]	[0.018]
chi2	565.7	703.4	947.5	1075.6	1278.9	1815.7	1287.5	1884.8
N	19,355	19,355	16,654	16,654	34,266	34,266	25,384	25,384

+ 1.7% (from 4,2% to 7%) > + 1%

+ 0.9% < + 2.3%

+ 2.5%

+ 2.1%

Findings

- The proprietary output of public research – measured in terms of public ownership of patents – is related to a higher probability of producing a radical invention in terms of recombination of components
  - However small portion of publicly owned radical patents
- Conversely, open science – captured by non-patent references – is more likely to be related to the generation of radical inventions based on application of a new phenomenon to existing components
- This overall patterns is however consistently heterogeneous across sectors
  - Absence of a relationship does not imply a low level of influence of public research on industrial technological change. It might be interaction is not captured by patent related information (we are capturing only the proximity of the codified public research to radical invention generation)

Conclusions

- Public (codified) research is linked to the probability of an invention being radical in different ways, depending on the type of novelty on which the radical invention is built and the type of public research outcome
- The relationship is heterogeneous across sectors and is more prevalent in those sectors that patent more and produce a higher share of radical inventions
- The share of public patents is quite low; the lion's share of the inventive activity leading to patents, is confined to the private sector
- Pushing universities to patent would lead to an increase of only chemistry-related radical inventions

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Thanks for your attention