Internationalized R&D activities and technological specialization: an analysis of patent data.

Lucio Picci and Luca Savorelli

U. of Bologna and U. of St Andrews

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Broad question & data

What are the relations between internationalization in R&D and technological specialization?

Patent counts (PATSTAT); all priority filings (de Rassenfosse, Dernis, Guellec, Picci, de la Potterie, Respol 2013).

International patents: inventors/applicants from different countries

"Inventor " vs. "applicant criterion", National vs. International

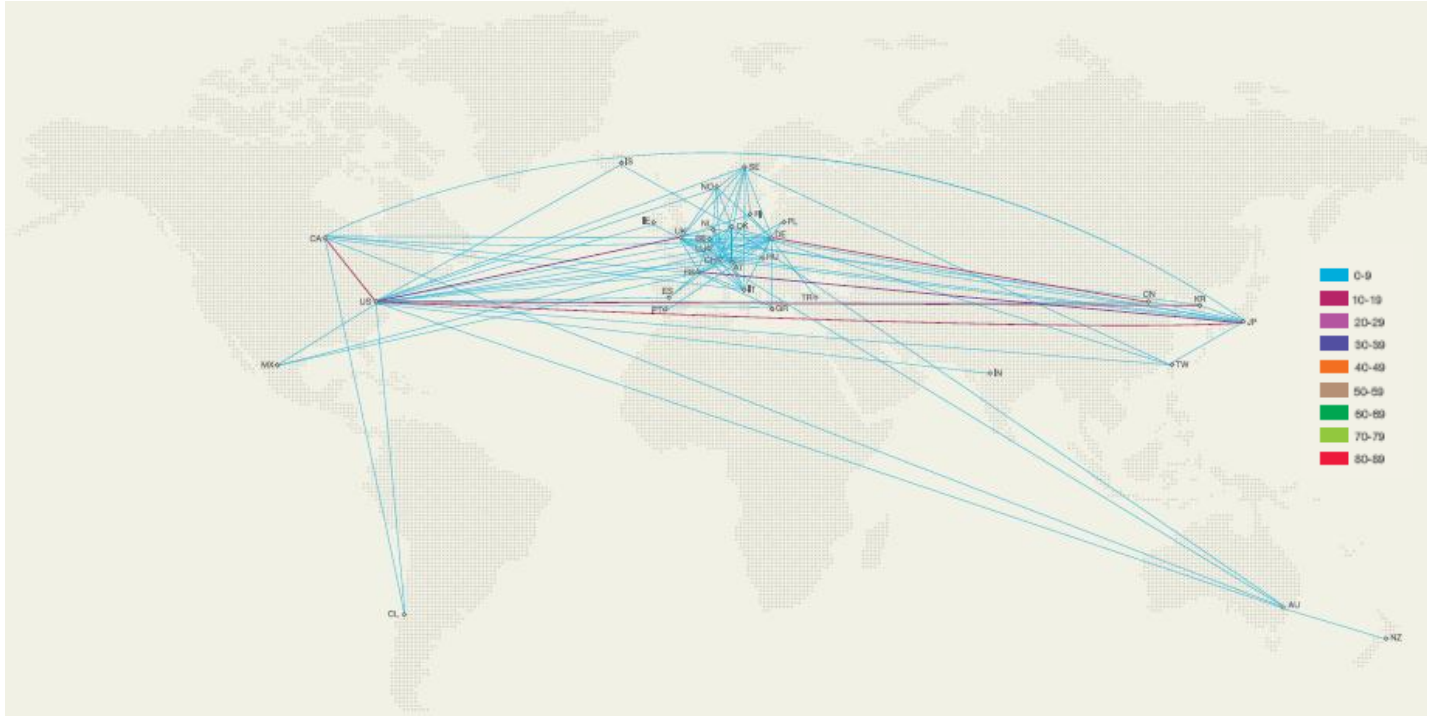
The internationalization of inventive activity

- *Patel and Pavit, 1991: internationalization of production vs. localized inventive activity*

- *"The times they are a changing": Patel and Vega, 1999; Le Bas and Sierra, 2002*
- *Anecdotal evidence: The Economist, 2010:* "Companies in the Fortune 500 list have 98 R&D facilities in China and 63 in India"
- *Industry case-studies:*

  - Wireless telecom; Di Minin and Bianchi, 2011; Pharmaceuticals; Bennato and Magazzini, 2009 ; Biotech; Shan and Song, 1997 ; Semiconductors; Almeida, 1996

1990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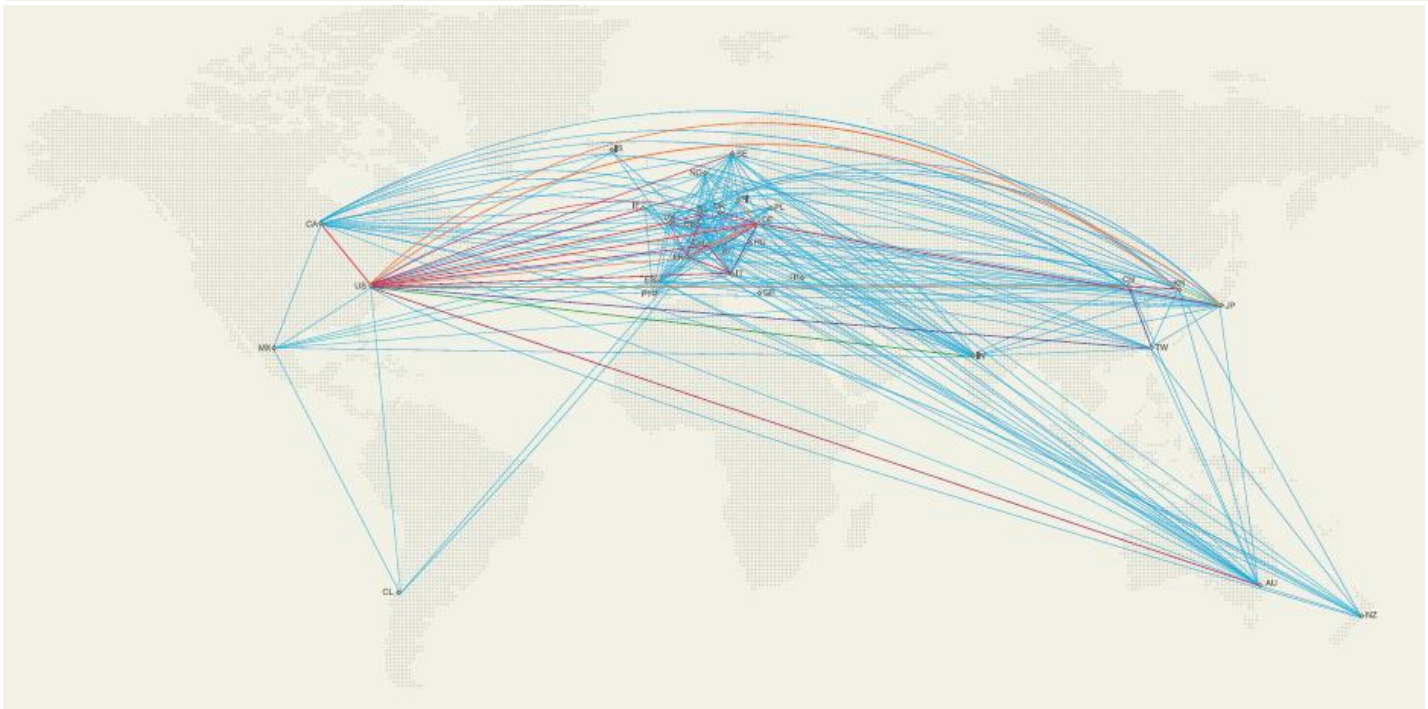
2006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The specialization of inventive activity

- *Sharp increase in specialization of inventive activity at national level from 1965 to 1990 (Archibugi and Pianta, 1992; Cantwell and Vertova, 2004).*
- *But: increasing diversification at firm level (e.g. Garcia-Vega, 2006)*

→ *Greater internationalization of MNEs leads overseas location to focus on the best that the foreign location has to offer*

Research questions

The relationship between technological specialization and internationalization

1.Are there differences across technologies and across countries?

2. What are the motivations for international collaborations and how do they evolve in time?

Contribution to the literature /1

Structural changes in internationalized patenting activity

Guellec and van Pottelsberghe de la Potterie,2001; OECD, 2008; Picci, 2010: take global view regardless of technological sectors.

→ We break down data by WIPO's International Patent Classification (IPC) taxonomy. Specific contributions:

1. Differences in intensity and nature by tech sector.

2. Disentangle pure growth effects from compositional effects

3.New index to contrast between different metrics: applicants vs inventors.

Contribution to the literature /2

Technological specialization and internationalization

Archibugi and Pianta (1992) and Cantwell and Vertova (2004): tech specialization at the coountry level increased until 1990

1. *We provide the missing picture afterwards*
2. *Tech profiles: international vs national*
3. *Tech profiles: applicants vs inventors*

Contribution to the literature /3

Motivations for international collaborations

Kuemmerle (1997): "home-base augmenting" vs "home-base exploiting"

Some evidence of a shift from exploiting to augmenting

Patel and Pavitt (1991); Cantwell (1999): shift to source abroad tech where they do not have a comparative advantage

system-driven vs sector-driven motivations

Gravity model at aggregate level and at sectorial level.

1.Technological proximity, at different levels of granularity.

2. More nuanced view on motivations for internationalization

Results / 1

Since 1990:

1. ***Internationalization has increased in all sectors.*** *Positive but modest role of compositional effects.*

2. ***Tech specialization has <u>not</u> increased.*** *This interrupts a trend.*

3. ***National specialization profiles are "amplified" in the production of internationalized inventions***

4. ***"Inventor" countries are more specialized than "applicant" countries.*** *MNEs tend to reinforce specialization patterns abroad*

5. ***Specialization cycles?*** *Specialized emerging (inventor) countries mature, become active in inventing abroad, and eventually de-specialize*

Results / 2

5. Technological proximity *negatively influences collaborations only in some sectors. R&D strategies are technology dependent.*

6. ***No increase over time*** *for home-base augmenting motives.*

7. "System-driven vs sector-driven".

Dataset

Patstat, EPO 2009

1990 – 2006

50 patent offices

40 countries (OECD + others)

IPC tech classes: WIPO taxonomy (36 classes re-grouped into 5)

10,940,242 priority applications

→*national patents: all inventors and applicants from the same country*

→*international: at least one inventor or applicant from another country*

263,220 or 2,6%

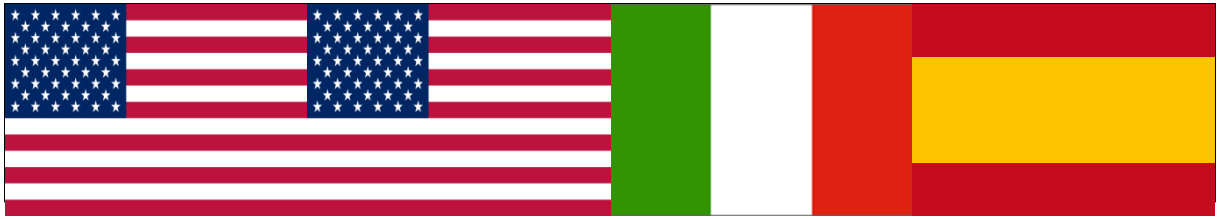
Fractional counting

1 Patent

4 inventors from: US, US, IT, ES

2 applicants: US, ES

Fractional counting



0,25 + 0,25 = 0,50

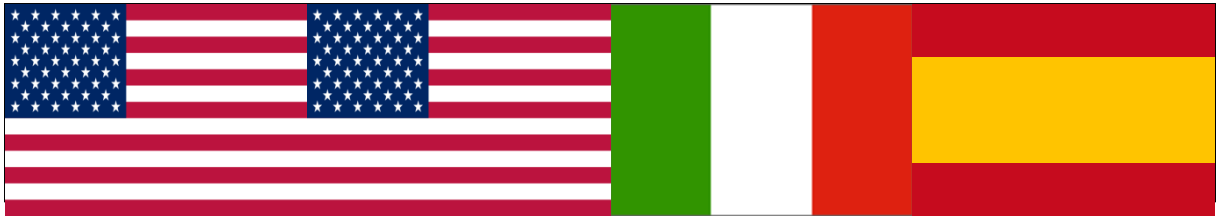
0,25

0,25

4 inventors from: US, US, IT, ES

2 applicants: US, ES

InvApp ***absolute*** *measure of internationalization*



0,25 + 0,25 = 0,50 0,25 0,25

4 inventors: US, US, IT, ES

2 applicants: US, ES

$InvApp_{US, ES} = Inv_{US} \times App_{ES} = 0.5 \times 0.5 = 0.25$

$InvApp_{ES, US} = Inv_{ES} \times App_{US} = 0.25 \times 0.5 = 0.125$

Relative *measures of internationalization/1*

$$InvApp_{US,\,ES} = Inv_{US} \times App_{ES} = 0.5 \times 0.5 = 0.25$$

1. This is the absolute measure for 1 patent.

2. Sum across patents and get the country score for internationalization.

3. Weight over the total fractional counting according to inventors or applicants.

→ *% of international patents:*

InvApp|Inv

$$\frac{InvApp_{i\,j}}{Inv_i}$$

InvApp|App

$$\frac{InvApp_{j\,i}}{App_i}$$

Relative *measures of internationalization/2: example*

InvApp|Inv

$$\frac{InvApp_{US,ES}}{Inv_{US}}$$

American inventors *collaborating with:*

Spanish applicants

relative to: ***total American inventors****.*

InvApp|App

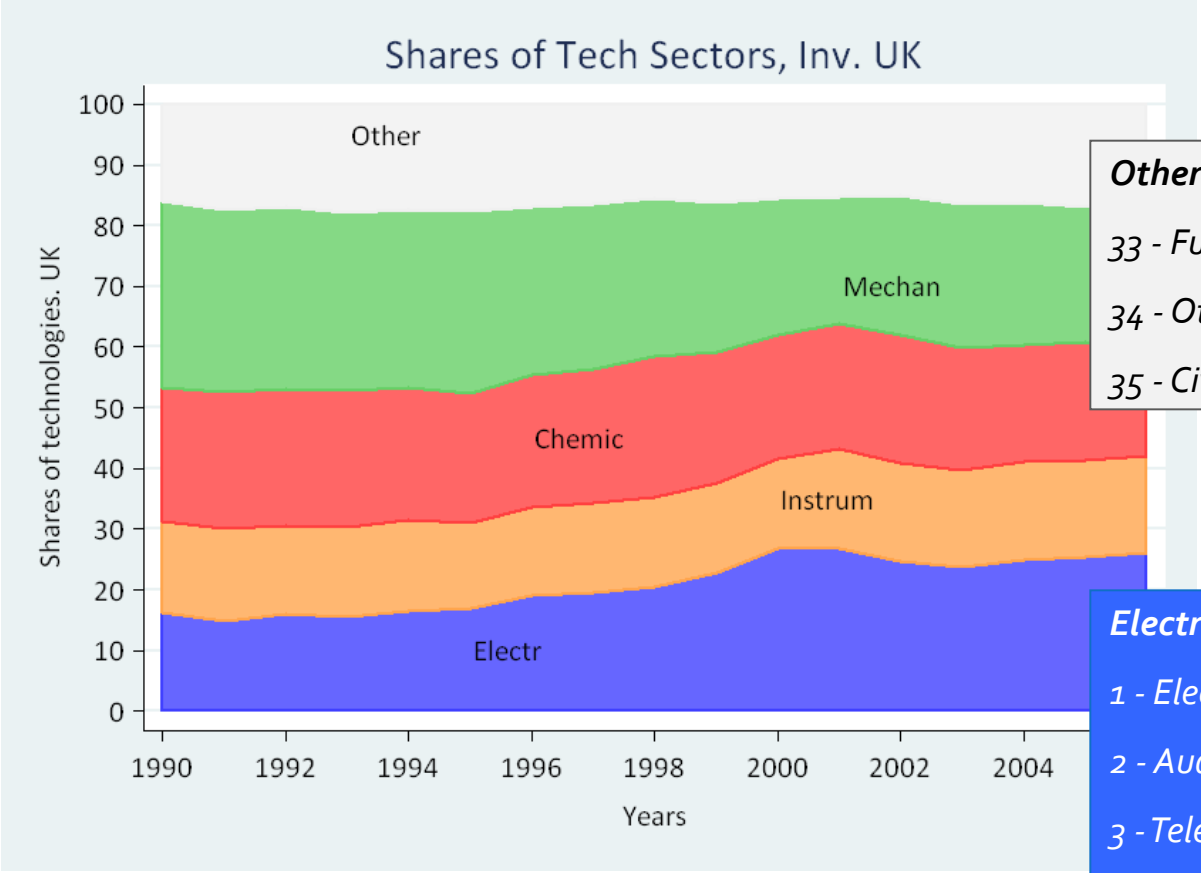
$$\frac{InvApp_{ES,US}}{App_{US}}$$

Spanish inventors *collaborating with:*

American applicants

relative to: ***total American applicants.***

Macro-technological sectors



United Kingdom

Other fields

33 - Furniture, games

34 - Other consumer goods

35 - Civil engineering

Electrical engineering

1 - Electrical machinery, apparatus, energy

2 - Audio-visual technology

3 - Telecommunications

4 - Digital communication

5 - Basic communication processes

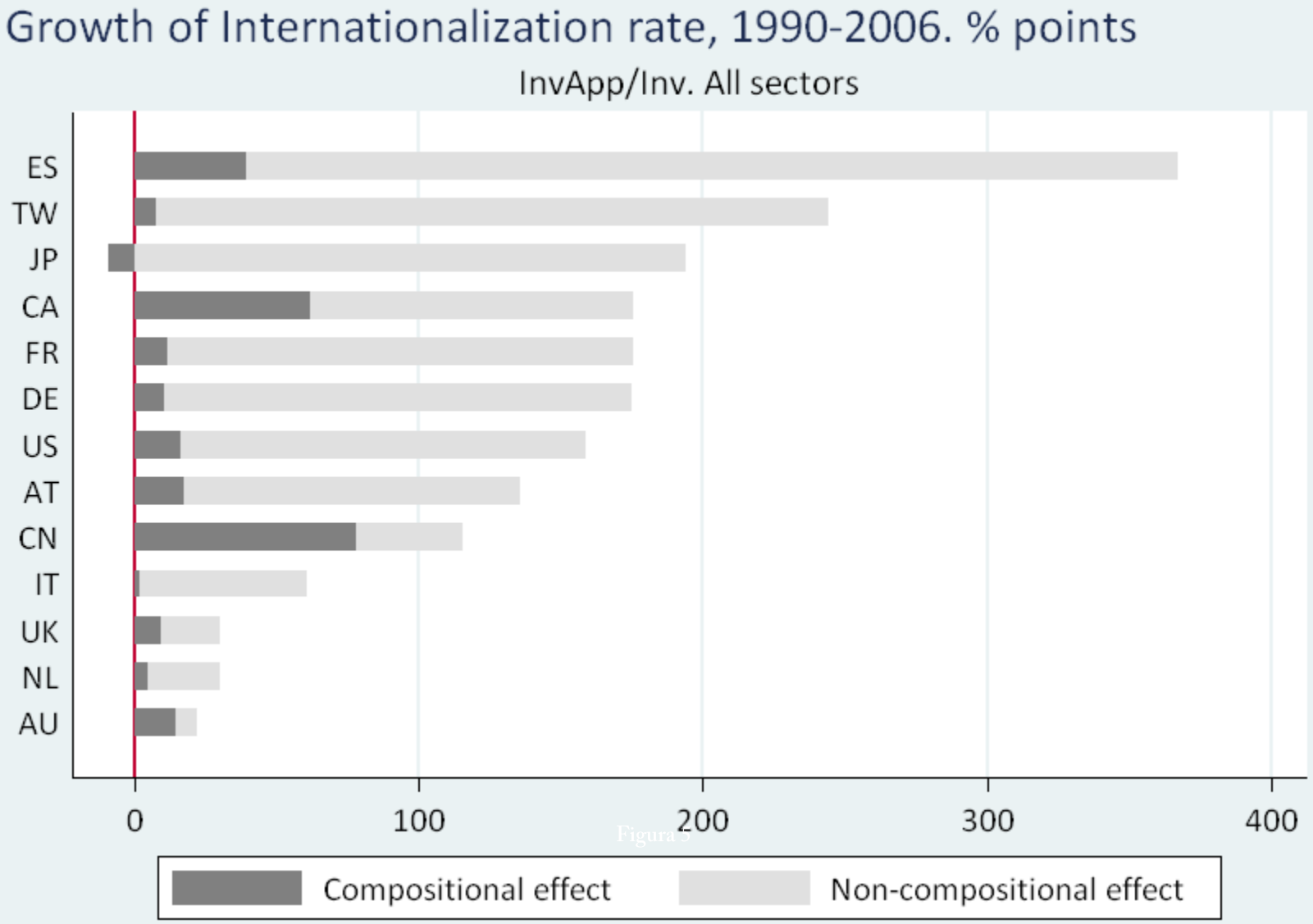
6 - Computer technology

7 - IT methods for management

8 - Semiconductors

Breakdown in compositional and pure growth effects

Growth rate of int., InvApp|Inv metric for selected countries



Comparison between measures of internationalization / 1

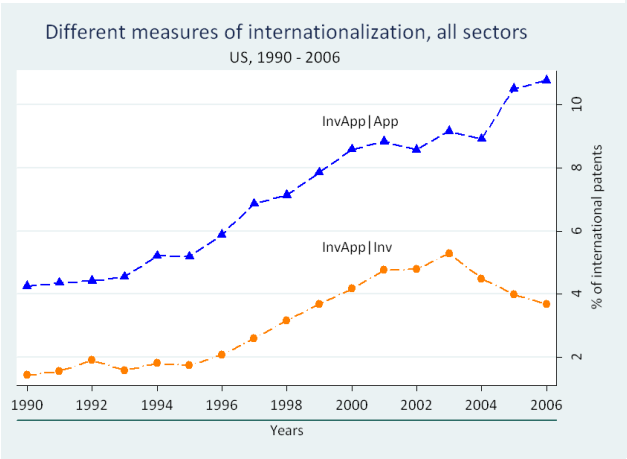
InvApp|Inv and InvApp|App metrics for the USA, France, and Germany, 1990 -2006

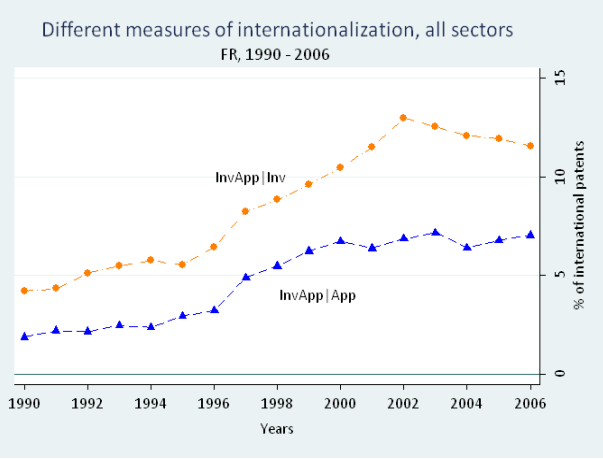
InvApp|App:

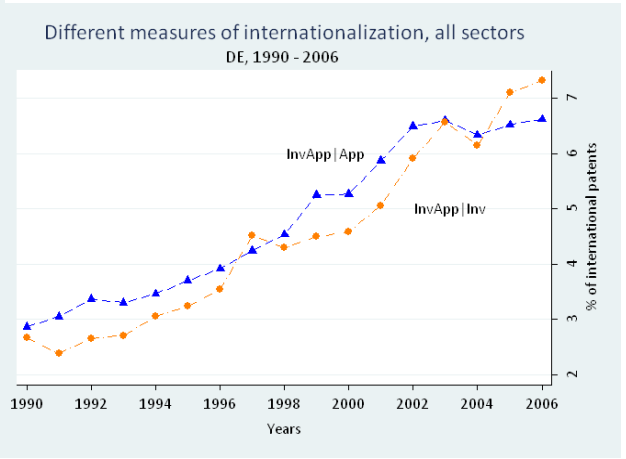
$$\frac{InvApp_{ES,US}}{App_{US}}$$

InvApp|Inv:

$$\frac{InvApp_{US,ES}}{Inv_{US}}$$







United States

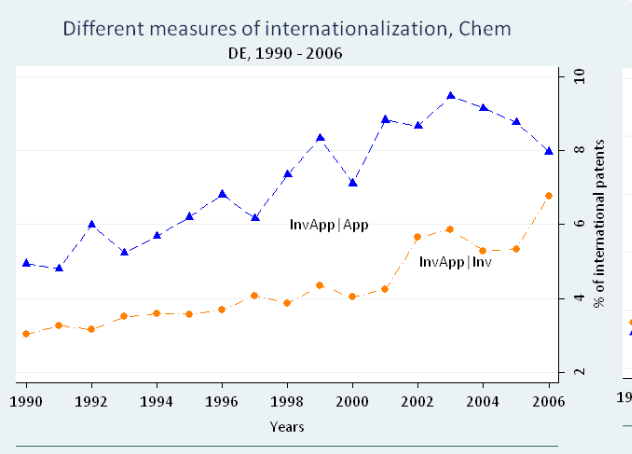
France

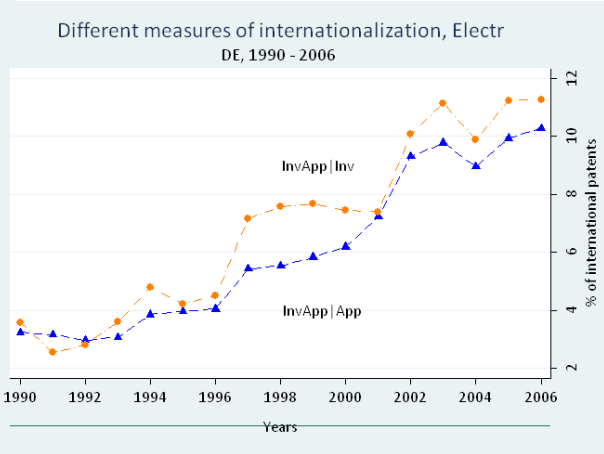
Germany

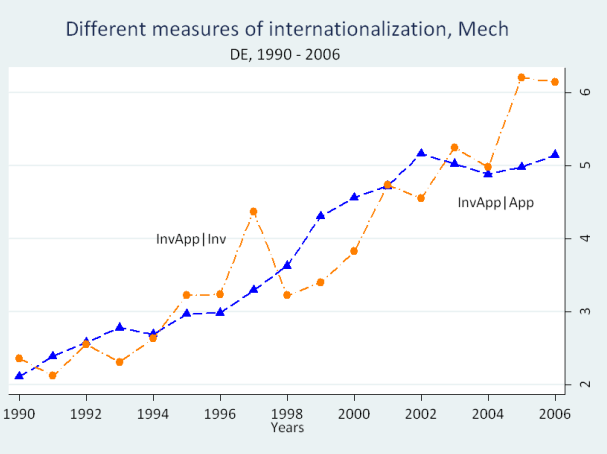
Comparison between measures of int. by tech sector / 2

InvApp|Inv and InvApp|App in Germany, 1990 -2006

Germany







Chem

Electr

Mech

Applicant Surplus

Bilateral

$$AppSur_{ij} = (1 - \frac{InvApp|App}{InvApp|Inv}) \cdot 100$$

→ *positive: country i contributes with relatively more applicants and country j with relatively more inventors.*

National → aggregate over ROW

Country applicant surplus

Period	Country	Technology					
		All tech	Electr	Instr	Chem	Mech	Other
1990-1994	JP	**-16.70**	-23.40	6.18	-28.35	8.43	-7.75
1995-1999		**-12.68**	-8.88	11.92	-30.24	-4.88	-10.66
2000-2004		**1.00**	24.08	-12.96	-24.88	-10.16	-17.18
2005-2006		**-1.63**	6.87	-1.37	-11.10	-11.63	-29.83
1990-1994	CN	**-46.68**	-60.43	-74.75	-34.65	-41.55	3.88
1995-1999		**-75.82**	-74.36	-23.64	-69.00	-93.66	-60.94
2000-2004		**-73.54**	-79.70	-51.60	-82.14	-59.48	-44.16
2005-2006		**-60.70**	-61.67	-57.23	-61.10	-62.00	-41.97
1990-1994	US	**174.45**	258.73	268.75	135.65	125.30	169.83
1995-1999		**172.36**	145.68	257.26	187.92	188.50	249.98
2000-2004		**91.58**	48.92	90.74	164.74	216.10	173.42
2005-2006		**151.73**	117.77	103.07	160.50	353.30	298.53
1990-1994	DE	**21.18**	1.38	19.35	62.50	5.88	-4.13
1995-1999		**7.52**	-17.32	-6.86	71.66	-5.18	2.18
2000-2004		**11.58**	-12.58	-5.82	78.28	10.96	1.14
2005-2006		**-4.87**	-9.97	-23.30	51.63	-12.67	-21.53

Specialization/1: TecSpec index (Krugman index)

How the tech shares of a country differ from the ROW

$$TecSpec_i = \sum_{k=1}^{5} abs(s_{k,i} - \bar{s}_k)$$

TecSpec=0 → ***same tech prof. ROW***

TecSpec=2 → ***no tech shared with ROW***

Period	National		International	
	(a)Inv	(b)App	(c)Inv	(d)App
1990-1993	.399	.410	.368	.618
1994-1998	.370	.384	.355	.577
1999-2002	.368	.398	.385	.555
2003-2007	.386	.413	.355	.682

Specialization/1: Correlation between tech profiles

		Nat		Int	
		Inv	**App**	**Inv**	**App**
Nat	**Inv**	1.00			
	App	0.94	1.00		
Int	**Inv**	0.57	0.52	1.00	
	App	0.48	0.47	0.28	1.00

Specialization/2: Technological Revealed Comparative Advantage

TRCA: world share in a sector / total world share in patenting activities

Advantage if >1

	Corr ($TRCA_{int}$, $TRCA_{naz}$) INV						Corr ($TRCA_{int}$, $TRCA_{naz}$) APP					
Period	**Electr**	**Inst**	**Chem**	**Mech**	**Other**	**AVG**	**Electr**	**Inst**	**Chem**	**Mech**	**Other**	**AVG**
All periods	0.471	0.310	0.246	0.484	0.218		0.557	0.193	0.467	0.223	0.304	0.557

1) International specialization patterns reflect national patterns.

	$StDev(TRCA_{int})/StDev(TRCA_{naz})$ INV						$StDev(TRCA_{int})/StDev(TRCA_{naz})$ APP					
1990-1993	**1.86**	**3.51**	0.83	**1.44**	**1.65**	1.86	**1.59**	**5.51**	0.99	**7.81**	**5.97**	4.37
1994-1998	**1.43**	**2.17**	0.57	**1.80**	**1.26**	1.45	1.18	**2.74**	1.16	**5.44**	**2.72**	2.65
1999-2002	1.20	**1.46**	0.86	**1.81**	1.21	1.31	**1.42**	**4.10**	0.90	**3.18**	**1.79**	2.28
2003-2007	1.01	**1.43**	0.93	**1.63**	0.90	1.18	**1.47**	**2.65**	**1.68**	**3.39**	**4.45**	2.73
Total	**1.42**	**2.04**	0.80	**1.70**	**1.27**		**1.40**	**3.69**	**1.31**	**5.12**	**4.08**	

2) National profiles are amplified in international. No change over time.

Specialization/3: Applicant surplus

Inventors surplus countries should be more specialized

→ negative relation with AppSur

Spearman correlations between the two measures are low, negative and significant at 1%

Motivations: A gravity model of sectorial inventive activity

$$\ln(InvApp_{ijt}^{s}) = \beta_0 + \beta_1 \ln(A_{it}^{s}) + \beta_2 \ln(A_{jt}^{s}) + \beta_3 \ln(dist_{ij}) + \lambda L_{ijt} + \beta_4 D_{it} + \beta_5 D_{jt} + \varepsilon_{ijt}$$

macro-sector

Inv.mass country i

(pat count)

Inv.mass country j

(pat count)

Vars vector:

Tech(s) →*35 sect*

Tech →*5 sect*

Country spec. Fixed-fxs

Distance between i & j capital cities

- *Com. borders*
- *Com. language*
- *Similar language*
- *Religion*
- *EU members*
- *Eu. Monetary Un.*
- *IP protection*

Poisson/1

	VARIABLES	Dependent variable					
		$InvApp^0$ All technologies	$InvApp^1$ Electrical	$InvApp^2$ Instruments	$InvApp^3$ Chemistry	$InvApp^4$ Mechanical	$InvApp^5$ Other
A	*Tech*	+ 0.667***	+ 1.034***	+ 0.795***	+ 0.0274	- -0.284***	+ 0.109
		(0.0176)	(0.0336)	(0.0542)	(0.0424)	(0.0432)	(0.0751)
	Techsec s=1…,5		- -0.0848***	- -0.0139	+ 0.427***	+ 0.406***	- -0.253***
			(0.0312)	(0.0419)	(0.0250)	(0.0353)	(0.0275)

Tech: country vector correlation *between macro-sectors*

Techsec: country vector correlation *within macro-sectors*

Negative: home-base augmenting

Poisson/2: time variation in the role of the country portfolio

		VARIABLES		Dependent variable					
				$InvApp^0$ All technologies	$InvApp^1$ Electrical	$InvApp^2$ Instruments	$InvApp^3$ Chemistry	$InvApp^4$ Mechanical	$InvApp^5$ Other
$\ln(Inv_{is})$ s=0,1…,5	+	**a.** 1990-1998	=	4.860***	1.953***	4.611***	3.215***	5.859***	9.087***
				(0.221)	(0.112)	(0.333)	(0.168)	(0.369)	(0.664)
		b. 1999-2006		4.267***	1.895***	4.030***	3.173***	5.550***	10.15***
				(0.186)	(0.0896)	(0.304)	(0.160)	(0.318)	(0.608)
$\ln(Inv_{js})$ s=0,1…,5	-	**a.** 1990-1998	=	-4.721***	-2.755***	-1.584***	-1.996***	-4.341***	-3.786***
				(0.182)	(0.164)	(0.231)	(0.210)	(0.341)	(0.353)
		b. 1999-2006		-4.550***	-2.258***	-1.563***	-2.114***	-4.103***	-3.976***
				(0.162)	(0.123)	(0.207)	(0.198)	(0.290)	(0.335)
$\ln(App_{is})$	-	**a.** 1990-1998	=	-3.987***	-1.092***	-3.936***	-2.655***	-5.149***	-8.298***
				(0.217)	(0.101)	(0.334)	(0.154)	(0.363)	(0.641)
		b. 1999-2006		-3.441***	-0.953***	-3.789***	-2.578***	-4.745***	-9.299***
				(0.181)	(0.0834)	(0.307)	(0.147)	(0.314)	(0.578)
$\ln(App_{js})$	+	**a.** 1990-1998	=	4.887***	2.962***	2.361***	2.214***	4.936***	4.460***
				(0.191)	(0.153)	(0.233)	(0.212)	(0.340)	(0.365)
		b. 1999-2006		4.636***	2.410***	2.226***	2.436***	4.837***	4.444***
				(0.168)	(0.116)	(0.211)	(0.202)	(0.292)	(0.343)

No increase over time

Home-base augmenting

Summary of results & future research

1. *Increase of internationalization over time across tech sectors, no compositional effects.*
2. *No increase in specialization over time →Specialization cycles?*
3. *National technological profiles differ sensibly from international ones.*
4. *Countries with an inventors surplus are more specialized →role of MNEs.*
5. *Technological proximity affects collaborations with important differences across sectors →sector-specific policies.*
6. *Evidence of home-base augmenting motives. But other taxonomy?*
7. *No increase over time. Intriguingly consistent with no increase in specialization.*

→ *Specialization & internationalization policies should be connected: competition for subsidiaries charters (Birkinshaw and Hood, 1989)*

→ *Hollowing out*

Thanks!

lucio.picci@unibo.it