Institutions of higher education and long term technological performance

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Outline

- The poor performance of Europe in Information Technology. Alternative explanations
- An anatomy of careers of top scientists in Computer Science

- country performance

- pattern of production

- pattern of professional mobility

- A conjecture and some policy implications

Revealed technological advantage (RTA) in ICT by country, based on US patents. 1969-1994

	1969-74	1979-84	1989-94
Europe	0.86	0.84	0.73
US	1.02	0.98	0.90
Japan	1.40	1.47	1.53

The competitiveness of European producers in ICT seems to be weak in general.

B.Dalum, C.Freeman, R. Simonetti, N.von Tunzelmann, B.Verspagen *Europe and the information and communication technologies revolution* (1999)

The implicit industrial policy of European R&D
The case of IT

1. Systemic failure in the support of “national champions” in IT/ hardware:
   - Bull (France)
   - Siemens Nixdorf (Germany)
   - Olivetti (Italy)
   - ICL (UK)

These companies almost disappeared from international competition

2. Almost complete absence in software (exc. SAP) and innovative services. Good position only in related semiconductors (STM)
3. No radically new technology in IT after the Internet revolution
4. A combination of myopia and strong lobby by large incumbents (mainly final *users* of technology, often *captive* technology) and lack of support to Schumpeterian innovation

At the origins of poor performance in European IT

More radically, the poor performance of in IT is rooted in the **weakness of European science in IT**

Contrary to the common wisdom (so called “European paradox”), **European science in several fields, including IT, lags behind US and Asia**

Almost all technological breakthroughs in IT have their origin (although indirect and lagged) into radically new ideas created in the scientific environment

Top ten ideas in computer science

1. Turing machine (Goldstine and von Neumann; Turing)
2. Programming languages; formal description of syntax and semantics; LISP (Mc Carthy)
3. Memory hierarchy; cache memory
4. User interface; Graphic User Interface (GUI); concept of window (Xerox Palo Alto Research Center; Apple)
5. Internet (UCLA/DARPA); packet switched multinetworks; http and html protocols; WWW (Berners-Lee)
6. Computational complexity; computational intractability; pseudocausality
7. Relational database
8. Fourier Fast Transform (FFT) (Cooley and Tuckey)
9. Efficient algorythms; data structure (Knuth and Tarjan)
10. Artificial intelligence

Source: our elaboration from expert opinion

An examination of the professional career of top 1000 scientists in computer science

- Excellence measured by total number of citations received in all published articles in the field (source: www. citeseer. com)
- Well recognized source in the scientific community
- Identify top 1,010 scientists by number of citations
- Download CVs from individual websites, or search CVs on the web
- Codify CV data and build the dataset
- Analysis: (a) overall career pattern (b) by cohort of age.

This presentation

- Only descriptive analysis
- Modeling effort on research productivity (by age, cohort, country, affiliation) under way
- Build arguments about the relation between institutional features of higher education systems in Europe, USA and Asia, and long term technological performance

Top current affiliation of scientists

Institution	Count Institution
Stanford University	45
Carnegie-Mellon University	42
Massachusetts Institute of Technology	42
University of California at Berkeley	36
University of Washington	23
Microsoft Research	20
Cornell University	18
University of Maryland	18
University of Wisconsin	16
University of Illinois	16
University of California at San Diego	16
University of Texas	14
Princeton University	14
Brown University	14
Bell Laboratories	14
University of Pennsylvania	13
University of Massachusetts	12
University of Toronto	12
Yale University	11
Columbia University	11
University of Southern California	10
Rice University	10
AT&T Labs Research	10
University of California at Los Angeles	10
University of Michigan	9

Ranking of Top 15 Affiliation per PhD

University	Count	%
Massachusetts Institute of Technology	82	9.6%
Stanford University	78	9.1%
University of California at Berkeley	69	8.1%
Carnegie Mellon University	43	5.0%
Harvard University	35	4.1%
Cornell University	27	3.2%
Princeton University	26	3.0%
University of Illinois	22	2.6%
University of Michigan	20	2.3%
University of Cambridge	16	1.9%
Yale University	15	1.8%
University of Wisconsin	14	1.6%
University of Toronto	13	1.5%
University of Edinburgh	13	1.5%
University of Pennsylvania	13	1.5%

USA | Asia | Europe | Other

Tot: 855

Ranking of Top 15 Affiliation per Master

University	*Count*	*%*
Massachusetts Institute of Technology	47	10.3%
Stanford University	29	6.3%
University of California at Berkeley	27	5.9%
Harvard University	14	3.1%
Carnegie Mellon University	13	2.8%
University of Illinois	12	2.6%
Cornell University	12	2.6%
University of Wisconsin	10	2.2%
University of Michigan	9	2.0%
University of Massachusetts	8	1.8%
University of Toronto	7	1.5%
University of Washington	7	1.5%
University of California at Los Angeles	7	1.5%
Yale University	7	1.5%
Indian Institute of Science	7	1.5%

USA Asia Europe Other

Tot: 457

Ranking of Top 15 Affiliation per Bachelor

University	*Count*	*%*
Massachusetts Institute of Technology	45	7.0%
Indian Institute of Technology	34	5.3%
Harvard University	25	3.9%
University of California at Berkeley	20	3.1%
University of Michigan	18	2.8%
University of Cambridge	18	2.8%
Princeton University	15	2.3%
Yale University	14	2.2%
National Taiwan University	13	2.0%
California Institute of Technology	12	1.9%
Technion Israel Institute of Technology	11	1.7%
Cornell University	11	1.7%
Brown University	10	1.6%
Stanford University	10	1.6%
University of Toronto	9	1.4%

USA Asia Europe Other Tot: 641

Area of PhD

Area	*Count*	*%*
USA	**654**	**76.5%**
Europe	**142**	**16.6%**
Asia	**9**	**1.1%**
Other	**50**	**5.8%**
Total	***855***	***100.0%***

Area of Master

Area	***Count***	***%***
USA	**332**	**72.6%**
Europe	**58**	**12.7%**
Asia	**30**	**6.6%**
Other	**37**	**8.1%**
Total	***457***	***100.0%***

Area of Bachelor

Area	*Count*	*%*
USA	**363**	**56.6%**
Europe	**112**	**17.5%**
Asia	**96**	**15.0%**
Other	**70**	**10.9%**
Total	***641***	***100.0%***

Mobility between country of BS and country of PhD

		Country_BS_Area					Total
			Asia	Europe	Other	USA	
Country_PhD_Area		133	0	6	0	16	155
	Asia	2	7	0	0	0	9
	Europe	54	4	74	7	3	142
	Other	19	1	1	22	7	50
	USA	161	84	31	41	337	654
Total		369	96	112	70	363	1010

Tab. Education per year of PhD and Area of PhD

Year	n.d.	Europe	USA	Other	Asia	Total
<1950	0	4	4	0	0	8
1950-1959	0	3	19	0	0	22
1960-1969	0	9	66	3	2	80
1970-1979	0	48	134	10	1	193
1980-1989	2	37	207	18	4	268
1990-present	1	17	122	7	1	148
TOT	3	118	552	38	8	719

Ranking of Bachelor per discipline

Bachelor in	*Count*	*%*
Mathematics	165	25.7%
Engineering	165	25.7%
Computer Science	102	15.9%
Physics	45	7.0%
Psychology	9	1.4%
Biology	4	0.6%
Chemistry	4	0.6%
Statistics	3	0.5%
Other or not specified	144	22.5%
		Total : 641

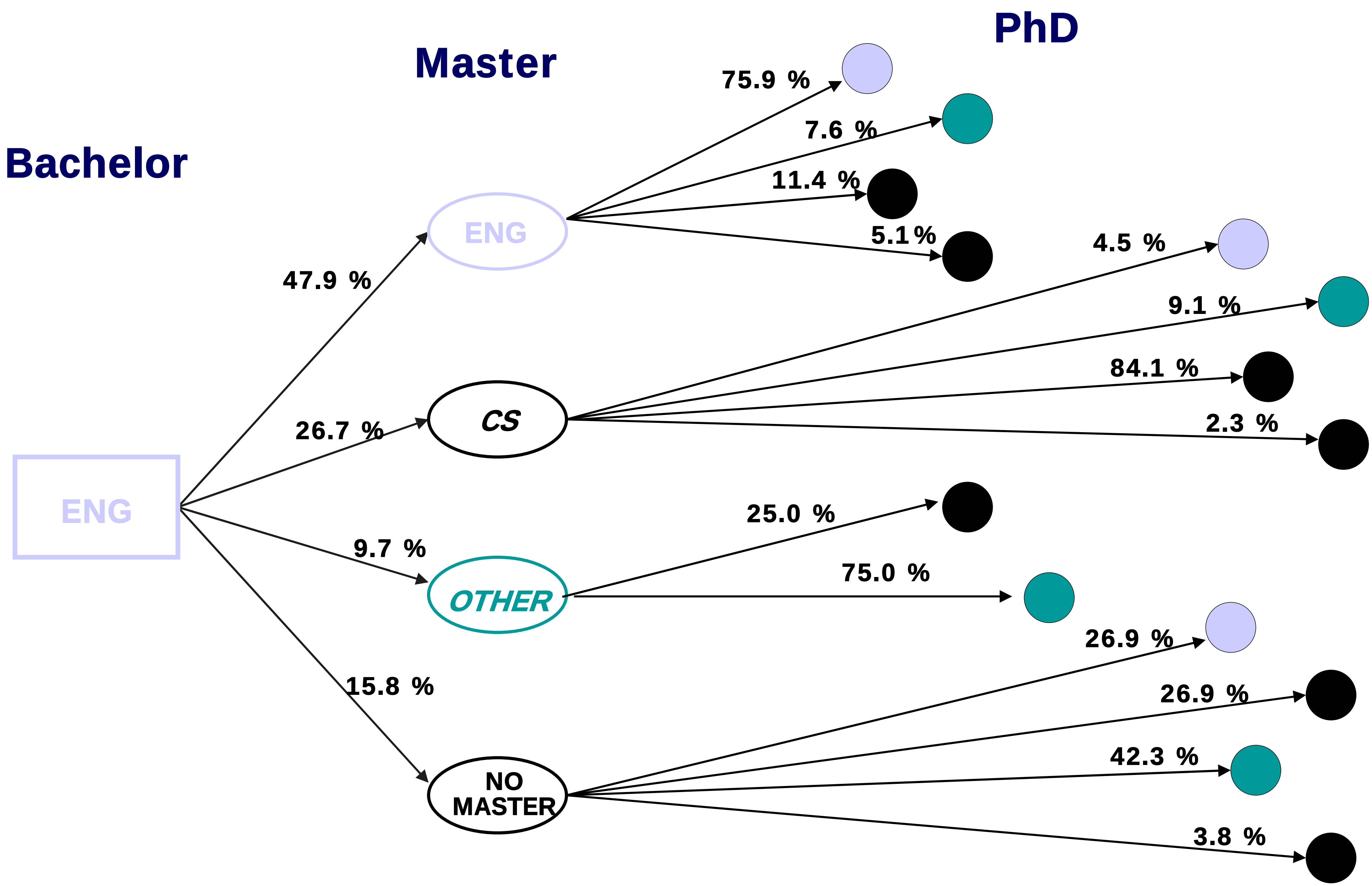
Ranking of Master per discipline

Master in	*Count*	*%*
Computer Science	156	34.1%
Engineering	113	24.7%
Mathematics	75	16.4%
Physics	14	3.1%
Statistics	6	1.3%
Economics	6	1.3%
Literature	4	0.9%
Psychology	2	0.4%
Other or not specified	81	17.7%
		Total : 457

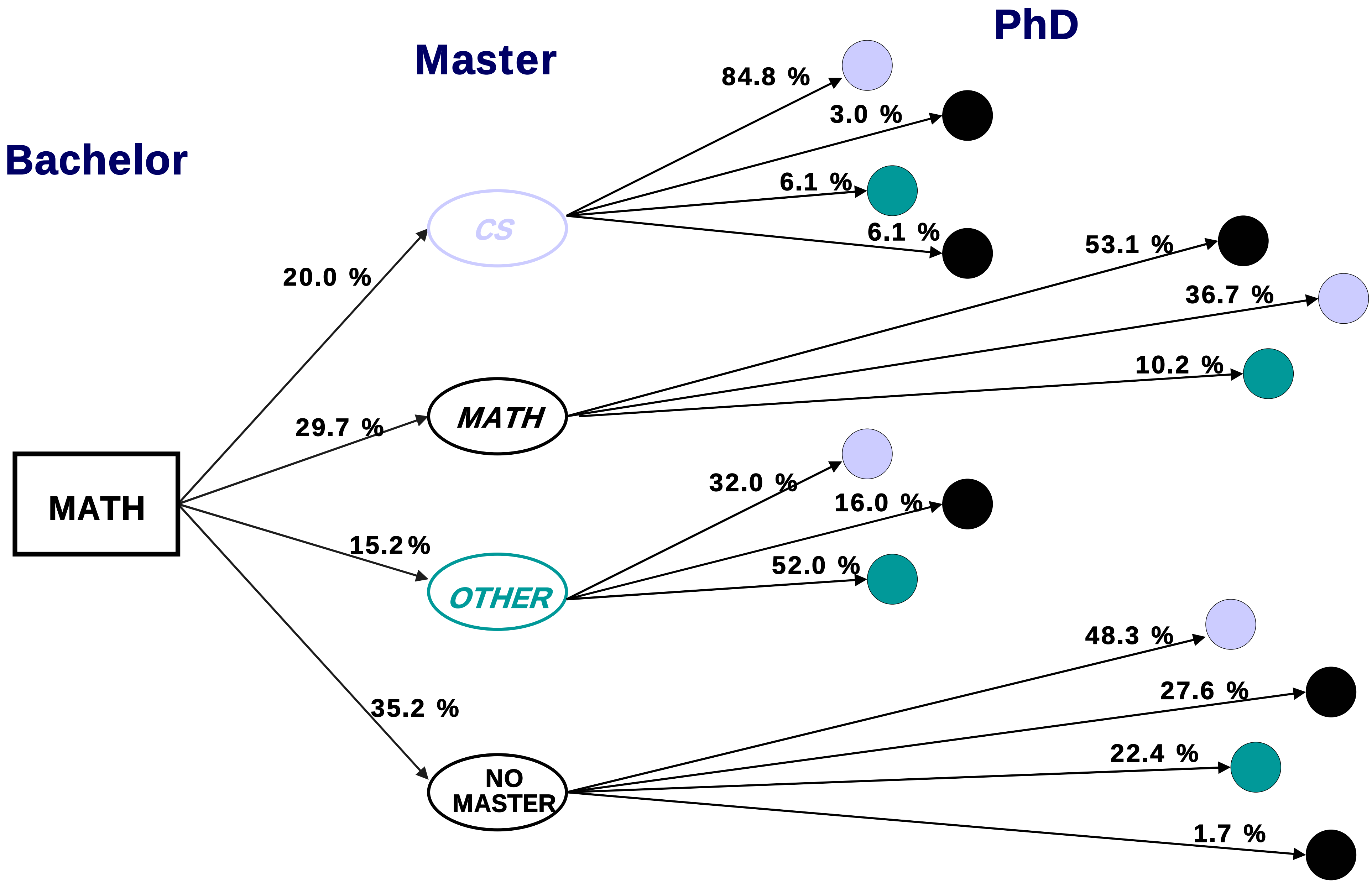
Ranking of PhD per discipline

PhD in	***Count***	***%***
Computer Science	327	38.2%
Engineering	116	13.6%
Mathematics	90	10.5%
Physics	25	2.9%
Statistics	9	1.1%
Psychology	8	0.9%
Linguistics	4	0.5%
Economics	2	0.2%
Other or not specified	274	32.0%
		Total : 855

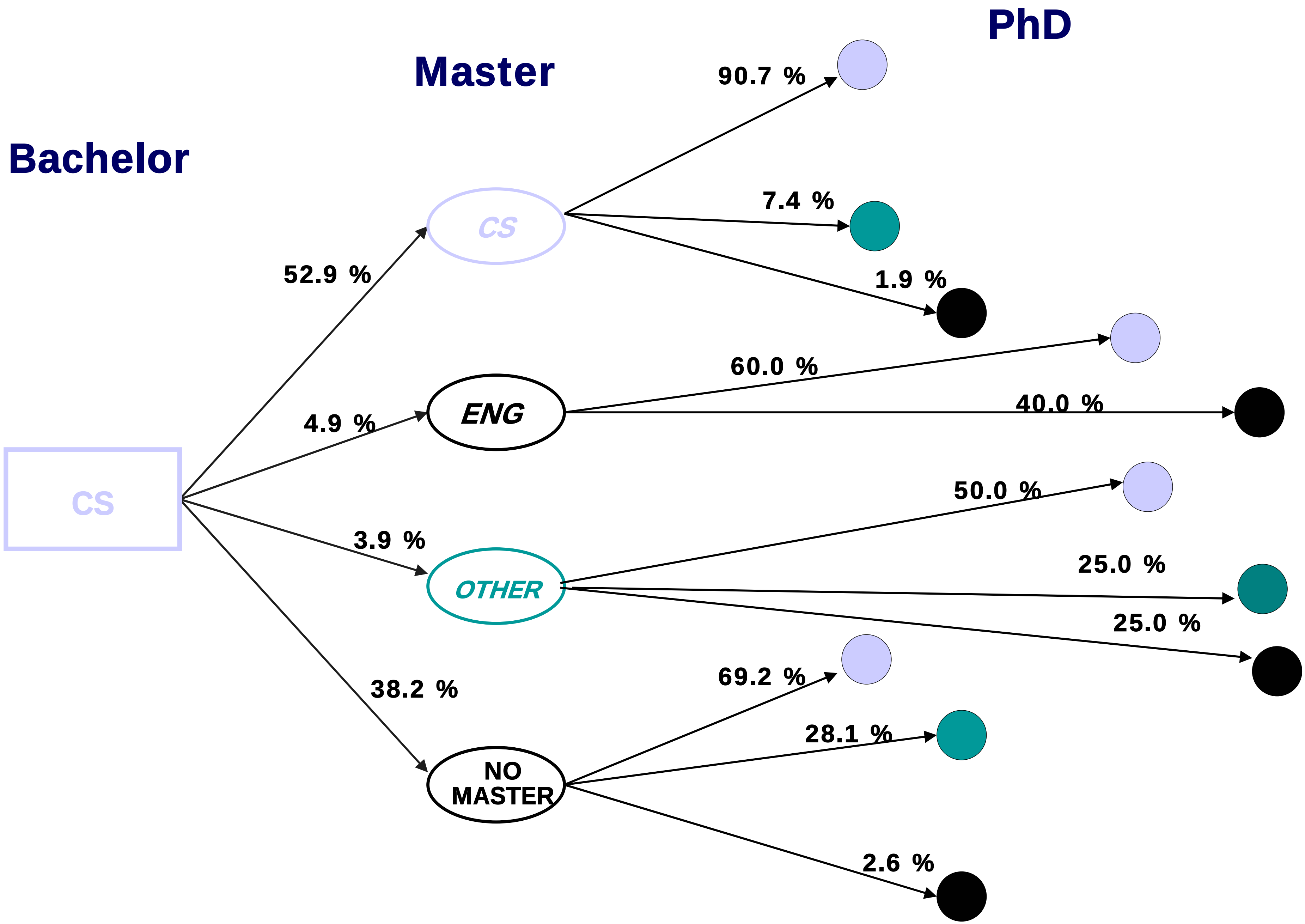
Transition path from the Bachelor in Engineering



Transition path from the Bachelor in Mathematics



Transition path from the Bachelor in Computer Science



Bachelor vs PhD Discipline (count)

Bachelor \ *PhD*	*Math*	*Eng*	*Comp Sci*	*Other*	*No PhD*	*Tot*
Mathematics	47	14	82	19	3	*165*
Engineering	4	69	57	29	6	*165*
Computer Science	-	2	81	16	3	*102*
Tot	*51*	*85*	*220*	*64*	*12*	*432*

Bachelor vs PhD Discipline (%)

PhD / Bachelor	Math	Eng	Comp Sci	Other	No PhD	Tot
Mathematics	**28.5%**	**8.5%**	**49.7%**	**11.5%**	**1.8%**	***100.0%***
Engineering	**2.4%**	**41.8%**	**34.5%**	**17.6%**	**3.6%**	***100.0%***
Computer Science	**-**	**2.0%**	**79.4%**	**15.7%**	**2.9%**	***100.0%***
Tot	***11.8%***	***19.7%***	***50.9%***	***14.8%***	***2.8%***	***100.0%***

Professional positions over the career of top scientists

Number of scientists: 1010.

Number of different positions: 4418.

Mean 4,36

Prof career	Count position
University	2620
University-director	497
Industry	463
Consulting	332
Industry-director	323
Government	183

Rapid academic career

Duration of the career steps

	N	Minimum	Maximum	Mean	Std. Deviation
Per_status_postdoc	68	0	7	1,81	1,499
Per_status_researcher	412	0	36	4,89	5,33
Per_status_associate professor	336	0	40	5,39	4,175
Per_status_full professor	348	0	44	11,51	9,05

Ranking of top 15 affiliations in the total number of positions over the career. Academic positions

Institution	Count
Massachusetts Institute of Technology	174
Stanford University	166
University of California at Berkeley	102
Carnegie-Mellon University	102
University of Illinois	59
University of Maryland	58
Cornell University	52
University of Washington	45
University of Pennsylvania	44
Harvard University	44
Princeton University	44
University of Texas	44
University of Massachusetts	42
Brown University	41
University of Toronto	34

Mobility pattern

	N	*Min*	*Max*	*Mean*	*Std. Dev.*
Age	**173**	**30**	**86**	**56.97**	**11.585**
N. diff. country	**786**	**1**	**6**	**1.35**	**.686**
N. diff. Employment positions after PhD	**786**	**1**	**49**	**5.32**	**4.376**
N. diff. Country mobility/ Years of age	**163**	**.01**	**.11**	**.029**	**.017**
N. diff. country/ Years of seniority	**604**	**.02**	**2.00**	**.078**	**.111**

Distribution of industry positions in the career per country of PhD

		Country_PhD_Area				Total
			Europe	Other	USA	
empl_ind	0	1	2	0	2	5
	1	15	20	7	127	169
	2	3	8	3	44	58
	3	1	1	0	25	27
	4	1	0	1	9	11
	5	0	0	0	5	5
	6	0	0	0	1	1
	7	0	0	0	2	2
Total		21	31	11	215	278

Distribution of industry top management positions in the career per country of PhD

		Country_PhD_Area				Total
			Europe	Other	USA	
empl_ind_dir	1	10	18	2	76	106
	2	1	5	3	30	39
	3	1	1	0	12	14
	4	0	1	0	9	10
	5	1	0	0	2	3
	6	0	0	0	1	1
	7	0	0	0	2	2
	10	0	0	0	1	1
	12	0	0	0	1	1
Total		13	25	5	134	177

Scientific production of top scientists

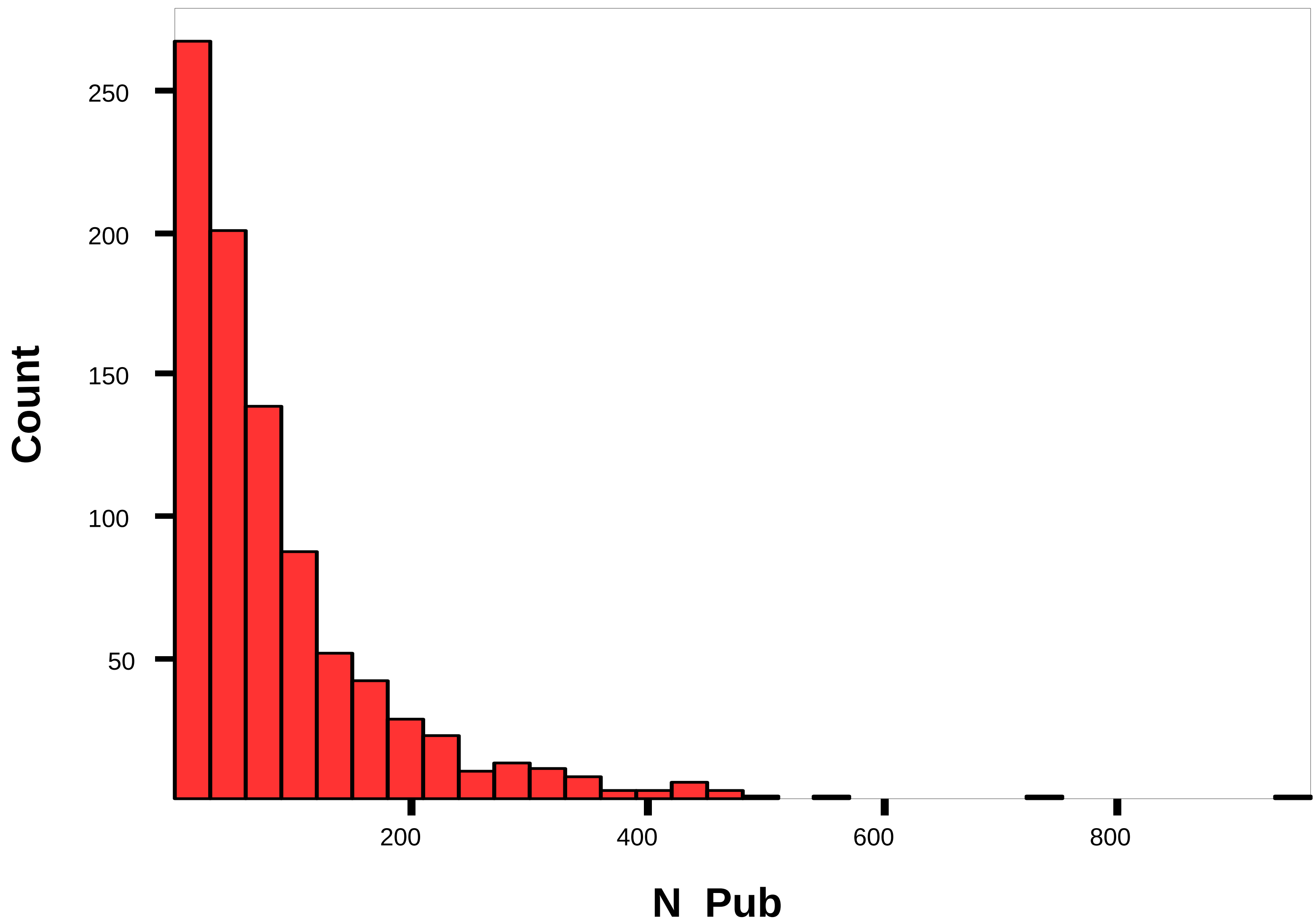
Tab. Pub_CV and Pub ISI

	N	Minimum	Maximum	Mean	Std. Deviation
N_Pub_CV	903	1	964	87,74	95,58
N_Pub_ISI	983	1	284	24,73	34,59

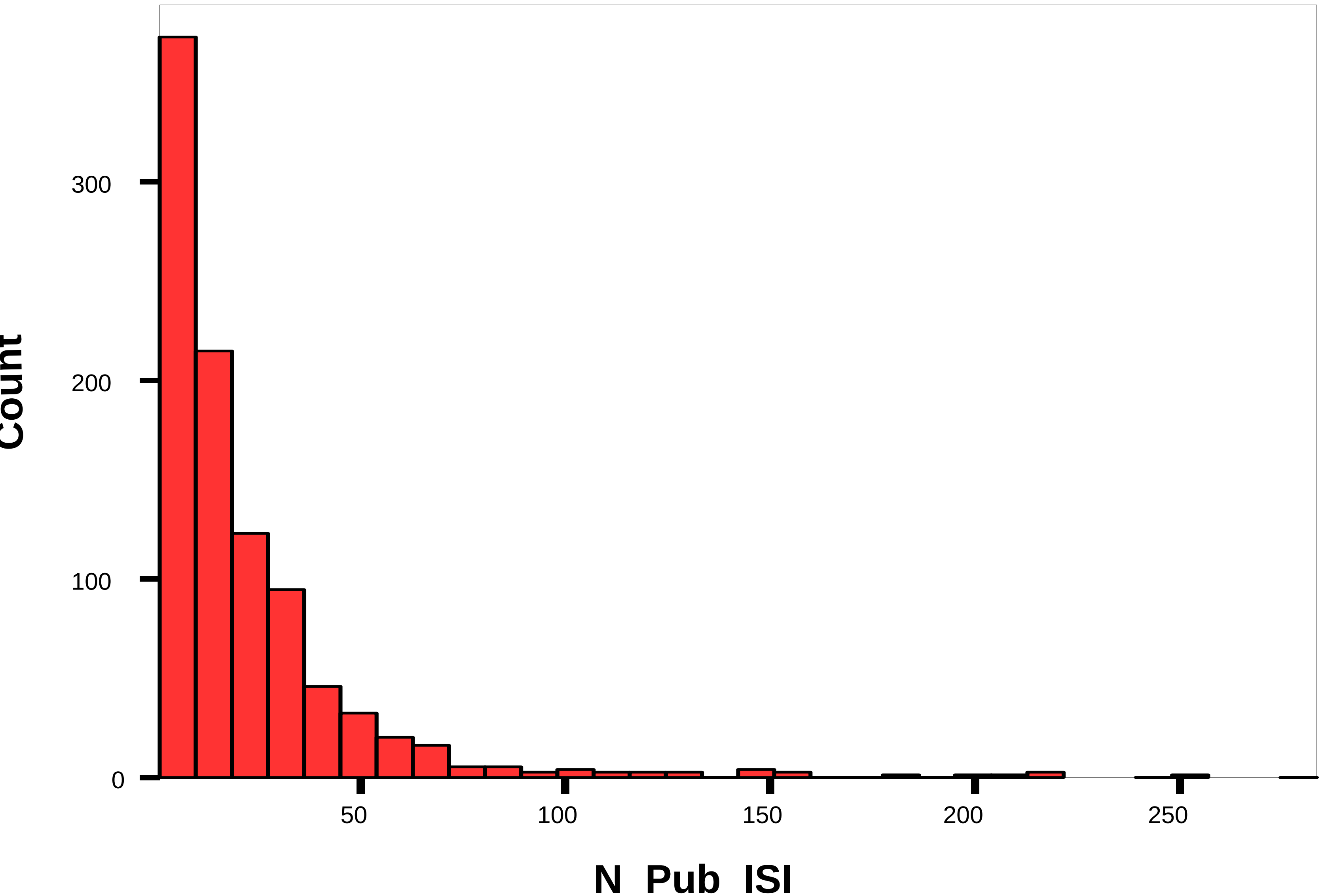
Tab. Other scientific output

	N	Minimum	Maximum	Mean	Std. Deviation
Software	204	1	56	4,14	6,081
Patents	137	1	47	6,57	8,342

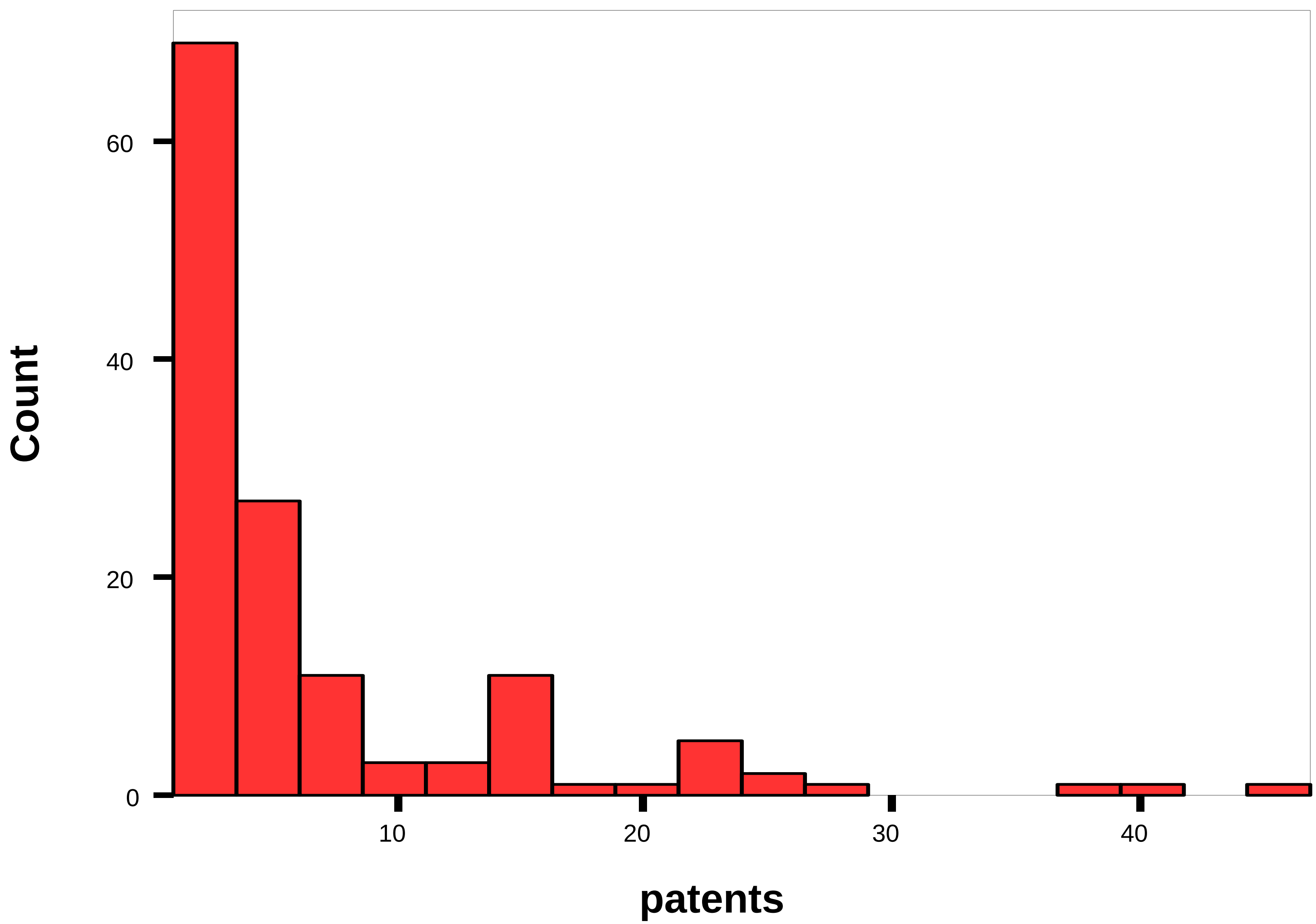
Frequency distribution of self-declared publications



Frequency distribution of ISI publications



Frequency distribution of patents



Conclusions

Why do we (Europeans) failed in fast moving scientific fields?

Notion of *search regime* (Bonaccorsi, 2005):
- rate of growth of production of knowledge
- degree of diversity
- level and nature of complementarity.

Leading search regimes, or fast moving fields:
- rapid growth (sometimes exponential)
- pattern of proliferation of research programmes
- new types of complementarity (human capital, institutional)

Life science, materials science, nanotechnology, information technology.

In fast moving fields:

- new and divergent research directions are generated within established scientific paradigms

- the reputation of the university is a powerful **signaling** mechanism, due to the difficulty to evaluate the merits of competing claims centrally

- there is a need to **rapidly** mobilize resources and to build up the required institutional and human capital complementarity

- **opportunity costs** for young and brilliant scientists are extremely high

- high **mobility** is the rule of the game

Doctoral education, particularly in the sciences, is perhaps the most efficient competitive market in higher education. Each winter a limited number of students with the requisite qualifications apply to those science and engineering departments that would most like to attend and that would be most likely to accept them. The applicants are well informed about the training they seek, and they are highly mobile as well.

Each department is a small, autonomous producer, and the departments in each subject area collectively form a national market. Except for pricing, doctoral education approaches the requirements for perfect competition (Geiger, 2004, p. 163).

The key feature of this market is that both applicants and departments vary in quality in ways that are fully understood by both parties: applicants and departments can therefore be ranked according to desirability.

Thus, a dual competition takes place- departments seek to attract the most preferred students and students seek places at the most preferred departments in their field.

This situation produces a *queuing* process of allocation. Top departments choose, and are chosen by, the best students; departments in the next tier do the same with the remaining students; and so on down the list. However, this market is highly competitive and the terms of competition fairly delimited (ib. p. 163-4).