Research and innovation in Europe towards 2020: Reinforcing excellence, addressing the innovation divide

Andrea Bonaccorsi

University of Pisa
RISE Expert Group, DG Research and Innovation

May 28, 2015

Outline

1. The European model of academic excellence
2. Business R&D
3. The innovation divide
4. Horizon 2020 and Smart Specialization Strategies
5. Implications for national and European policies

The European model of excellence in academic research

The aggregate production of scientific research in Europe is comparable to the US by volume and has been growing

European scientific research suffers from three issues

1. It is still relatively weak in the upper tail of scientific excellence (e.g. highly cited scientists, or most influential researchers)
2. There is a small number of world-class universities, or universities that are able to compete at top level in *many* scientific fields
3. Scientific research is relatively weak in those areas in which the science-technology linkages are stronger and generate more opportunities for innovation
   - Information and Communication Technology
   - Life sciences

The European model of business R&D

R&D intensity (R&D expenditure/turnover) of existing European companies is comparable to the R&D intensity of US companies in the same industries

The overall business R&D in Europe suffers from three issues

1. Composition effect: industries with high R&D intensity are relatively weaker than industries with intermediate intensity
2. Age effect: companies investing in R&D are old
3. Regional effect: business R&D is mostly concentrated in Central and Northern European regions

The European model of innovation and productivity growth

Europe is fighting to identify a sustainable and competive innovation model

The overall innovation model in Europe suffers from three issues

1. Innovative companies do not grow fast enough
2. Innovation in services is hampered by several obstacles
3. Innovation divide

(1) Assessing the European academic excellence model

Publications in all disciplines and indicators of quality, 2000-2011

* The average of relative citation (ARC) is a field-normalized measure of the scientific impact of publications, based on the impact factors of the journals in which they were published.

Source: Data from Campbell *et al.* (2013)

Geographical zone		Number of publications	Number of publications, fractional	Growth index	Average of relative citation*	Share of top 10% cited publications in total publications, %
ERA		6,673,485	5,920,382	1.19	1.08	12.7
EU		6,038,673	5,281,856	1.19	1.08	11.0
US		4,947,133	4,221,118	1.08	1.37	14.9
China		2,528,134	2,337,281	1.77	0.73	6.7
Japan		1,282,630	1,129,660	1.00	0.89	8.1
World		17,500,890	17,500,890	1.28	1	10

Source: Sachwald (2015)

Share of all science and engineering articles, top 1% cited articles and index of highly cited articles, 2002 and 2012

	Share of articles in world total, %					Share of top 1% cited articles in world total, %					Index of highly cited articles*			
	EU	US	Japan	China		EU	US	Japan	China		EU	US	Japan	China
2002	35.6	30.8	9.0	2.6		28.2	57.0	5.0	0.3		0.8	1.8	0.6	0.1
2012	31.6	26.6	6.3	9.2		29.8	46.4	4.0	5.8		0.9	1.7	0.6	0.6

* *Share of the world top 1% cited articles divided by the share of world articles in the cited-year window.*

Source: Nat ac, based on Thomson Reuters data

Source: Sachwald (2015)

The European model of academic excellence

- Most analyses on the European position in the global scientific competition are based on aggregate data
- Stylized facts
    - Europe is #1 in terms of number of publications
    - Europe lags behind USA in terms of number of citations, particularly in the number of highly cited scientists
    - Asian research is a threat but still lags behind

- Innovation 4 Growth (I4G) (Bonaccorsi et al., 2013) provided a disaggregated view of the European position, based on data on individual universities (microdata)
    - 251 scientific fields (journal subject categories)- but only STEM
    - Publication data: Scopus
    - Year 2007-2010 combined
    - Threshold at 50 publications per Subject category/ university
    - No data on Public Research Organisations (PROs)
    - Source: *Global Research Benchmarking System* (includes universities from Usa and Canada, Far East Asia, Europe)
    - Disambiguation of names of European universities carried out manually by a group of experts, mainly recruited within the EUMIDA network of national correspondents.

Share of regions in total scientific production of universities. All fields. Year 2007-2010

Source: Bonaccorsi et al. (2015)

	Total Pubs	Pubs in 10% SNIP	Pubs in 25% SNIP	Total Cites	Cites from 10% SNIP	Cites from 25% SNIP	H-Index
Europe	3.687.216	1.693.691	2.776.059	15.056.878	6.889.759	11.003.256	82.684
Asia Pacific	3.548.419	1.026.521	2.163.556	8.287.210	3.306.552	5.603.883	132.492
Norh America	3.396.580	1.773.187	2.713.656	17.085.125	8.348.186	12.894.281	181.671
Total	10.632.215	4.493.399	7.653.271	40.429.213	18.544.497	29.501.420	396.847

Source: I4G elaboration on data from *Global Research Benchmarking System*, based on Scopus.

Please note that the overall number include duplications, since the same article may be assigned to more than one Subject Category.

Share of regions in total scientific production of universities (percentage values). All fields. Year 2007-2010

	Total Pubs	Pubs in 10% SNIP	Pubs in 25% SNIP	Total Cites	Cites from 10% SNIP	Cites from 25% SNIP	H-Index
EU_2	34,7	37,7	36,3	37,2	37,2	37,3	20,8
APR	33,4	22,8	28,3	20,5	17,8	19,0	33,4
NAM	31,9	39,5	35,5	42,3	45,0	43,7	45,8
	100	100	100	100	100	100	100

A microdata approach

- Aggregate data hide the distribution of scientific production across units (i.e. universities)
- The distribution of production across universities should be analyzed in terms of
    - **Volume** (number of publications)
    - **Impact** (number of citations, H-index)
    - **Quality** (publications and citations in top journals)
- Composite indicator
    - 7 indicators available
    - Each indicator is normalized into a 0-100 scale with respect to the world distribution of universities in the GRBS dataset
    - Equal weight assigned to the 7 indicators
    - Composite indicator is itself within the 0-100 scale: taking universities in the range 90-100 gives Band 1, 70-100 gives Band 3. Uneven number of universities in Bands (not deciles).
- Some of the indicators are **size-dependent** (number of publications, number of citations, H-index), while others are **size-independent** (% of publications and citations in top 10% journals or top 25% journals, respectively).

Distributions of regions in top 10% by number of publications and number of citations

Region	Number of publications	Share of publications (%)	Number of citations	Share of citations (%)
Europe	47,915	14.3	217,636	13.9
North America	159,174	47.6	1,000,186	63.7
Asia Pacific	127,060	38.0	351,321	22.4
Total	334,149	100.00	1,569,143	100.00

Note. This table is a slightly revised version of Table 2 in *I4G Policy brief # 10*

Distributions of regions in top 30%: unweighted and by number of publications and number of citations

Region	Number of universities in top 30% in at least one field	Total number of fields in top 30%	Share of the number of fields out of the world total (%)		
			Unweighted	Weighted by number of publica tions	Weighted by number of citations
Europe	273	2863	32,9	30,6	30,8
North America	188	4064	46,8	45,4	50,2
Asia Pacific	181	1765	20,3	24,0	19,0
Total	642	8692	100	100	100

Explaining the paradox: the European model of academic excellence

The paradox can be explained by looking at the distribution of excellent results in the population of universities.

- US and Asian excellence is based on a good number of **global research universities**, or **world-class universities** that are able to excel in a large number of scientific fields
- European excellence is based on a much smaller number of global research universities, which are also themselves much smaller than US and Asian
- European excellence comes also from a **long tail of niche players**, able to excel only in 1-2 fields

Distribution of universities by number of fields in top 10% and by region

Region	Global players (>10)	Moderate players (3-9)	Niche players (1-2)	Total number of universities in top 10%	Total number of fields in top 10%	% of fields by region
North America	13	23	33	69	412	50,9
Europe	3	17	43	63	180	22,2
Asia	7	15	29	51	217	26,8
Total	23	55	104	182	809	100,0

Distribution of universities by number of fields in top 30% and by region

Region	Global players (>10)	Moderate players (3-9)	Niche players (1-2)	Total number of universities in top 30%	Total number of fields in top 30%	% of fields
North America	91	50	47	188	4064	47%
Europe	82	82	109	273	2863	33%
Asia Pacific	50	57	74	181	1765	20%
Total	223	189	230	642	8692	100%

Global ranking by number of large scientific fields in top 30%

(n=15)

University Name	Country	Region	No. of Subjects in Top 3
Massachusetts Institute of Technology	United States	NAM	15
Stanford University	United States	NAM	15
University Michigan - Ann Arbor	United States	NAM	15
University of California - Los Angeles	United States	NAM	15
Harvard University	United States	NAM	14
University of Toronto	Canada	NAM	14
University of Washington - Seattle	United States	NAM	14
Columbia University in the City of New York	United States	NAM	13
University of California, Berkeley	United States	NAM	13
Duke University	United States	NAM	12
The University of British Columbia	Canada	NAM	12
The University of Cambridge	United Kingdom	EU_2	12
The University of Oxford	United Kingdom	EU_2	12
University of California - San Diego	United States	NAM	12
Yale University	United States	NAM	12
Johns Hopkins University	United States	NAM	11
Cornell University	United States	NAM	10
Pennsylvania State University - University Park	United States	NAM	10
University of North Carolina at Chapel Hill	United States	NAM	10
University of Pennsylvania	United States	NAM	10
University of Texas - Austin	United States	NAM	10
University of Wisconsin - Madison	United States	NAM	10
Washington University in St. Louis	United States	NAM	10
California Institute of Technology	United States	NAM	9
Federal Institute of Technology Zurich	Switzerland	EU_2	9
Northwestern University	United States	NAM	9
Princeton University	United States	NAM	9
University of California - San Francisco	United States	NAM	9
University of Maryland - College Park	United States	NAM	9
University of Minnesota - Twin Cities	United States	NAM	9

Global ranking

National University of Singapore	Singapore	APR	8
Ohio State University - Columbus	United States	NAM	8
University of Illinois - Urbana-Champaign	United States	NAM	8
University of Tokyo	Japan	APR	8
Georgia Institute of Technology	United States	NAM	7
Texas A&M University	United States	NAM	7
Tsinghua University	China	APR	7
University of Alberta	Canada	NAM	7
University of California - Davis	United States	NAM	7
University of Florida	United States	NAM	7
University of Melbourne	Australia	APR	7
Utrecht University	Netherlands	EU_2	7
Carnegie Mellon University	United States	NAM	6
Hong Kong University of Science and Technology	Hong Kong SAR, China	APR	6
McGill University	Canada	NAM	6
Nanyang Technological University	Singapore	APR	6
National Taiwan University	Taiwan, Province of Ch	APR	6
Purdue University - West Lafayette	United States	NAM	6
Universite Pierre et Marie Curie	France	EU_2	6
University College London	United Kingdom	EU_2	6
University of California - Santa Barbara	United States	NAM	6
University of Chicago	United States	NAM	6
University of Queensland	Australia	APR	6
University of Southern California	United States	NAM	6
City University of Hong Kong	Hong Kong SAR, China	APR	5
Korea Advanced Institute of Science and Technology	South Korea	APR	5
Kyoto University	Japan	APR	5
University of Science and Technology, Korea	South Korea	APR	5
Wageningen University and Research Centre	Netherlands	EU_2	5
Arizona State University	United States	NAM	4
Boston University	United States	NAM	4

Global ranking

Federal Institute of Technology Lausanne	Switzerland	EU_2	4
Hong Kong Polytechnic University	Hong Kong SAR, China	APR	4
Lund University	Sweden	EU_2	4
Michigan State University	United States	NAM	4
National Cheng Kung University	Taiwan, Province of Ch	APR	4
Peking University	China	APR	4
Pohang University of Science and Technology	South Korea	APR	4
Shanghai Jiaotong University	China	APR	4
Southeast University	China	APR	4
Tohoku University	Japan	APR	4
University of Arizona	United States	NAM	4
University of California - Riverside	United States	NAM	4
University of California - Santa Cruz	United States	NAM	4
University of California, Irvine	United States	NAM	4
University of Hawaii at Manoa	United States	NAM	4
University of Massachusetts - Amherst	United States	NAM	4
University of Waterloo	Canada	NAM	4
Zhejiang University	China	APR	4
Australian National University	Australia	APR	3
Colorado State University	United States	NAM	3
Eindhoven University of Technology	Netherlands	EU_2	3
Emory University	United States	NAM	3
Erasmus University Rotterdam	Netherlands	EU_2	3
Ghent University	Belgium	EU_2	3
Karolinska Institute	Sweden	EU_2	3
Leiden University	Netherlands	EU_2	3
National Tsing Hua University	Taiwan, Province of Ch	APR	3
Rice University	United States	NAM	3
Seoul National University	South Korea	APR	3
The University of Edinburgh	United Kingdom	EU_2	3
The University of Manchester	United Kingdom	EU_2	3

Global ranking

University of Aarhus	Denmark	EU_2	3
University of Colorado - Boulder	United States	NAM	3
University of Copenhagen	Denmark	EU_2	3
University of Helsinki	Finland	EU_2	3
University of New South Wales	Australia	APR	3
University of Pittsburgh	United States	NAM	3
University of Texas - M. D. Anderson Cancer Center	United States	NAM	3
University of Victoria	Canada	NAM	3
VU University Amsterdam	Netherlands	EU_2	3
Yonsei University	South Korea	APR	3
Baylor College of Medicine	United States	NAM	2
Boston College	United States	NAM	2
Chinese University of Hong Kong	Hong Kong SAR, China	APR	2
Delft University of Technology	Netherlands	EU_2	2
Fudan University	China	APR	2
Graduate University of Chinese Academy of Sciences	China	APR	2
Harbin Institute of Technology	China	APR	2
Indiana University - Bloomington	United States	NAM	2
Iowa State University	United States	NAM	2
Jilin University	China	APR	2
Katholieke Universiteit Leuven	Belgium	EU_2	2
L'Observatoire de Paris	France	EU_2	2
Monash University	Australia	APR	2
Nanjing University	China	APR	2
National Chiao Tung University Taiwan	Taiwan, Province of Ch	APR	2
New York University	United States	NAM	2
North Carolina State University	United States	NAM	2
Oregon State University	United States	NAM	2
Osaka University	Japan	APR	2
Risø National Laboratory	Denmark	EU_2	2
Rockefeller University	United States	NAM	2

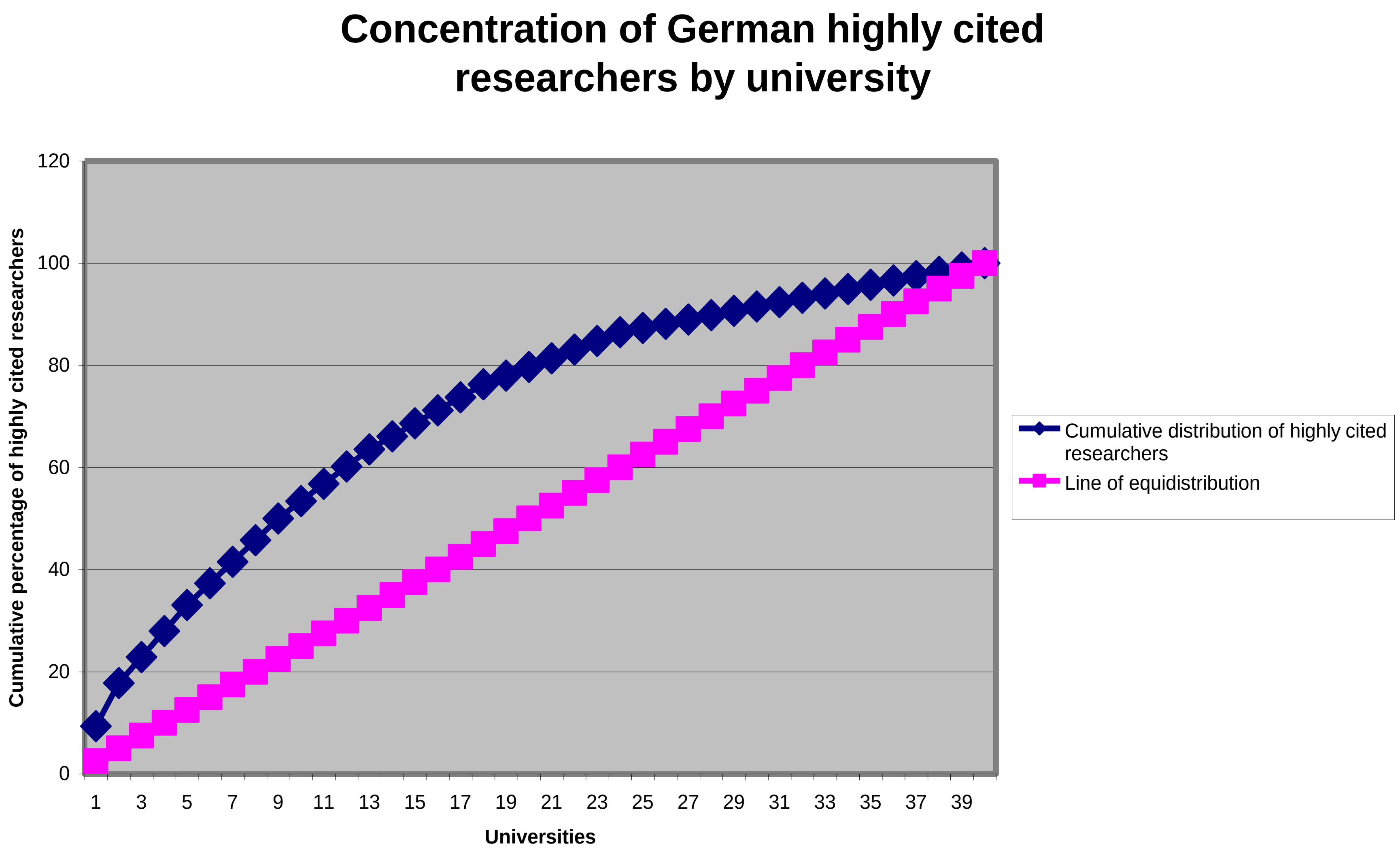
The long tail of niche players

Rockefeller University	United States	NAM	2
Rutgers, The State University of New Jersey - New Brur	United States	NAM	2
Stockholm University	Sweden	EU_2	2
Swedish University of Agricultural Sciences	Sweden	EU_2	2
Technical University of Denmark	Denmark	EU_2	2
The University of Leeds	United Kingdom	EU_2	2
The University of Liverpool	United Kingdom	EU_2	2
The University of Sheffield	United Kingdom	EU_2	2
Tokyo Institute of Technology	Japan	APR	2
Universite Strasbourg	France	EU_2	2
University of Colorado - Denver and Health Sciences Ce	United States	NAM	2
University of Connecticut Storrs	United States	NAM	2
University of Georgia	United States	NAM	2
University of Groningen	Netherlands	EU_2	2
University of Iowa	United States	NAM	2
University of Oslo	Norway	EU_2	2
University of Padova	Italy	EU_2	2
University of Science and Technology of China	China	APR	2
University of Sydney	Australia	APR	2
University of Western Australia	Australia	APR	2
Auckland University of Technology	New Zealand	APR	1
Case Western Reserve University	United States	NAM	1
Deakin University	Australia	APR	1
Feng Chia University	Taiwan, Province of Ch	APR	1
Georgia State University	United States	NAM	1
Göteborg University	Sweden	EU_2	1
Hokkaido University	Japan	APR	1
King's College London	United Kingdom	EU_2	1
Korea University	South Korea	APR	1
Kyushu University	Japan	APR	1
Liverpool John Moores University	United Kingdom	EU_2	1
London Business School	United Kingdom	EU_2	1
London School of Economics and Political Science	United Kingdom	EU_2	1
Loughborough University	United Kingdom	EU_2	1
Louisiana State University - Baton Rouge	United States	NAM	1
Ludwig-Maximilians-Universität München	Germany	EU_2	1
Maastricht University	Netherlands	EU_2	1

McMaster University	Canada	NAM	1
Nagoya University	Japan	APR	1
Nankai University	China	APR	1
New Jersey Institute of Technology	United States	NAM	1
Norwegian School of Sport Sciences	Norway	EU_2	1
Radboud University Nijmegen	Netherlands	EU_2	1
Royal Institute of Technology	Sweden	EU_2	1
San Diego State University	United States	NAM	1
Stonybrook University	United States	NAM	1
Swinburne University of Technology	Australia	APR	1
The University of Aberdeen	United Kingdom	EU_2	1
The University of Birmingham	United Kingdom	EU_2	1
The University of Central Lancashire	United Kingdom	EU_2	1
The University of East Anglia	United Kingdom	EU_2	1
The University of Glasgow	United Kingdom	EU_2	1
The University of Hong Kong	Hong Kong SAR, China	APR	1
The University of Keele	United Kingdom	EU_2	1
The University of Lancaster	United Kingdom	EU_2	1
The University of Leicester	United Kingdom	EU_2	1
The University of St Andrews	United Kingdom	EU_2	1
The University of Western Ontario	Canada	NAM	1
The University of York	United Kingdom	EU_2	1
Tilburg University	Netherlands	EU_2	1
Tufts University	United States	NAM	1
Umeå university	Sweden	EU_2	1
Universidad Autónoma Barcelona	Spain	EU_2	1
Universidad de La Laguna	Spain	EU_2	1
University at Albany	United States	NAM	1
University of Alaska - Fairbanks	United States	NAM	1
University of Amsterdam	Netherlands	EU_2	1
University of Antwerp	Belgium	EU_2	1

University of Bologna	Italy	EU_2	1
University of Cincinnati	United States	NAM	1
University of Delaware	United States	NAM	1
University of Durham	United Kingdom	EU_2	1
University of Erlangen-Nürnberg	Germany	EU_2	1
University of Geneva	Switzerland	EU_2	1
University of Guelph	Canada	NAM	1
University of Hertfordshire	United Kingdom	EU_2	1
University of Houston	United States	NAM	1
University of Lausanne	Switzerland	EU_2	1
University of New Hampshire - Durham	United States	NAM	1
University of Ontario Institute of Technology	Canada	NAM	1
University of Otago	New Zealand	APR	1
University of Ottawa	Canada	NAM	1
University of South Carolina	United States	NAM	1
University of Tasmania	Australia	APR	1
University of Tennessee - Knoxville	United States	NAM	1
University of Texas - Dallas	United States	NAM	1
University of Texas Health Science Center at San Anton	United States	NAM	1
University of Texas Southwestern Medical Center	United States	NAM	1
University of Twente	Netherlands	EU_2	1
University of Utah	United States	NAM	1
Université Laval	Canada	NAM	1
Université Simon Fraser	Canada	NAM	1
Université du Québec à Montréal	Canada	NAM	1
Vanderbilt University	United States	NAM	1
Wake Forest University	United States	NAM	1
Weill Cornell Medical College	United States	NAM	1

Even highly cited scientists are not concentrated in a few excellent institutions but distributed across many universities



Source: Bonaccorsi (2012)

The solitude of stars

University	Number of highly cited researchers	Rank in Shangai ranking
Technische Universität München	11	56
U. Würzburg	10	102-150
Johann Wolfgang Goethe-Universität Frankfurt am Main	6	102-150
Johannes Gutenberg-Universität Mainz	6	151-202
Ruprecht-Karls-Universität Heidelberg	6	65
U. Hamburg	5	102-150
Ludwig-Maximilians-Universität München	5	53
Albert-Ludwigs-Universität Freiburg	5	94
Eberhard Karls Universität Tübingen	5	102-150
U. Bielefeld	4	305-402
Georg-August-Universität Göttingen	4	87
U. Konstanz	4	305-402
Rheinische Friedrich-Wilhelms-Universität Bonn	4	99
Heinrich-Heine-Universität Düsseldorf	3	305-402
Philipps-Universität Marburg	3	203-304
Technische Universität Berlin	3	203-304
Westfälische Wilhelms-Universität Münster	3	N.R.
Humboldt-Universität zu Berlin	3	N.R.

Source: A. Bonaccorsi (2012) The solitude of stars. Highly cited researchers in European universities

University	Number of highly cited researchers	Rank in Shangai ranking
Bergische Universität Wuppertal	2	N.R.
Christian-Albrechts-Universität zu Kiel	2	151-202
Friedrich-Alexander Universität Erlangen-Nürnberg	2	N.R.
U. Karlsruhe	2	203-304
Ruhr-Universität Bochum	2	203-304
U. Stuttgart	2	305-402
U. Bayreuth	1	305-402
U. Dortmund	1	N.R.
Ernst-Moritz-Arndt-Universität Greifswald	1	305-402
U. Essen	1	305-402
U. Hannover	1	403-510
U. Hohenheim	1	N.R.
Justus-Liebig-Universität	1	N.R:
U. Köln	1	151-202
Martin-Luther-Universität Halle-Wittenberg	1	203-304
U. Regensburg	1	305-402
U. Rostock	1	403-510
Technische Universitaet Hamburg - Harburg	1	N.R.
Technische Universität Carolo-Wilhelmina zu Braunschweig	1	N.R.
Technische Universität Dresden	1	305-402
Technische Universität Kaiserslautern	1	N.R.
U. Ulm	1	305-402

Assessing the European model of academic excellence

- Not easy policy implications
- Empirical evidence for **economies of scale** in research is missing (hence *not* easy argument from efficiency-enhancing consolidation, in analogy with other sectors)
- However, **economies of scope** across disciplines highly relevant for attractiveness, PhD education and research multi-disciplinarity

- **Distributed model of excellence**
    - Larger involvement of universities in the scientific competition
    - More diffused territorial impact

- **Model of excellence driven by global research universities**
    - Better positioned to exploit the increased mobility of PhD students and post-doc
    - Job market for academic talent («competition for input»)
    - Knowledge-based foreign policy

(2) Assessing the European businesss R&D model

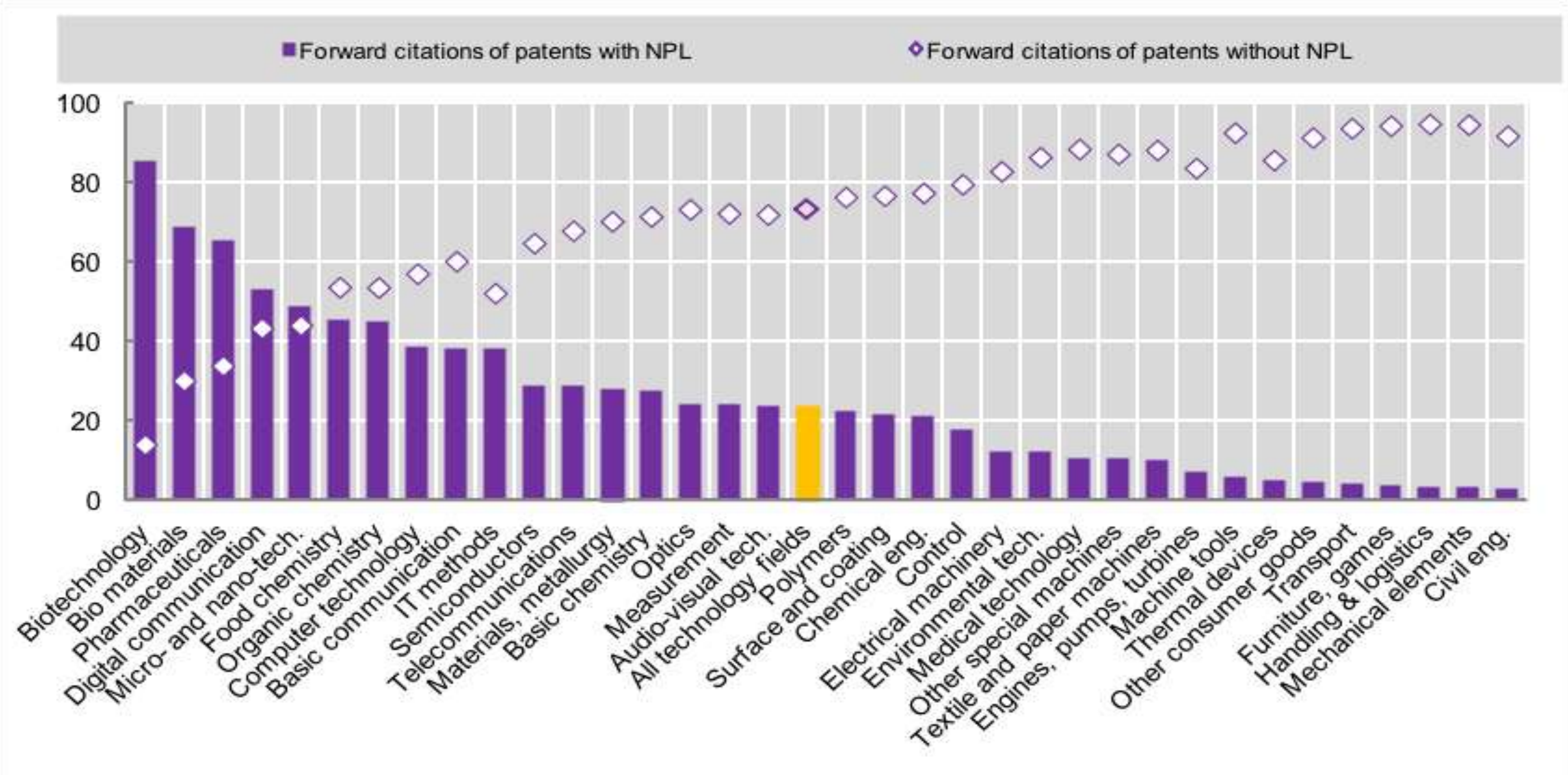
R&D is more productive when it is applied in industries in which:

- completely new functionalities are created (radical innovation)
- there is a strong linkage between research and technological applications
- consumer demand grows fast

In these industries the European competitive position is relatively weaker

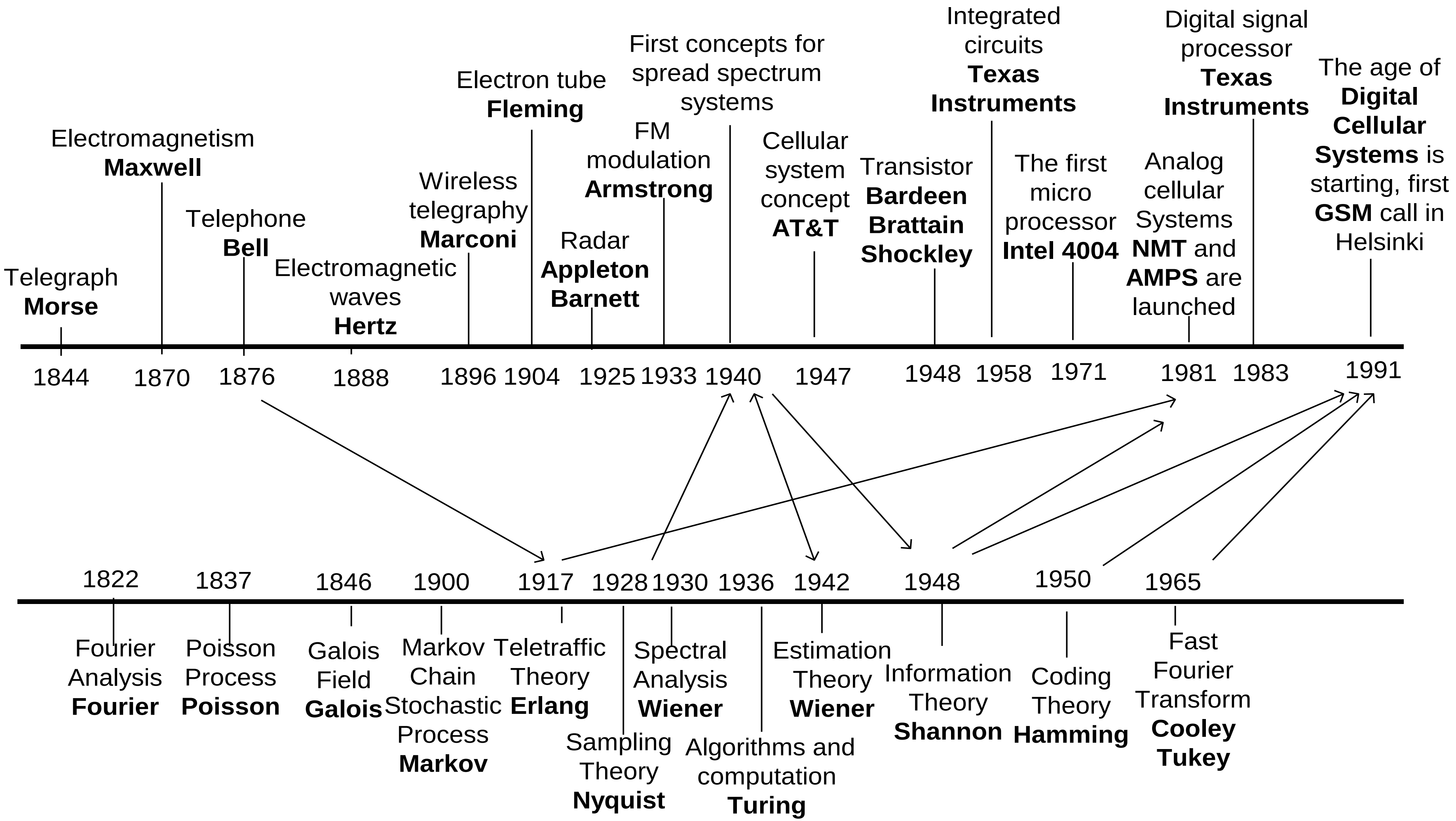
Citations to patents that include non-patent literature, by technology field, 2007-12

from Sachwald (2015)

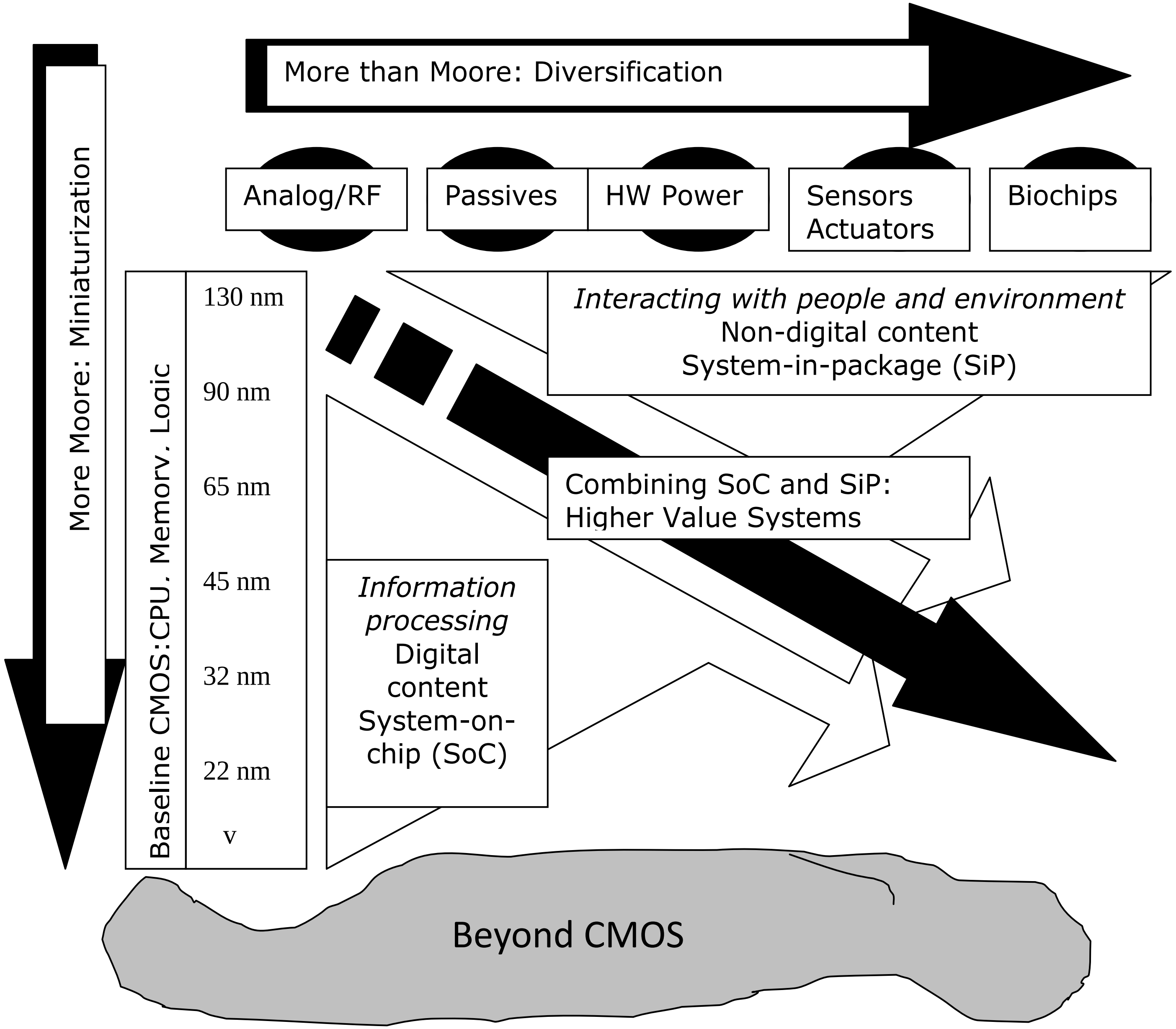


Source : OECD (2013) based on EPO patents

Historical Milestones of Technology and Mathematics Leading to Cellular Systems



Source: courtesy of Nokia company



Moore's Law and more.
Source: The International Technology Roadmap for Semiconductors, Edition 2007. See http:// www.itrs.net.

Tracing back the role of universities in the development of technology/ Programming languages

The role of academic research is also evident in the field of high level programming languages. While the single most important language, FORTRAN, was invented by John Backus at IBM in 1954 (Pugh, 1995)

-the APT language for the control of machine tools was developed by the Servomechanisms Laboratory of MIT in 1955

- COBOL was promoted by a group of universities and computer users which held a meeting at the Computation Center of the University of Pennsylvania in 1959

- the LISP language was developed by John McCarthy at MIT in 1958 (Moreau, 1984)

- PASCAL was developed by Niklaus Wirth at ETH in Zurich in the years 1968-1969 (Wirth, 1996)

- PROLOG was born in 1972 after the work of several French researchers mostly based at the University of Marseille (Colmerauer and Roussel, 1996)

- C++,was developed in 1979 at Bell Laboratories by Bjarne Stroustrup, on the basis of the work done in the PhD dissertation at Cambridge University in England (Stroustrup, 1996).

Tracing back the role of universities in the development of technology/ Internet

High level academic research was also responsible for the long incubation of ideas that eventually led to the development of the Internet.

- early work on connection of computers for the ARPA was done by a group of scientists at MIT's Lincoln Lab (Hafner and Lyon, 1998)

-the idea of packet switching was introduced independently by Paul Baran at Rand Corporation and by the English mathematician Donald Davies (Gillies and Cailliau, 2000; Abate, 1999; Rowland, 2006)

- the detailed application of queuing theory to the Internet was carried out by the team led by the mathematician Leonard Kleinrock at UCLA (Ceruzzi, 2008).

Turing prize in Computer Science, 1966-2007

USA	29
United Kingdom	4
Israel	2
Norway	2
Netherlands	1
Greece	1
Switzerland	1
Denmark	1
India	1
Taiwan	1

If we include non-Member countries such as Switzerland and Norway in the overall number, European countries account for 23.2% of the total, USA for 67.5%, Middle and Far East countries for 9.2%.

The share of Europe falls at 16.2% if we limit to EU countries.

Source: our elaboration from the Turing Prize website, updated from Bonaccorsi (2000)

(3) Assessing the innovation model

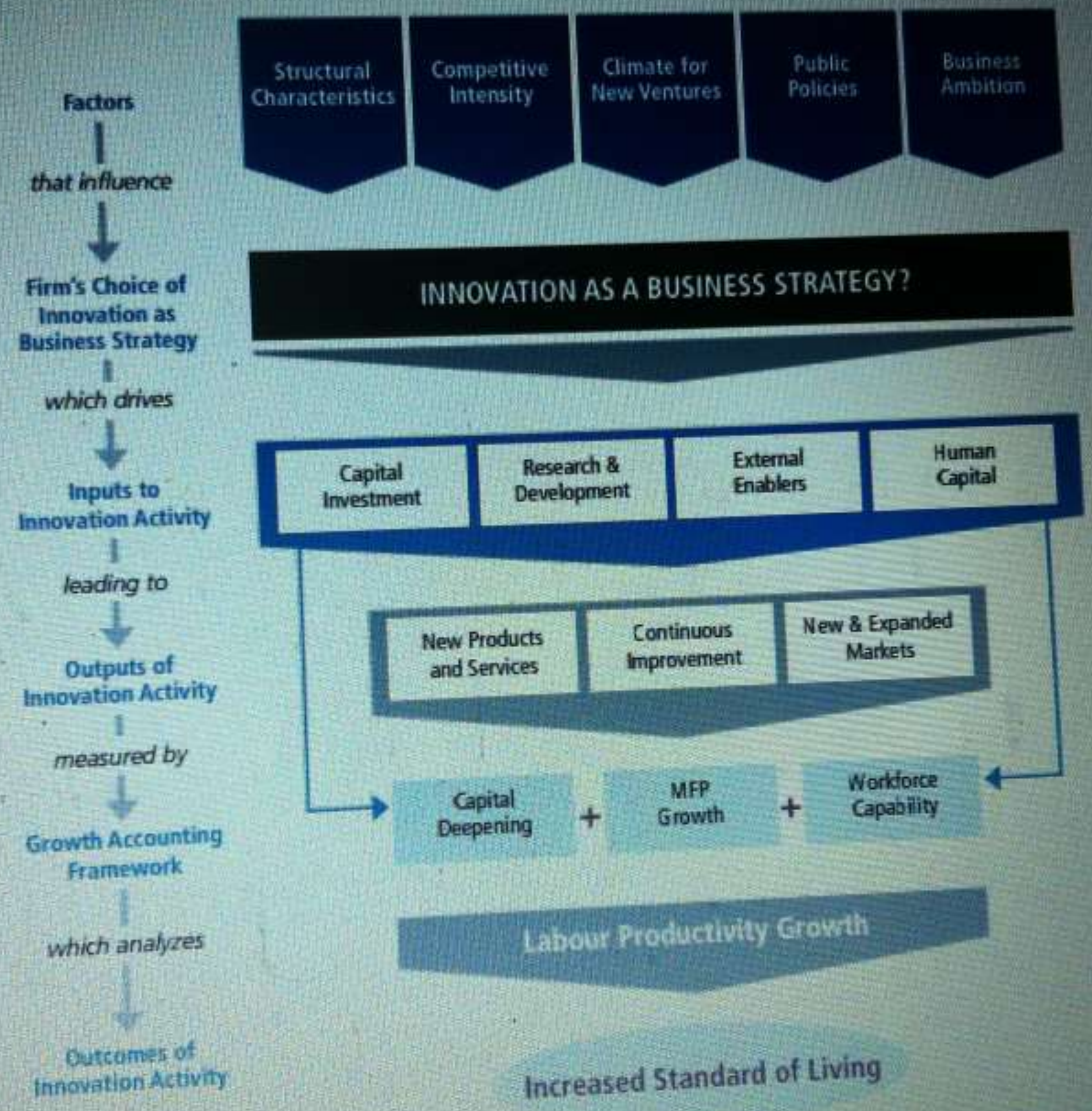
Learning from other countries: the case of Canada

- Canadian academic research, overall, is strong and well regarded internationally.
- Canadian business innovation, by contrast, is weak by international standards, and this is the primary cause of Canada's poor productivity growth.

Why has Canada's research excellence not translated into more business innovation?
The paradox is resolved once it is recognized that
(i) **most innovation does not work according to a "linear" model** in which academic research yields a pipeline filled with ideas that, following some research and development (R&D), are commercialized by business
(ii) business strategy in Canada is powerfully influenced by **many factors besides those that motivate innovation**.

Council of Canadian Academies, 2013.
Paradox Lost: Explaining Canada's Research Strength and Innovation Weakness.
Ottawa (ON): Advisory Group, Council of Canadian Academies.

Exhibit 3.7
Logic Map of the Business Innovation Process

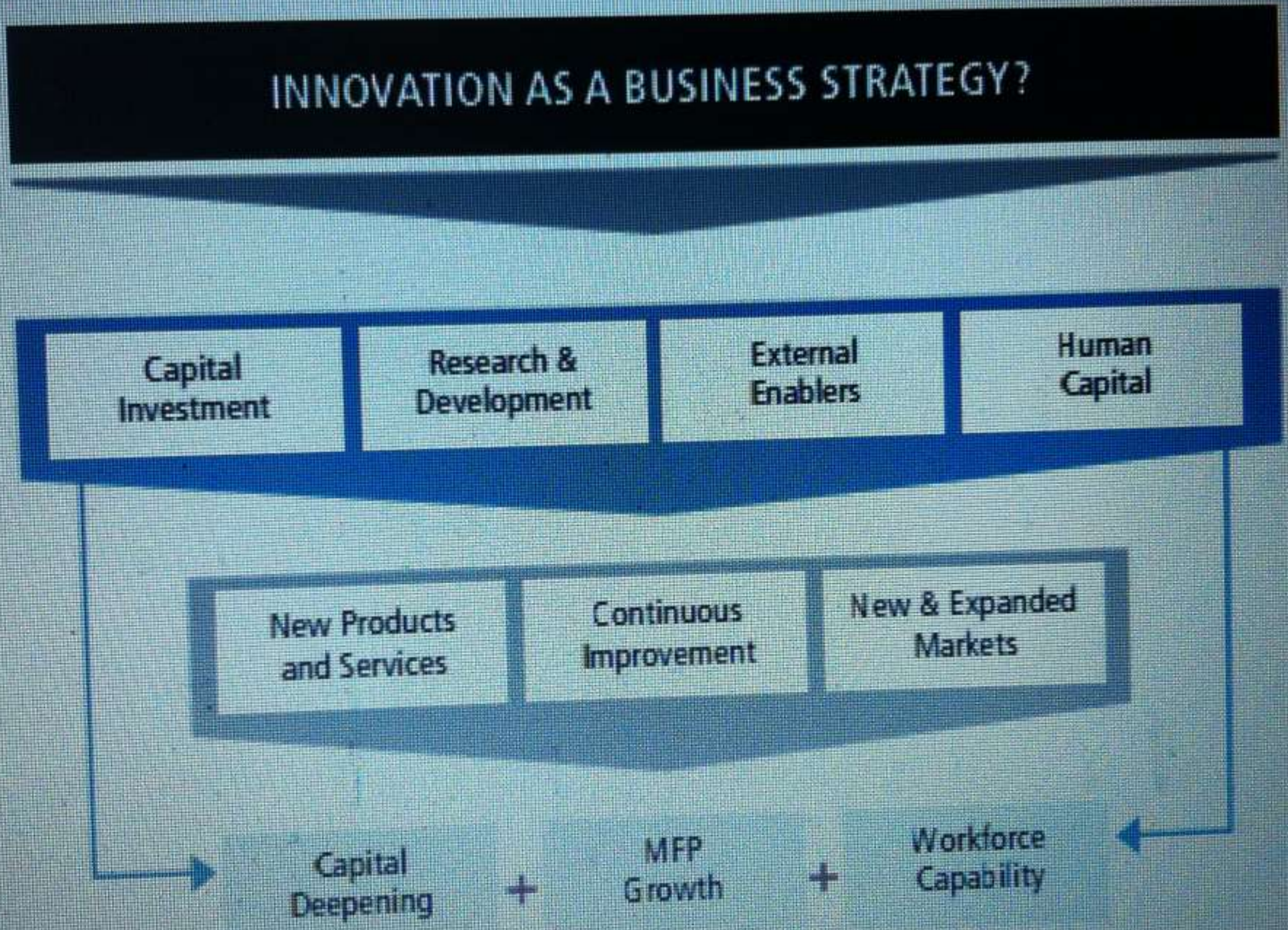


Data source: CCA (2009), Figure 4.2

...and the determinants of business

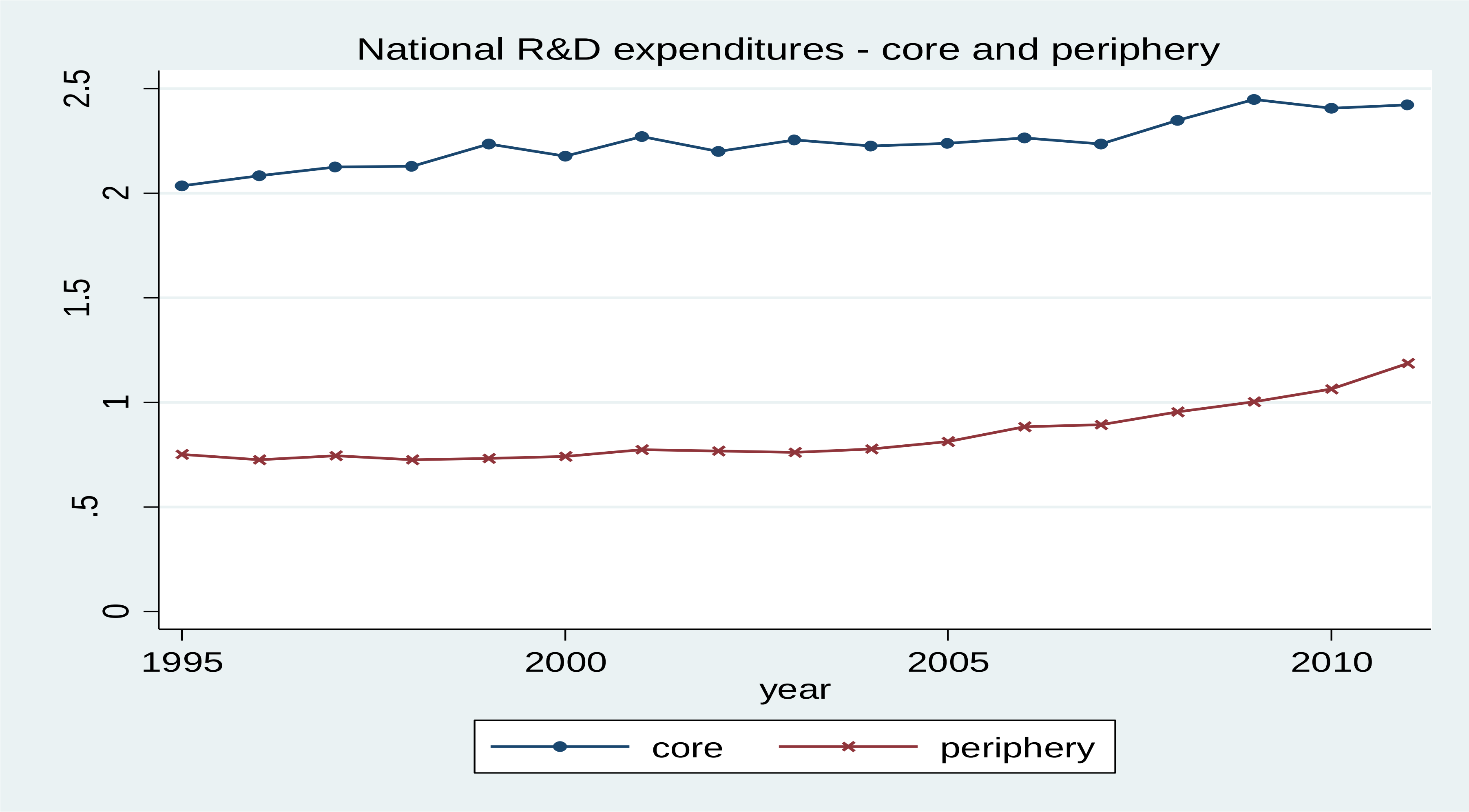
on Process

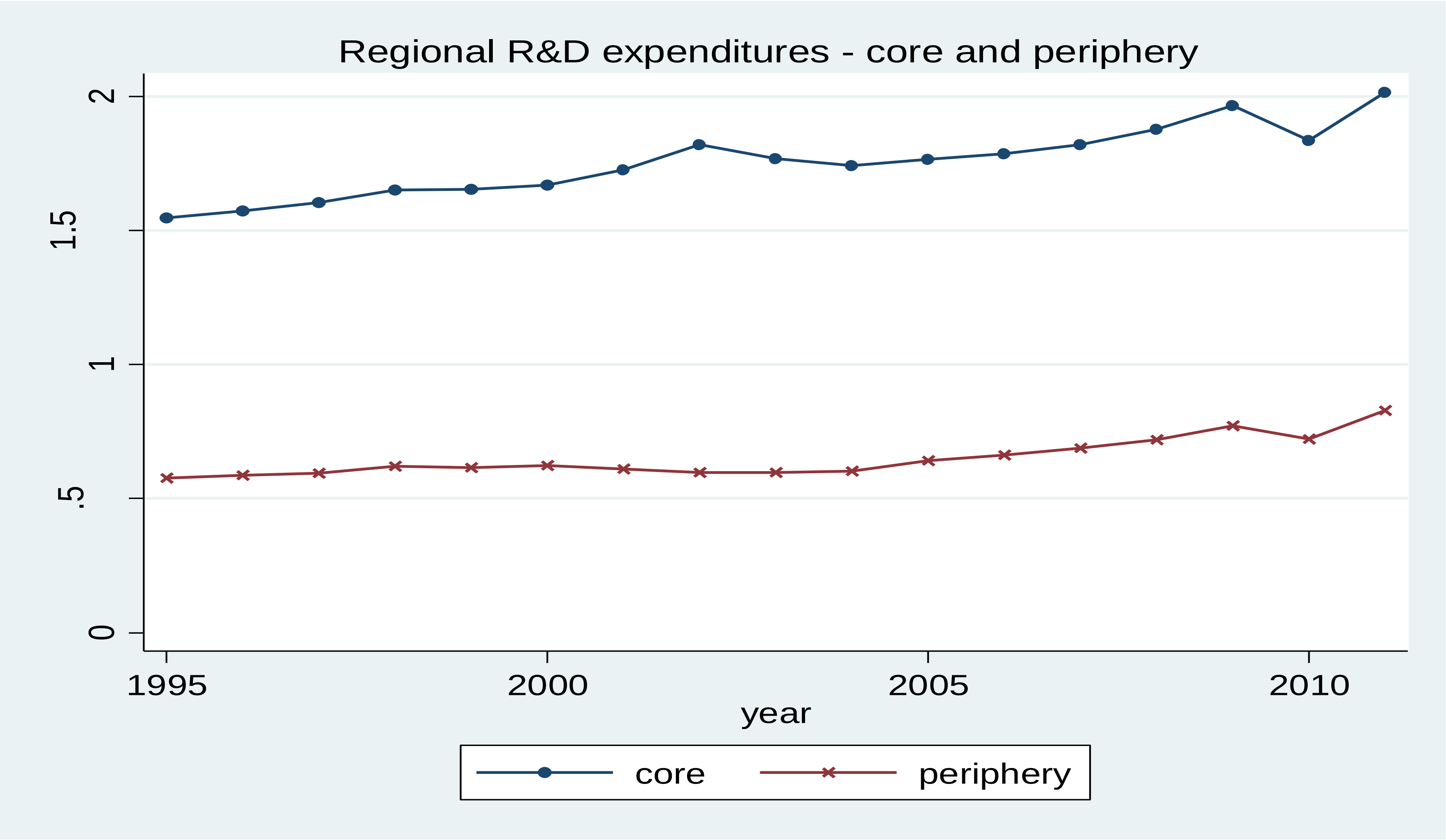

Structural Characteristics
Competitive Intensity
Climate for New Ventures
Public Policies
Business Ambition
INNOVATION AS A BUSINESS STRATEGY?
Capital Investment
Research & Development
External Enablers
Human Capital



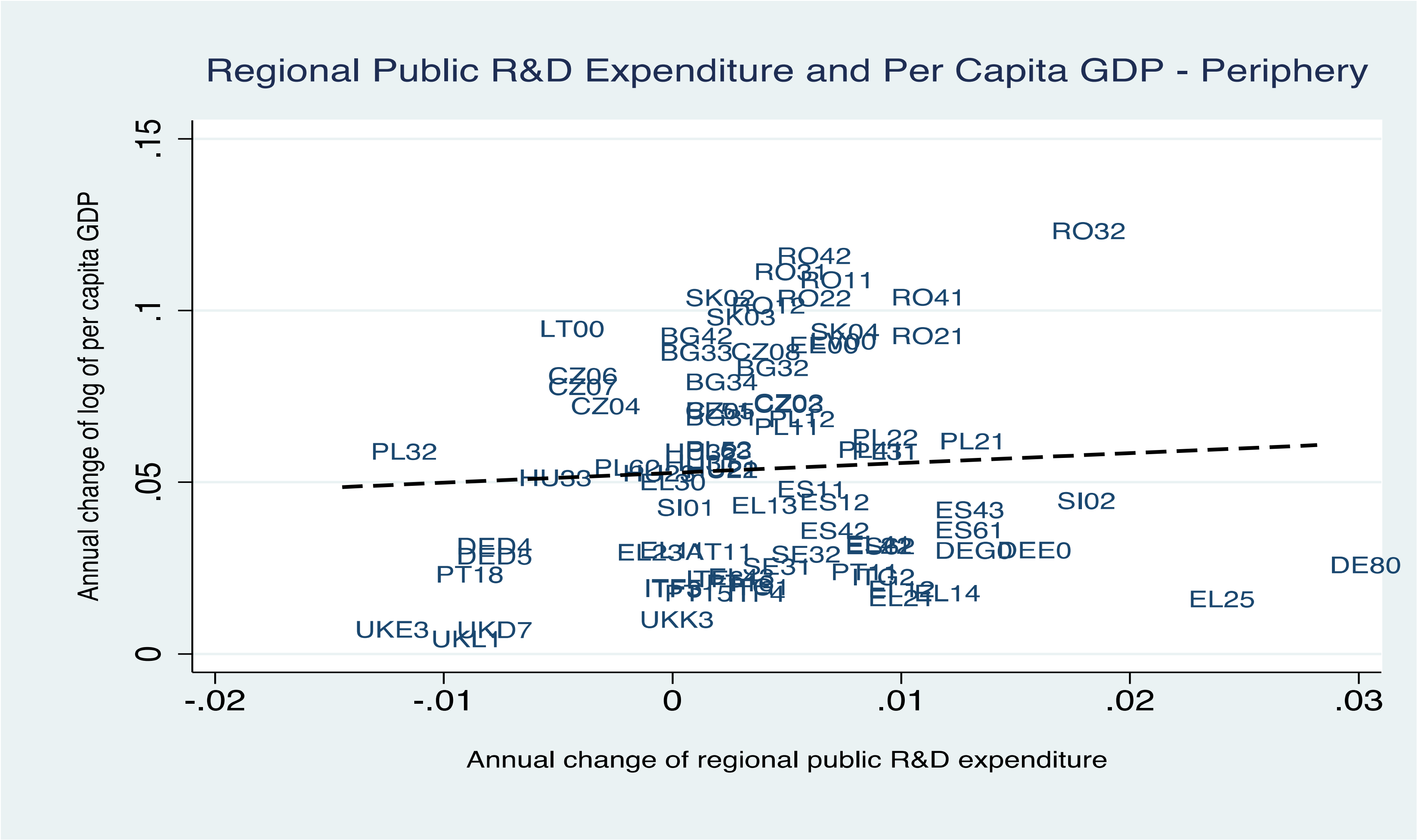
INNOVATION AS A BUSINESS STRATEGY?
Capital Investment
Research & Development
External Enablers
Human Capital
New Products and Services
Continuous Improvement
New & Expanded Markets
Capital Deepening
+
MFP Growth
+
Workforce Capability


New Products and Services
Continuous Improvement
New & Expanded Markets
Capital Deepening
+
MFP Growth
+
Workforce Capability
Labour Productivity Growth
Increased Standard of Living


National R&D expenditures - core and periphery
0
.5
1
1.5
2
2.5
1995
2000
2005
2010
year
core
periphery

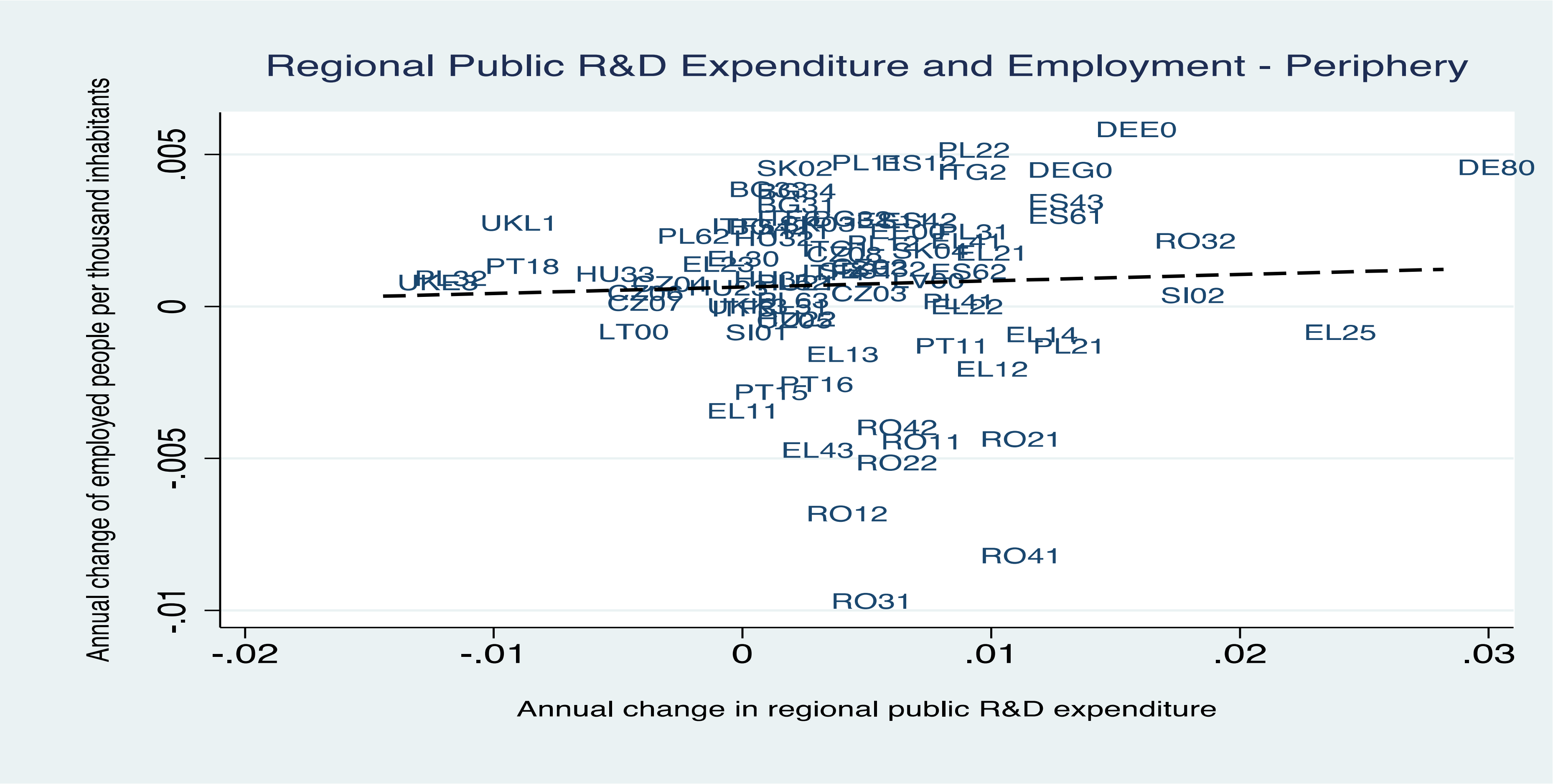

Regional R&D expenditures - core and periphery
0
.5
1
1.5
2
1995
2000
2005
2010
year
core
periphery

Average change in public R&D expenditure vs. average change in GDP p/c, peripheral regions (2000-2011).



Source: Rodriguez-Pose (2014)

Average change in public R&D expenditure vs. average change in employment, peripheral regions (1999 -2011).



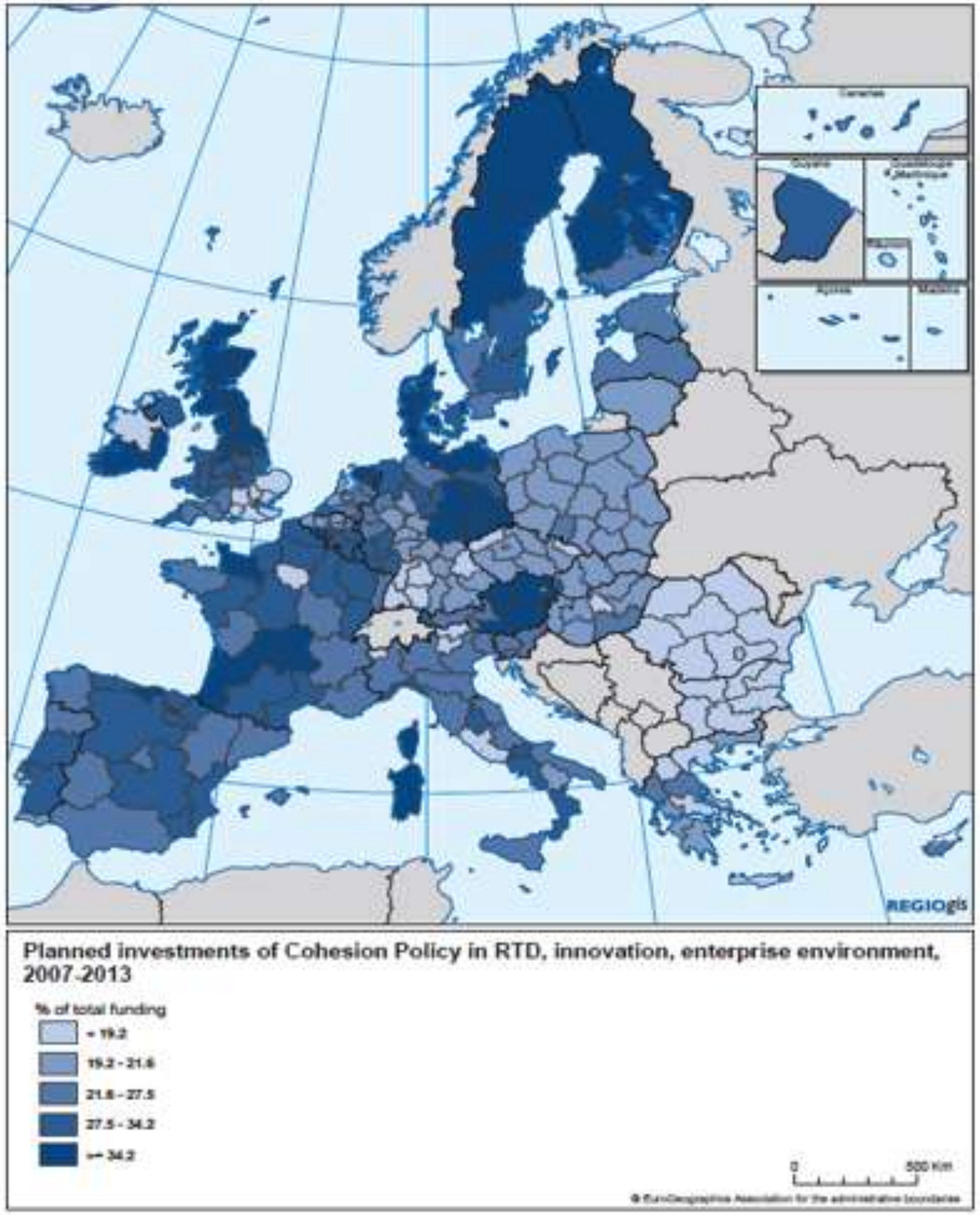
Source: Rodriguez-Pose (2014)

The role of cohesion policy

In 2007-2013, the global resources assigned to R&D and innovation by EU Cohesion Policy at regional level exceed those in FP7 and CIP (86.0 Vs. 56.9 billion Euro).

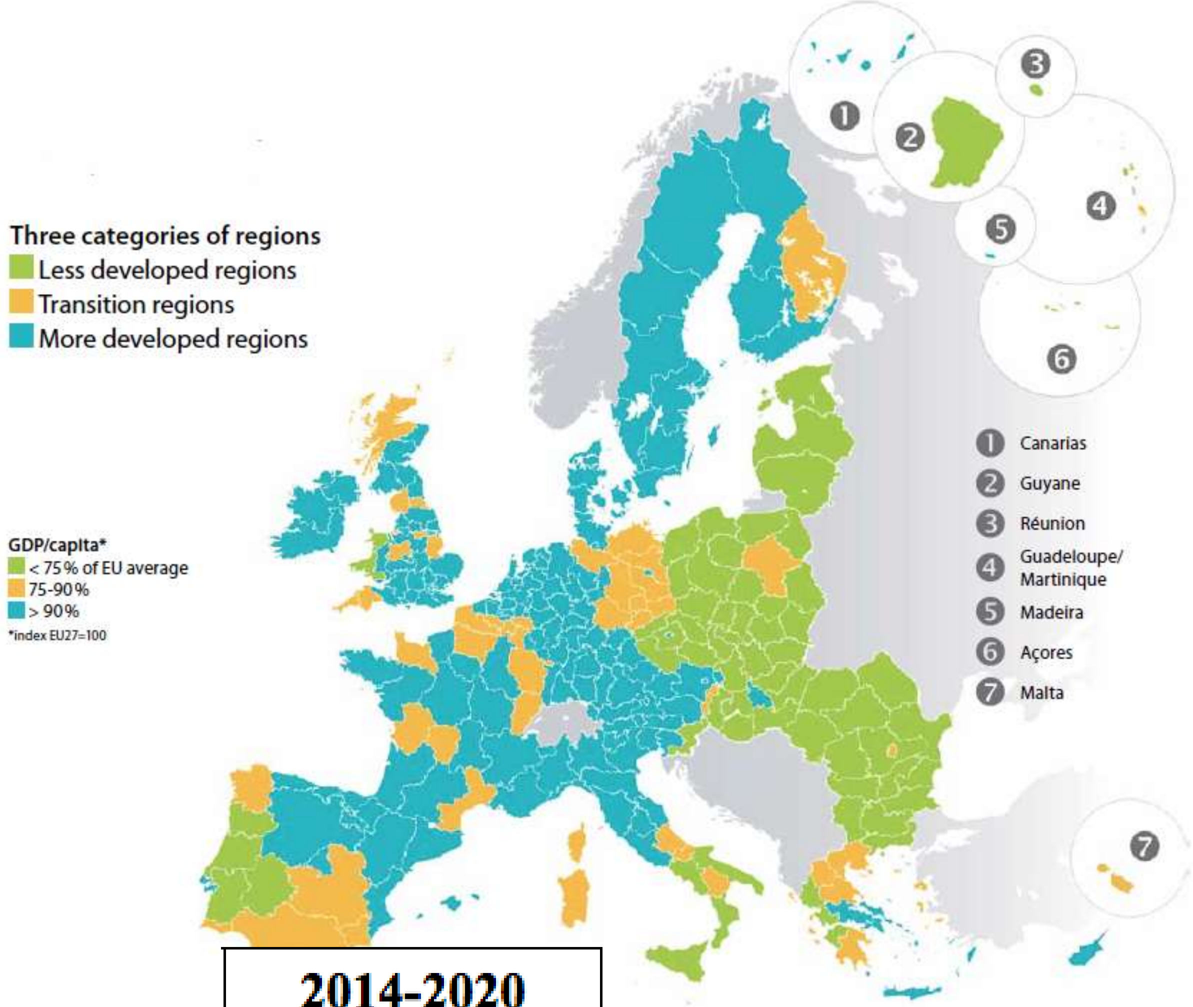
This growing spend of EU Structural Funds on R&D&I has been called “the silent revolution” (Landabaso 2010).

Before 1988	1989-1993	1994-1999	2000-2006	2007-2013
0.2	2.0	7.6	21.4	86.0
=	4%	7%	11%	25%



Linking cohesion policy and H2020

The Europe 2020 flagship initiative “Innovation Union”, the new Framework Programme “Horizon 2020” and the new Cohesion Policy Agenda for 2014-2020, aim at furthering this trend by calling for more integration between instruments and funding priorities along the R&D&I value chain.



Before 1988	1989-1993	1994-1999	2000-2006	2007-2013
0.2	2.0	7.6	21.4	86.0
=	4%	7%	11%	25%

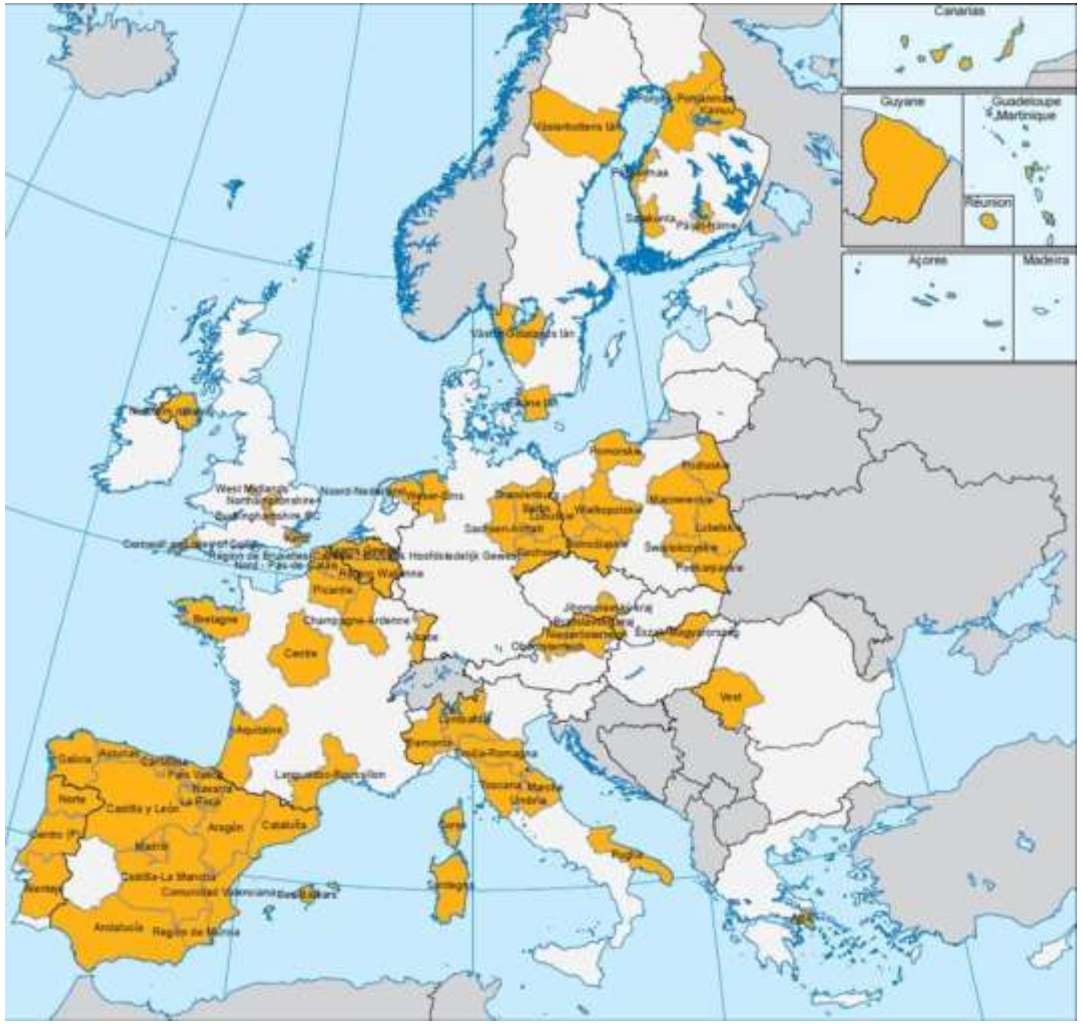
2014-2020
???

Smart specialisation

SMART SPECIALISATION PLATFORM

Established in 2011, the S³ Platform (S³P) assists Member States and regions to develop, implement and review Research and Innovation Strategies for Smart Specialisation (RIS³).

→ A platform concept in search of a network

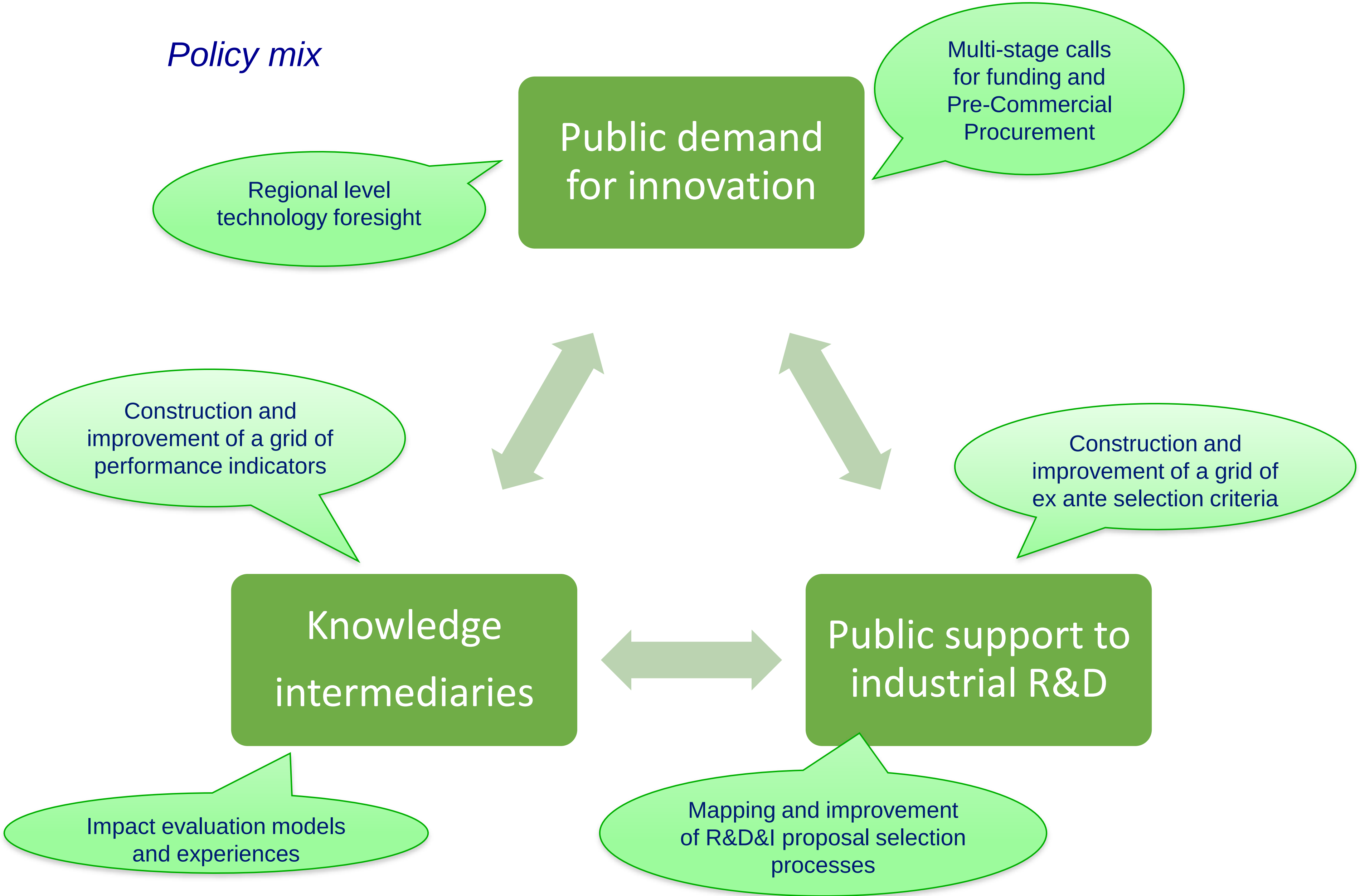


Source: http://s3platform.jrc.ec.europa.eu/s3-platform-registered-regions - 16 Sep 2012

Key implications

- Need to ensure vertical coordination of policies
  - From EU to Member States
  - From Member States to Regions
- Need to integrate horizontal with vertical coordination
  - Along the R&D&I value chain
  - Towards external stakeholder communities
  - Across the business sectors
  - Between the PA “silos”
- Need for policy alignment, reducing inefficiencies and gaps, but also preserving local specificities
- Need for capacity building at the lower “tiers” of PA

Policy mix


Public demand for innovation
Multi-stage calls for funding and Pre-Commercial Procurement
Regional level technology foresight
Construction and improvement of a grid of performance indicators
Construction and improvement of a grid of ex ante selection criteria
Knowledge intermediaries
Public support to industrial R&D
Impact evaluation models and experiences
Mapping and improvement of R&D&I proposal selection processes

Policy implications

1. Link Cohesion policy to H2020
    - Place-based policies within enlarged competition at European level
    - Joint schemes

2. **Complementarity** is crucial
    - Between research and innovation
    - Between research, innovation and education/training

3. New policy mix
    - Demand-driven innovation policies
    - Joint research-innovation-training initiatives
    - Non-technological innovation

4. Need to go ahead with excellence-based policies
    - Place pressure on European universities and PROs
    - Establish a linkage with world-wide networks of researchers

Is there a need for “small catastrophes”?

[…] It is uncertain whether any incentive plan to stimulate the growth of domestic technology and innovation, or to make corporations expand aggressively into foreign markets, can achieve significant success when it is applied to companies in which the drive to do these things has not already been forced to emerge because of exposure to a real stimulus from the economic environment. What we seem to need in Canada are ‘small catastrophes’.”

V.O. Marquez, CEO of Northern Electric (then Nortel)
Building an innovative organization, *Business Quarterly* (1972)

The effect of Higher Education Institutions on the creation of new firms: A comprehensive evidence on the Italian case

Small Business Economics (2013)

Andrea Bonaccorsi*

Massimo G. Colombo§

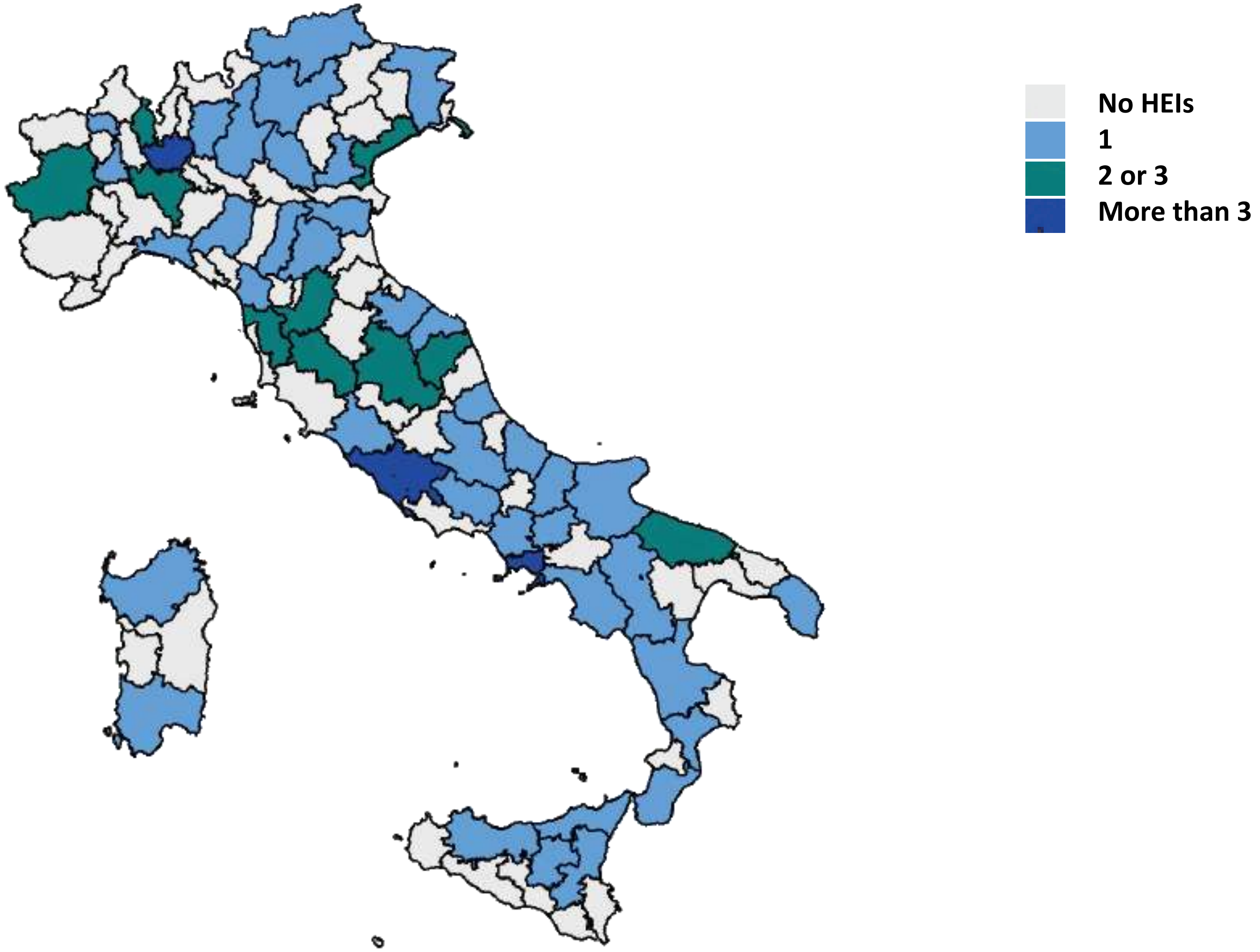
Massimiliano Guerini*

Cristina Rossi Lamastra§

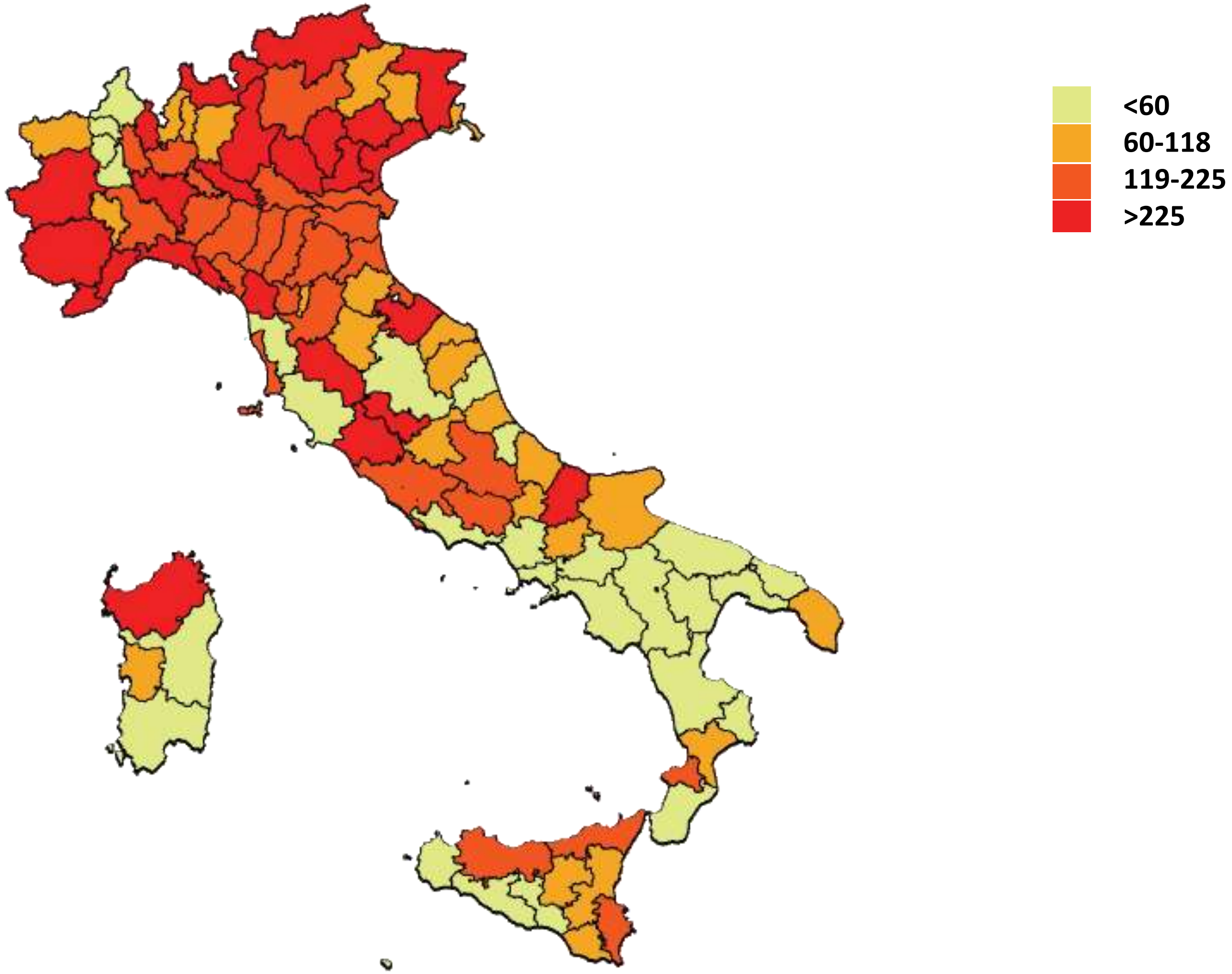
*University of Pisa, DESE

§Politecnico di Milano, DIG

HEIs at NUTS3 level



new firms at NUTS3 level



Results research and human capital

	SB	SS	SI	SD	IN	PN	SDS	KIBS
Patents*$_i$	3.628 ***	0.771	0.561	0.324	-0.372	1.230 **	0.782	1.333 **
	(1.236)	(0.650)	(0.669)	(0.691)	(1.014)	(0.591)	(0.620)	(0.585)
PhD*$_i$	-0.118	-0.102	-0.025	-0.081	-0.033	0.049	-0.024	-0.013
	(0.164)	(0.081)	(0.081)	(0.093)	(0.122)	(0.048)	(0.075)	(0.069)
Graduates*$_i$	0.082	0.110 ***	0.052	0.111 **	0.081	0.023	0. 058	0.062 *
	(0.086)	(0.042)	(0.042)	(0.046)	(0.062)	(0.036)	(0.039)	(0.037)

- According to previous findings, results suggest that new firm creation in high-tech industries is strongly influenced by the characteristics of HEIs at the local level:
  - strong impact of formal transfers of knowledge (patents) on both high tech manufacturing and services industries
  - graduates are an important source of knowledge for high-tech service industries
- In addition, some interesting results emerge when looking at medium and low tech industries.
  - graduates from HEIs play an important role in SS and SD (quite surprising)

Results field of sciences

	SB	SS	SI	SD	IN	PN	SDS	KIBS
MEDICAL	1.296	0.545 *	-0.066	0.400	0.442	0.155	0.295	0.364 **
	(0.854)	(0.328)	(0.214)	(0.289)	(0.323)	(0.177)	(0.187)	(0.182)
SOCIAL	5.093	2.711 **	0.502	1.670	0.795	0.882 *	0.360	0.641
	(3.257)	(1.324)	(0.554)	(1.139)	(0.889)	(0.471)	(0.467)	(0.461)
ENGINEERING	1.386 *	1.065 ***	0.696 ***	0.645 **	0.694 **	0.329 *	0.232	0.397 **
	(0.832)	(0.344)	(0.230)	(0.307)	(0.344)	(0.191)	(0.207)	(0.200)
NATURAL	0.470	0.113	-0.169	0.280	-0.664	-0.322	-0.304	-0.198
	(0.654)	(0.348)	(0.334)	(0.372)	(0.449)	(0.282)	(0.301)	(0.282)

- The analysis on fields of sciences show a very clear pattern:
  - new firm creation is more likely in regions with HEIs that are highly specialised in engineering, but not in natural sciences
  - basic research (natural sciences) within HEIs does not have a direct impact on entrepreneurship at the local level

Discussion and conclusion

- **Policy implications**
  - HEIs may encourage new firm creation by favouring the formal transfer of knowledge in **applied sciences** (engineering) to high-tech industries!
  - Impact of **graduates** is important in medium and low tech-industries, such as SS and SD, but **not in SB**. No matching between the demand and the supply of skilled human capital?
  - Basic and informal research activities do not generate positive externalities for new firm creation at all! Need to elaborate new mechanisms in order to **incline the scientific community to the business**

- **Limitations**
  - alternative measures for informal research activities (# of publications)
  - unobserved heterogeneity, further controls?
  - cross-sectional study at 2010 (crisis?)
  - comprehensive analysis but limited to the Italian case

Universities, geographical distance, and the creation of knowledge intensive firms

Small Business Economics (2014)

Andrea Bonaccorsi[*]

Massimo G. Colombo[§]

Massimiliano Guerini[*]

Cristina Rossi Lamastra[§]

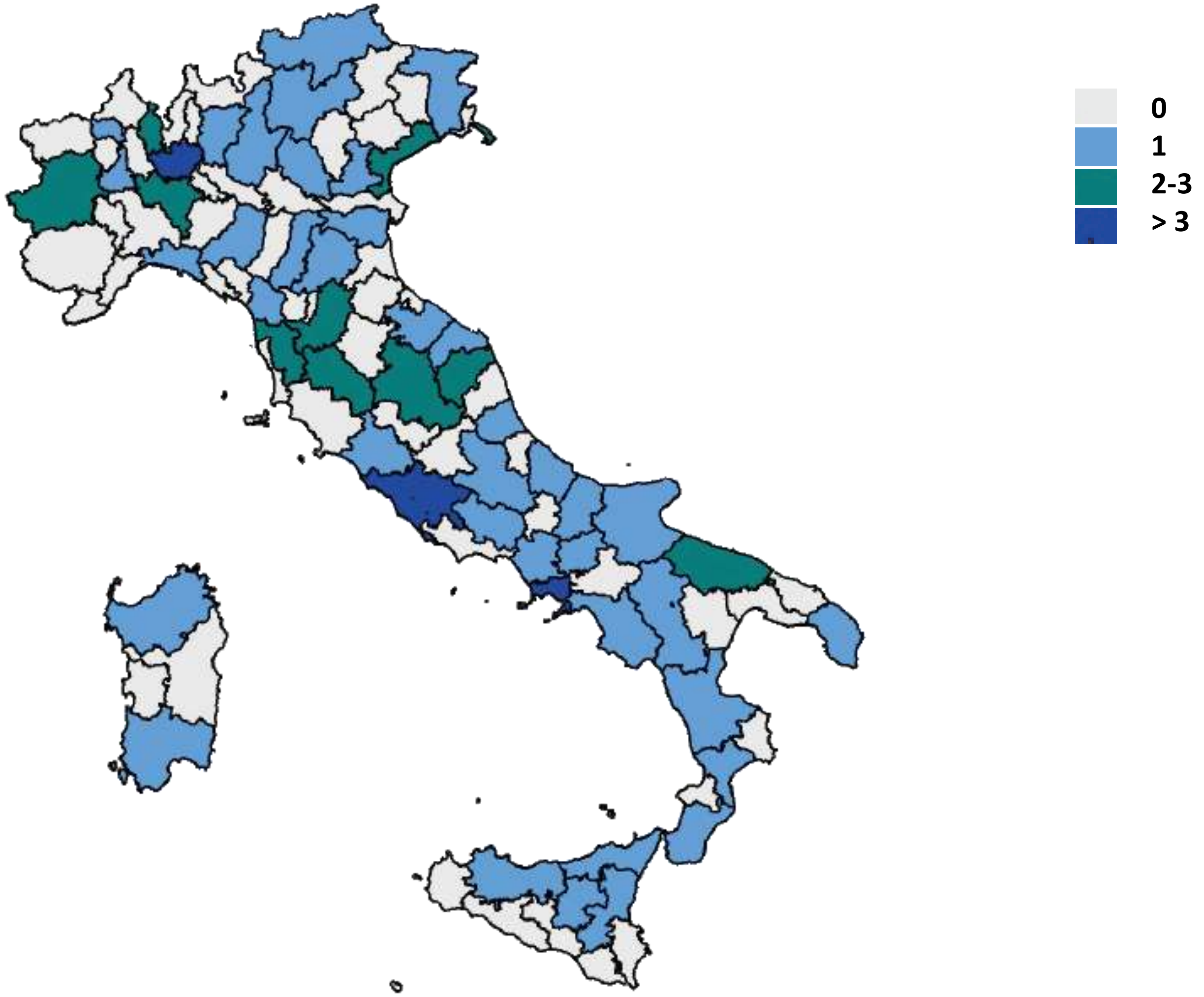
[*]University of Pisa, DESE

[§]Politecnico di Milano, DIG

Knowledge Intensive Industries

NACE	Description
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C26	Manufacture of computer, electronic and optical products
J62	Computer programming, consultancy and related activities
J63	Information service activities
M69	Legal and accounting activities
M70	Activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74	Other professional, scientific and technical activities
R90	Creative, arts and entertainment activities
R91	Libraries, archives, museums and other cultural activities

Universities at NUTS3 level



Results

- In line with the findings of previous studies, the creation of KIFs in a province is positively related to knowledge generated by Universities located in the same province
- Moreover, codified knowledge flows (**patents**) cross the boundaries of the provinces
  - they positively affect the creation of KIFs in surrounding provinces, with distance up to about **200 kilometres**
- Conversely, knowledge flows from **academic staff and graduates are more localized**, being bounded within the provinces in which Universities are located

Discussion

- Codified knowledge (i.e. *patents*) is easier to transfer than knowledge generated in research and education activities and embedded in individuals (i.e. *academic staff* and *graduates*).
- As to the transfer of this latter (largely tacit) knowledge, direct personal interactions do play a role:
  - its transfer is restrained by the mobility of qualified human capital, which in Italy is notably low

Exploring the Role of Third-party Research in Italian Universities

Journal of Technology Transfer (2012)

A.Bonaccorsi, L.Secondi, A.Ancaiani, E.Setteducati

National Agency for the Evaluation of Universities and Research Institutes

3. An Analysis of third-party research activities in Italian Universities

3.3. Estimation results [1/2]

Variable	Coefficient	Standard Error	
Characteristics of the Department			
Age of professors	-0.014	0.011	
Number of Professor	0.012	0.003	***
Percentage of National project (PRIN) financed	-0.002	0.002	
Presence of a least a PhD course (1=Yes;	0.127	0.093	
Research funds from European Union (percentage on total funds)	0.012	0.003	**
Scientific area of the department (ref. Mathematics and Informatics)			
Physics	-0.351	0.265	
Chemistry	0.742	0.316	**
Biology	0.377	0.232	
Medicine	0.343	0.212	
Agricultural Science and Veterinary Studies	0.892	0.276	***
Civil Engineering and Architecture	0.881	0.269	***
Industrial and Information Engineering	1.397	0.360	***
Science of Antiquity, Philology, Literature and Art history	-1.090	0.213	***
Historical and Philosophical sciences, Pedagogy and Psychology	-0.923	0.215	***
Law	-0.989	0.214	***
Economic and Statistical Sciences	-0.152	0.228	
Political and social sciences	-0.359	0.290	
Characteristics of the University			
Dimension (ref. Medium)			
Small	-0.098	0.140	
Large	0.044	0.109	
Presence of Industrial Liaison Office in the University	0.373	0.168	**
Presence of the university in the Scimago International ranking			
(ref. University is located in the top 100 positions)			
University located over the top 100 positions	0.481	0.194	**
University not included in the ranking	0.172	0.354	
Department localization			
GDP per capita	0.043	0.008	***
Regional R&D expenses	0.236	0.148	
Constant	-1.114	0.700	

Larger departments are more likely to participate in third-party activities (than small departments)

The higher is the **percentage of research funds from EU** the higher is the probability in participating in third-party activities

The **scientific area of the departments** greatly influence the likelihood for participation in third-party research

The higher is the **GDP per capita** the higher is the probability to participate in external research

3. An Analysis of third-party research activities in Italian Universities

3.3. Estimation results [2/2]

Variable	Coefficient	Standard Error	
Characteristics of the Department			
Age of professors	-0.041	0.107	
Number of Professor	-0.172	0.024	***
Number of research fellows	0.516	0.045	***
Percentage of National project (PRIN) financed	-0.001	0.018	
Presence of a least a PhD course (1=Yes;	-0.825	0.930	
Research funds from European Union (percentage on total funds)	-0.046	0.026	*
Characteristics of the University			
Localization (ref. Central regions)			
North West	0.430	1.221	
North East	-1.856	1.247	
South	-1.092	2.135	
Islands	-4.193	2.337	*
Dimension (ref. Medium)			
Small	-2.616	1.409	*
Large	-0.878	1.004	
Presence of Industrial Liaison Office in the University	4.591	1.946	**
Presence of the university in the Scimago International ranking			
(ref. University is located in the top 100 positions)			
University located over the top 100 positions	-1.950	1.735	
University not included in the ranking	8.977	4.671	*
Department localization			
GDP per capita	-0.121	0.135	
Regional R&D expenses	2.735	1.468	*
Constant	13.306	8.605	

The **presence of the ILO** positively influence the amount per capita of third-party funds.

Universities located in **insular regions** have a lower level of third-party funds (than universities located in Northern regions).

The **number of research fellows** have a positive and significant influence on the amount of third-party research funds.

The non inclusion in the **Scimago ranking** leads a department to increase the amount of third-party research

The greater **the percentage of EU funds the** lower is the amount of third-party funds

Policy learning
The experience of Italy 2010-2012

- ✓ A policy learning project promoted by Department for Cohesion Policies (DPS) and Agency for Innovation
- ✓ Explicitly targeting public administration
- ✓ Approx. 200 Directors and Managers personally involved in 6 policy learning working groups
- ✓ Professional moderation of working groups (including web forum)
- ✓ 6 Policy Reports published
- ✓ Large take up of policy documents from the website (> 10,000 overall)

- ✓ Policy focus:
    - ✓ Cluster policies
    - ✓ Public incentives to industrial R&D
    - ✓ Public demand for innovation

Cluster policies

Critical background: fragmentation and lack of control

Policy focus

- ✓ Cluster policies as multi-period policies
- ✓ Risk sharing between policy makers and knowledge intermediaries
- ✓ Placing the burden of outcomes on the shoulders that are better equipped to manage the risk

Policy learning outcomes

- ▪ Selectivity of cluster policies
- ▪ Design of a model of intermediate outcome indicators to be used as a steering and evaluation tool

Source: Bianchi T. (2012); De Maggio (2012)

Intermediate indicators

DIMENSIONS AND INDICATORS

OBIETTIVI			NOTE	RISCHI	RAGGRUPPAMENTO DI SETTORE*				CICLO DI VITA (anni)			MOD. DI GOV.	
Dimensioni di analisi	Variabili	Indicatori			1	2	3	4	0-3	3-5	> 5	sg	Com

9 DIMENSIONS

1. *Efficiency and financial sustainability*
2. *Support services to firms*
3. *Capital investment attraction*
4. *Cooperation and networking*
5. *Technology Transfer*
6. *Entrepreneurship*
7. *Research*
8. *Innovation*
9. *Internationalization*

20 INDICATORS

Public incentives to industrial R&D

Critical background: lack of additionality of public incentives

Policy focus

- ✓ preparation stage: beyond the concertative model
- ✓ selectivity vs coverage
- ✓ length of the administrative process as a crucial variable for the effectiveness of policies

Policy learning outcomes

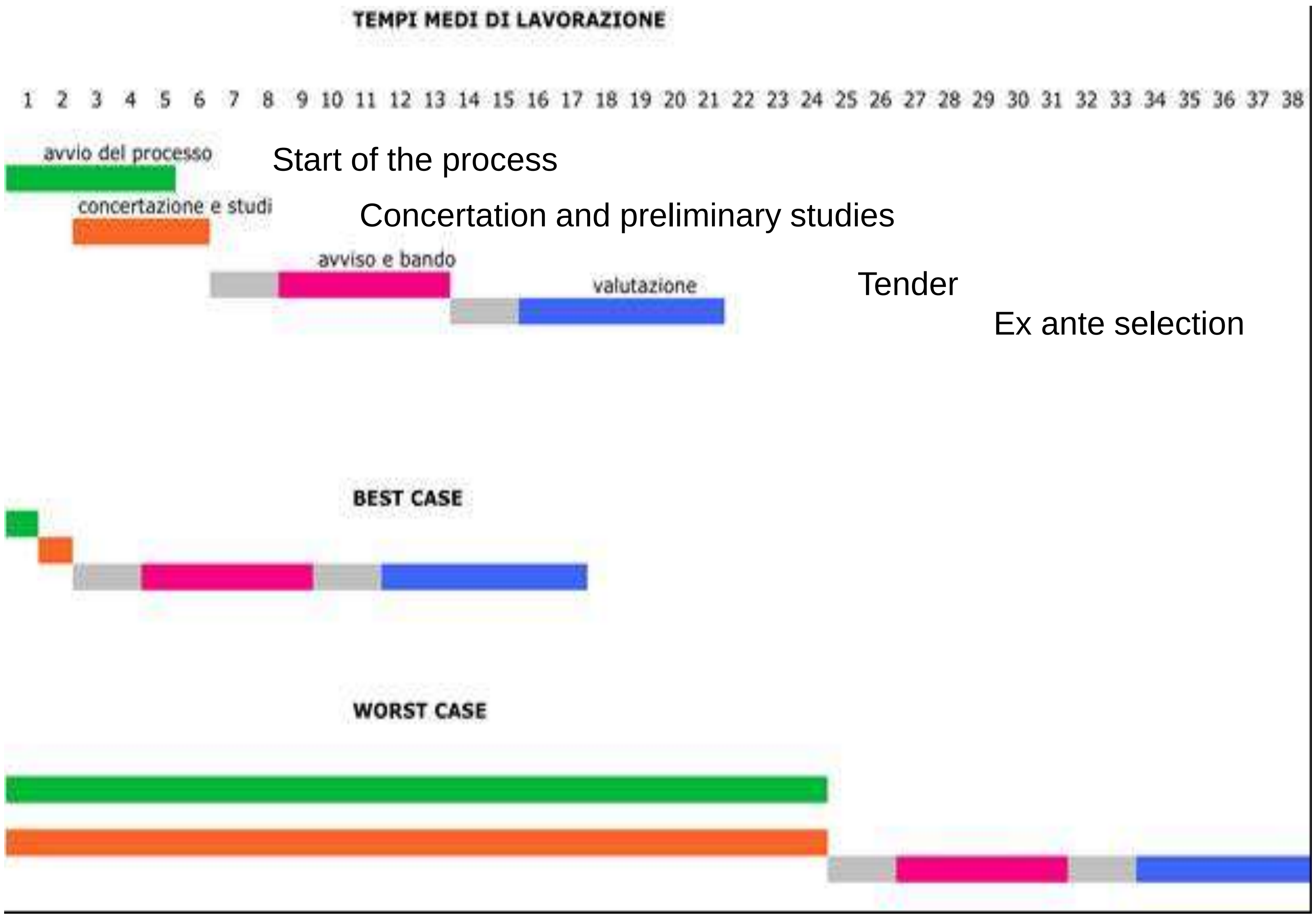
- Process re-engineering
    - Cutting time-to contract cycle
    - Standardizing ex ante selection process
    - Eliminating idle time
    - Reducing sequentialization of the administrative process
- Redesign of the involvement of local constituencies: from a political process oriented towards representativeness and fragmentation to a policy process oriented towards smart specialisation and selectivity

Survey on regional schemes for industrial R&D

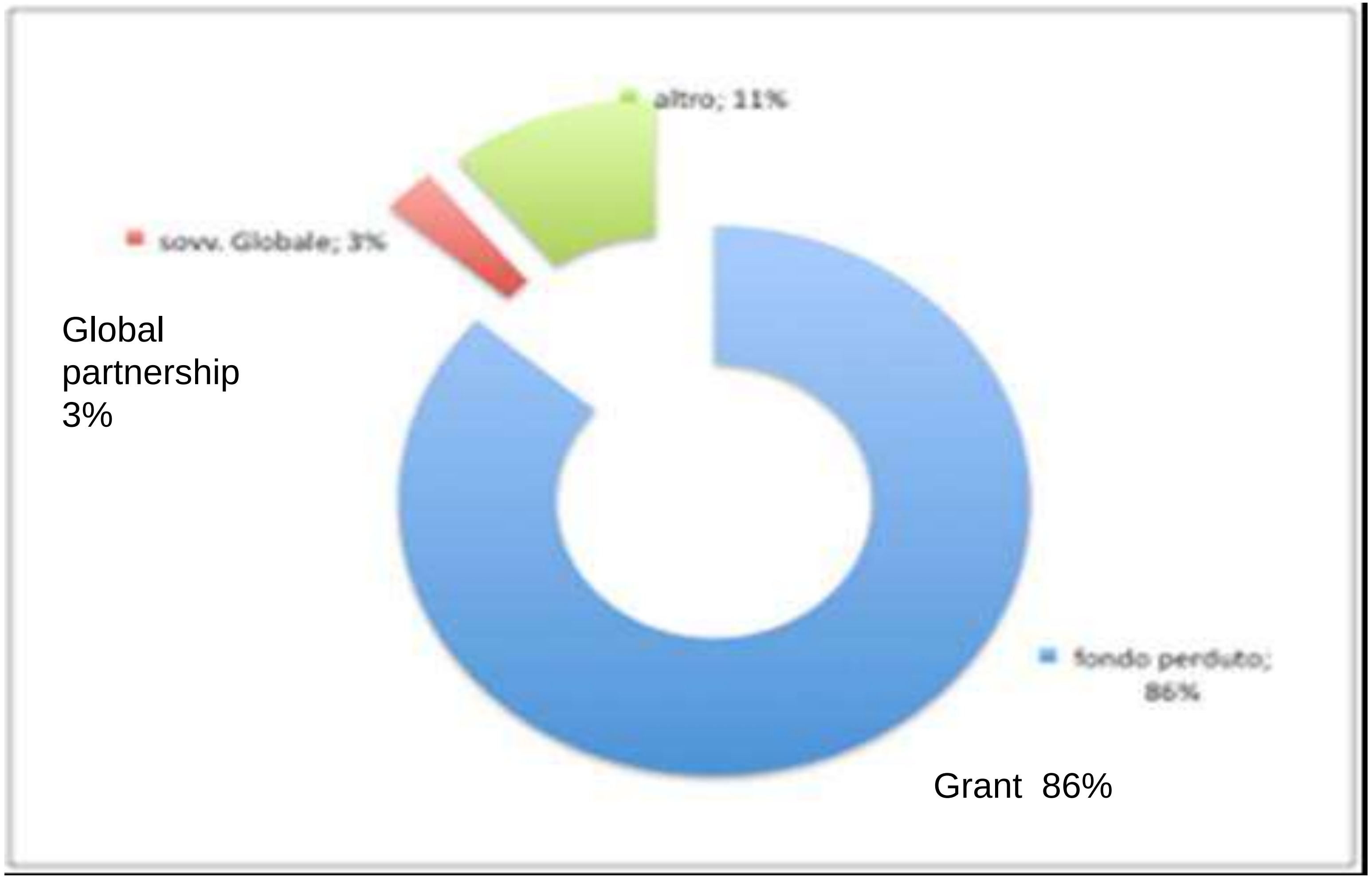
- 55 schemes examined
- period 2004-2010
- 15 Italian Regions involved
- FESR + regional budget
- 1,5 billion euro expenditure
- average expenditure 28 million euro
- largely untargeted (broad sectoral priorities)
- direct subsidies still dominant
- room for significant improvement in time-to-contract
- need for standardization of ex ante selection criteria and procedures

Source: Bairati (2012), Bologni (2012)

Large differences in time-to-contract



Traditional and untargeted mix of instruments



Public demand for innovation

Critical background: fashionable policy, but difficult to implement

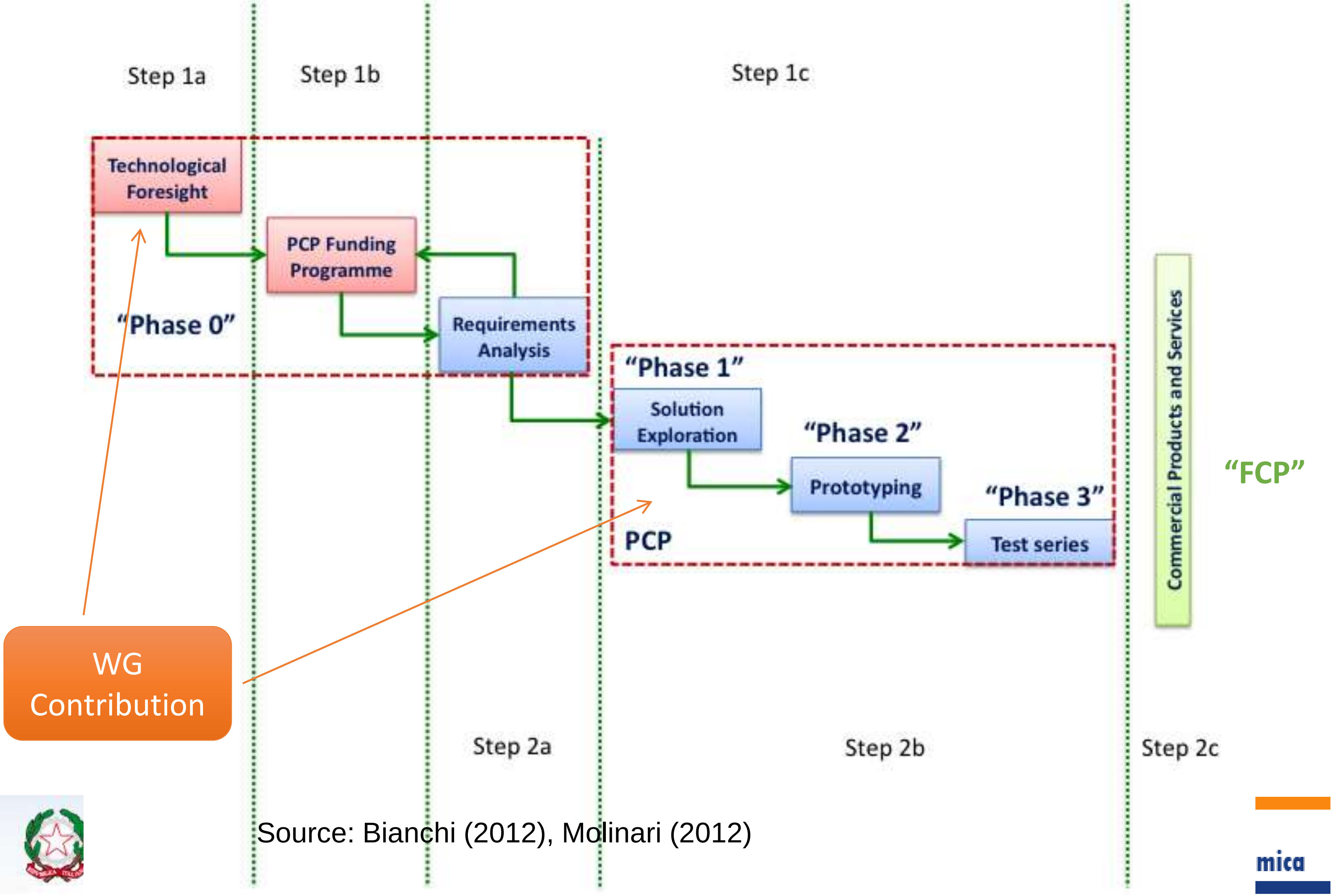
Policy focus

- ✓ Defining the legal setting (State aid, competition policy, regulation of tenders)
- ✓ Making the legal and financial risk sustainable by ordinary administrative staff (*no-hero* approach)
- ✓ Integrating competences at regional level
- ✓ Plug-and-play drafting of policy and administrative documents

Policy learning outcomes

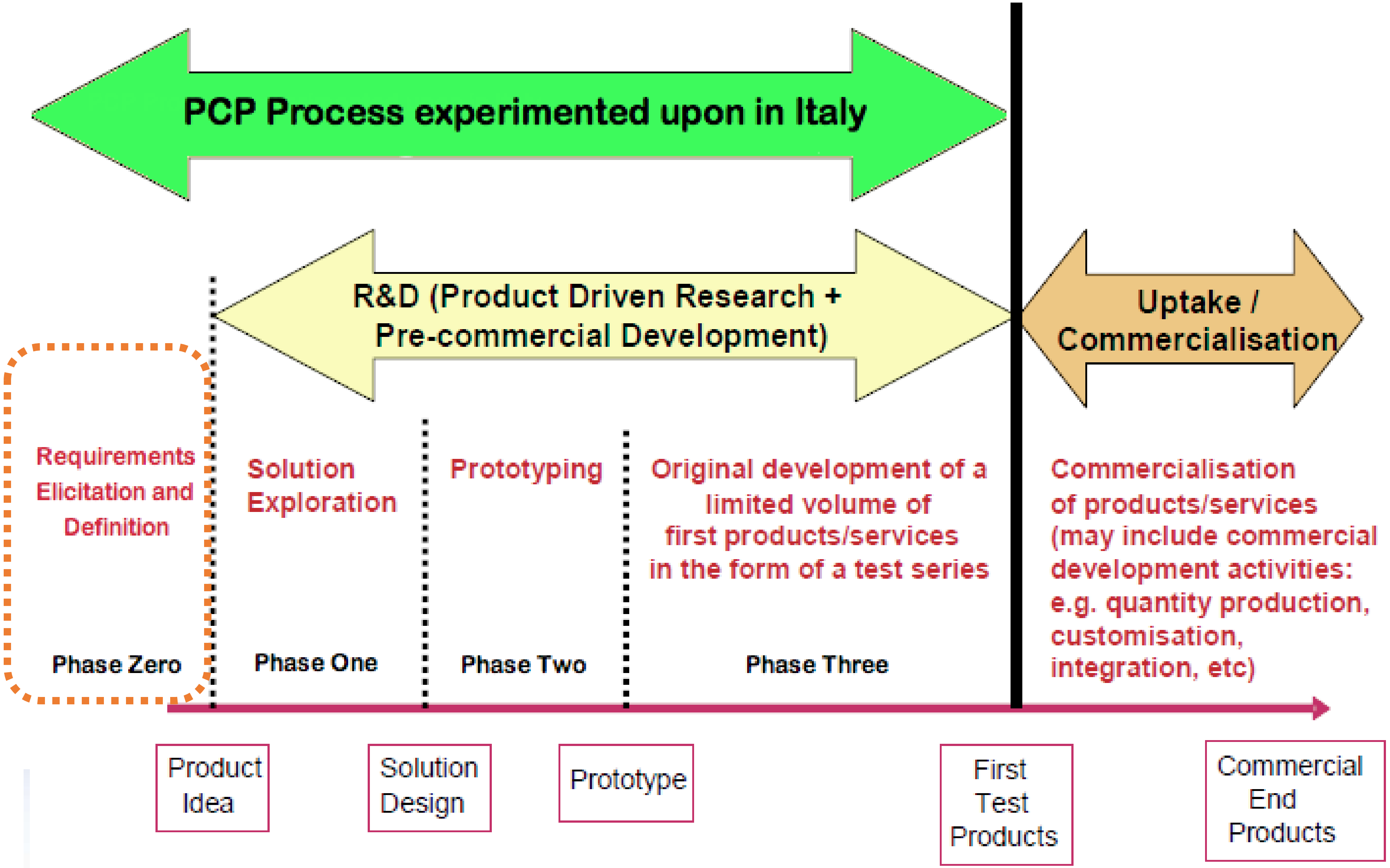
- Design of Stage zero of PCP (= simplified technology foresight at regional level)
- Funding model (suggestion to partially re-deploy R&D budget to PCP vs asking procurement organizations to fund PCP)

Policy learning (1/2)



Source: Bianchi (2012), Molinari (2012)

Policy learning (2/2)



Impact of policy learning

	Vallée d'Aoste	Apulia
Location	Northern Italy	Southern Italy
Population Size	Small (< 130,000)	Big (> 4,100,000)
Living Labs and PCP	Integrated in a single call for tender (PCP)	Two distinct calls (one PCP tender and one funding LL ad hoc)
Funding resources for PCP	About € 0.9 Million from EU Structural Funds (Objective 3 – Cross border cooperation Italy-France)	About € 5 Million from EU Structural Funds (Regional Operational Programme Objective 1)
Funding resources for Living Labs	None additional to the above	About € 15 Million from EU Structural Funds (Regional Operational Programme Objective 1)
Start of "Phase Zero" of PCP	October 2011	October 2011
End of "Phase Zero" of PCP	December 2011	March 2012
Duration of PCP pilot	12 months (six for "Phase One", six for "Phase Two")	18 months (six for "Phase One", twelve for "Phase Two")
Duration of Living Lab pilot	Same as above	About 15-18 months

Quite diverse size and location

One, "poor" Vs. two, "rich" calls

Different time frames… …a) for policy design

…b) for policy execution

Main outputs


Migliorare le politiche
di Ricerca e Innovazione
per le Regioni
Contenuti e processi di policy

Ministero dello Sviluppo Economico
Dipartimento per lo Sviluppo e la Coesione Economica

First published in 2009.

Initially printed in 600 copies.

Innumerable (literally /000's) downloads from http://www.dps.tesoro.it/documentazione/docs/all/DPS_Rapporto_Ricerca_e_Innovazione.pdf

Main outputs – Phase II

COLLANA DEL

Progetto Sostegno alle Politiche di Ricerca e

Innovazione delle Regioni

QI04CP01

Le politiche di ricerca e innovazione delle regioni

Paolo Martinez, Alessandra Modi

In collaborazione con

Innovation Café!

First published in October 2011 – report from a participatory evaluation event (“Innovation Café”) held with the working group members themselves.

No printed edition.

About 3.000 downloads from http://www.aginnovazione.gov.it/wp-content/uploads/2011/07/QI04CP01-Politiche_ricerche_e_innovazione_regioni.pdf

Main outputs – Phase II/2


COLLANA DEL

Progetto Sostegno alle Politiche di Ricerca e Innovazione delle Regioni

QI05CP02

Selezione ex ante dei progetti di ricerca industriale

Report intermedio del Gruppo di lavoro 3

Coordinatore: Leda Bologni

Dicembre 2011

First published in December 2011 – report from Working Group No. 3 on “ex ante” selection criteria.

No printed edition.

About 3.500 downloads from http://www.aginnovazione.gov.it/wp-content/uploads/2011/10/QI05CP02-Selezione-ex-ante-dei-progetti-di-ricerca-industriale.pdf

Main outputs – Phase II/3

Quaderni Innovazione

COLLANA DEL

Progetto Sostegno alle Politiche di Ricerca e Innovazione delle Regioni

QI07CP03

Mappatura e miglioramento dei processi di selezione nei bandi di ricerca industriale e sviluppo pre-competitivo

Report intermedio del Gruppo di lavoro 2

Coordinatore: Andrea Bairati

Gennaio 2012

First published in January 2012 – report from Working Group No. 2 on proposal selection processes.

No printed edition.

About 3.500 downloads from http://www.aginnovazione.gov.it/wp-content/uploads/2011/10/QI07CP03-Mappatura-e-miglioramento-dei-processi-di-selezione-nei-bandi-di-ricerca-industriale.pdf

Main outputs – Phase II/4

+ pilot projects on Pre-Commercial Procurement in several regions

First published in May 2012 – joint report from Working Groups No. 1 and 4 on technology foresight and pre-commercial procurement.

Initially printed in 440 copies.

About 2.500 downloads from http://www.aginnovazione.gov.it/wp-content/uploads/2012/05/QI08-QI09.pdf

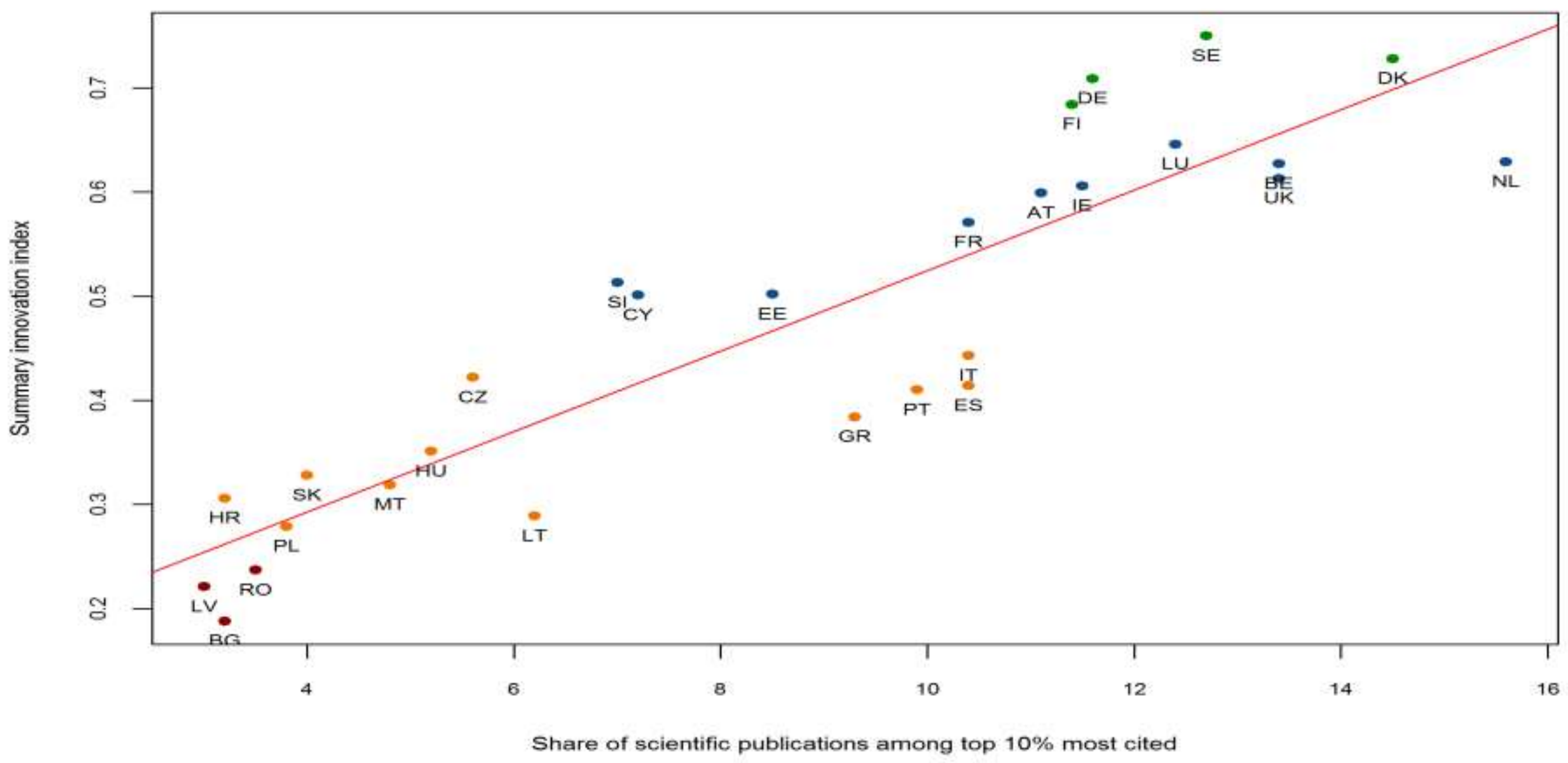
Main outputs – Phase II/5

First published in June 2012 – joint report from Working Groups No. 1 and 4 on technology foresight and pre-commercial procurement.

Initially printed in 440 copies.

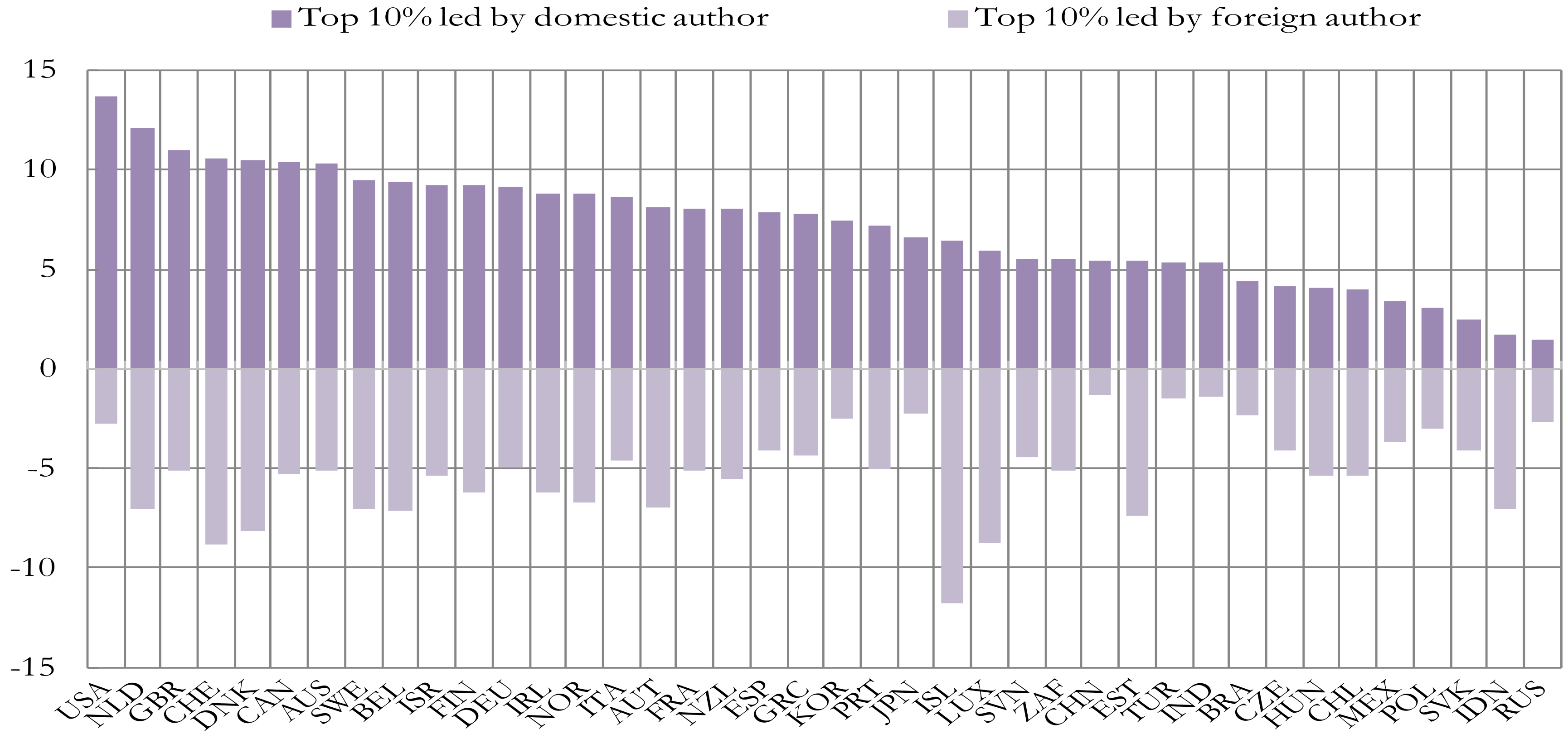
About 2.000 downloads from http://www.aginnovazione.gov.it/wp-content/uploads/2011/10/QI_10-11.pdf

High impact scientific publications and innovation performance, 2014



Source: Calculation from the Innovation Union Scoreboard 2014

Top 10% most cited documents and scientific leading authorship, 2003-12, %
of all documents, whole counts



Source: OECD (2015)

Tracing back the role of universities in the development of technology/ Early days

The era of digital computing was inaugurated by the electronic calculator ENIAC (Ceruzzi, 1998; Norberg, 2005). ENIAC was designed and built at the University of Pennsylvania’s Moore School of Electrical Engineering by Eckert and Mauchly, during Second World War

It is on the ENIAC concept that the great mathematician John von Neumann worked in 1945 in order to describe the abstract structure of a modern computing machine, which eventually became universally acclaimed as the von Neumann Architecture.

Its predecessor, the IBM Automatic Sequence-controlled Calculator (ASCC) went out in 1944 from a joint effort between IBM and the University of Harvard established in 1939 (Moreau, 1984).

Interestingly, as early as in 1946 the Moore School of the University of Pennsylvania and the US Army sponsored a course on the *Theory and techniques for design of electronic digital computers*.

Tracing back the role of universities in the development of technology/ Early days

IBM hired von Neumann as a consultant in January 1952 and started a collaboration with his organization, the Institute for Advanced Study at Princeton (Pugh, 1995).

Another company, Engineering Research Associates, starting from code-breaking activities during the War, hired engineers from the University of Minnesota, among which Seymour R. Cray, who eventually became a leader in supercomputing.

Another small company, Bendix, built the G-15 computer upon the design that Harry Huskey made in 1953 at the Wayne State University in Detroit.

Tracing back the role of universities in the development of technology/ Education and research

The role of universities greatly increased after a commercial move by IBM. In 1954 IBM delivered the 650, a machine that was installed mainly for business purposes in a thousand companies. Thomas Watson Jr decided that universities **could benefit of a discount up to 60% of the price of 650 if the university agreed to offer courses in business data processing or scientific computing** (Watson, 1990). This opened the way to a large diffusion of courses in computer science across US universities.

Meanwhile, American universities started to be involved in research on component technologies underlying the computer. Soon after the War, the University of Illinois, Harvard and MIT worked on core magnetic memories (Pugh, 1984; Wildes and Lindgren, 1985).

Bassett (2002) has shown that even in industrially-sensitive fields such as MOS (metal-oxide-semiconductor) technology, **large companies left their researchers relatively free to publish papers and to attend scientific conferences, interacting with academic researchers**

Tracing back the role of universities in the development of technology/ Large scale programmes

Universities were heavily involved in the first large scale software development programs (Campbell-Kelly, 2003):

- after the Valley Committee's report on air-defense system, MIT was contracted to develop a prototype of computer-based system to be operated in real time, called Project Lincoln

- the project was based on the Whirlwind prototype machine, developed at MIT's Lincoln Laboratory, which was at least 10 times faster than any comparable machine

- the Stanford Research Institute was commissioned the prototype of a check-reading machine for the banking industry, leading to the successful ERMA computer (Electronic Recording Machine Accounting)

Start up creation

Computer Usage Company (1955)
- John Sheldon, mathematical physicis, Director of the IBM's Technical Computing Bureau
- Elmer Kubie, mathematically oriented programmer at IBM

Computer Science Corporation (1959)
- Roy Nutt, "introverted mathematician", leading participant in FORTRAN development

Appendix

1. The effect of Higher Education Institutions on the creation of new firms: A comprehensive evidence on the Italian case

2. Universities, geographical distance, and the creation of knowledge intensive firms

3. Exploring the Role of Third-party Research in Italian Universities