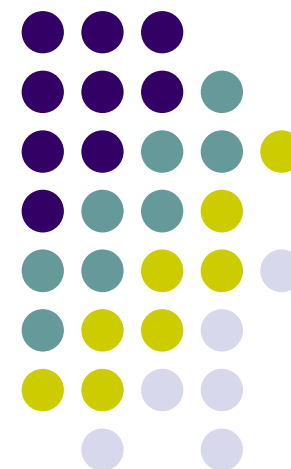


Influential Mathematicians: Where do they come and where do they go?

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Abstract

Research output and impact is currently the focus of serious debate worldwide. Quantitative analyses based on a wide spectrum of indices indicate a clear advantage of US institutions as compared to institutions in Europe and the rest of the world. However the measures used to quantify research performance are mostly static: Even though research output is the result of a process that extends in time as well as in space, indices often only take into account the current affiliation when assigning influential research to institutions. In this paper, we focus on the field of mathematics and investigate whether the image that emerges from static indices persists when bringing in more dynamic information, through the study of the "trajectories" of highly cited mathematicians: birthplace, country of first degree, country of PhD and current affiliation. While the dominance of the US remains apparent, some interesting patterns -that perhaps explain this dominance - emerge.



- There is currently a surge of interest in comparing research impact and performance, to produce league tables. These may be at various levels, ranking countries, universities, departments, programs, journals or even individual scientists, and are typically based on certain simple bibliometric measures, such as impact factors, the h-index etc.
- This interest is not purely academic: these rankings have caught the attention of policy makers, and have caused serious concern especially within European policy making due to the apparent lagging performance of Europe as compared to the US



- A different aspect that has not received attention is the static character of several of the indices employed, which fails to capture the “liquidity” of the modern academic landscape, where high mobility of scientists is the rule rather than the exception
- In general, comparable data on researchers’ movement between Europe, Asia or Africa to the US are incomplete
- A database on highly cited researchers (HCRs) is compiled by the Institute of Scientific Information (ISI) covering 21 disciplines and 6.103 researchers². These data are freely available by the Thomson Scientific (<http://hcr3.isiknowledge.com/>) and cover the time period between 1981 and 1999



- With regards to mathematics, the Thomson database lists 343 highly cited mathematicians from 152 Institutions
- While the Thomson database may provide the list of HCRs and their present affiliation, we had to conduct a personalized case-by-case search in order to obtain data on the country they obtained their first degree, and their PhD as well as their birthplace, either by searching through their web pages or by contacting them directly
- The following Table summarizes the data on HCRs in the field of Mathematics according to the country of their present affiliation. One easily sees that the US – as in all disciplines – gets the lion’s share of HCRs. The UK and France are far behind the US, but well ahead of the rest of the countries

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Country of present affiliation	Number of HCRs	Percentage of HCRs
United States	234	68.22%
United Kingdom	24	7.00%
France	22	6.41%
Germany	9	2.62%
Israel	8	2.33%
Australia	6	1.75%
Canada	6	1.75%
Japan	5	1.46%
Denmark	4	1.17%
Italy	4	1.17%
Netherlands	4	1.17%
Spain	4	1.17%
Switzerland	3	0.87%
Hungary	2	0.58%
Peoples Rep of China	2	0.58%
Belgium	1	0.29%
India	1	0.29%
Singapore	1	0.29%
Sweden	1	0.29%
Taiwan	1	0.29%
Turkey	1	0.29%
TOTAL	343	100,00%



- By bringing in the additional background data, we can immediately observe that intercontinental movement is indeed a very common practice.
- Specifically, based on the data collected, only the 46.9% of HCRs were born, educated and are working in the same continent, while a significant 42.6% of them have completed at least one of their degrees or are working in a continent other than the one they were born in (due to missing information we cannot answer this question for the 10.5% of HCRs)



Current affiliation of HCRs

Table 1: Frequencies and percentages of HCRs according to the country of their present affiliation

		FREQUENCY	PERCENTAGE (%)
Valid	US	234	68,2
	EU	78	22,7
	Israel	8	2,3
	Australia	6	1,7
	Canada	6	1,7
	Japan	5	1,5
	China/Taiwan	3	0,9
	India	1	0,3
	Singapore	1	0,3
	Turkey	1	0,3
TOTAL		343	100,0



Current affiliation of HCRs

- Table 1 presents the percentages of HCRs in the field of mathematics according to their current affiliation.
- The majority of researchers are working in the US (68.2%), while 22.7% work in Europe.
- Only 9% work in countries outside the US and Europe. (Countries with more than one HCR outside the US and Europe are Israel, Canada, Japan, and China)



PhD studies of HCRs

Table 2: *Frequencies and percentages of HCRs according to the country where the Ph.D. studies were completed*

		FREQUENCY	PERCENTAGE (%)
Valid	US	198	57,7
	EU	110	32,1
	Israel	7	2,0
	Canada	6	1,7
	Russia	5	1,5
	Japan	5	1,5
	India	2	0,6
	Australia	2	0,6
	Argentina	1	0,3
	South Africa	1	0,3
	Total	337	98,3
Missing		6	1,7
TOTAL		343	100,0



PhD studies of HCRs

- the US maintains an advantage over Europe and the rest of the world but not nearly as strong as when compared with respect to current affiliation of the HCRs
- 57.7% of HCRs in mathematics have acquired their Ph.D. degree in US universities, 32.1% in Europe and 8.5% in the rest of the world: the difference between the US and Europe drops by approximately 20 percentage points



Table 3: Contingency table between the country of present affiliation of the HCRs and the country of the Ph.D. degree of the HCRs

			Country of Present Affiliation of the HCRs			TOTAL
			US	EU	Rest of the world	
Country in which the Ph.D. Degree of the HCRs was obtained	US	Count	180	6	12	198
		% within	90,9%	3,0%	6,1%	100,0%
	EU	Count	37	65	8	110
		% within	33,6%	59,1%	7,3%	100,0%
	Rest of the world	Count	16	2	11	29
		% within	55,2%	6,9%	37,9%	100,0%
TOTAL		Count	233	73	31	337
		% within	69,1%	21,7%	9,2%	100,0%

- The distribution provided in Table 3 reveals that a stunning one in three HCRs who completed their doctorate in Europe is now affiliated with a US institution.
- Even more extreme is the situation when looking at HCRs with PhDs from outside the US or Europe, one in two of whom have eventually settled in the US



BSc studies of HCRs

Table 4: Frequencies and percentages of HCRs according to the country where the first degree was completed

		FREQUENCY	PERCENTAGE (%)
Valid	EU	114	33,2
	US	112	32,7
	China/Taiwan	18	5,2
	Canada	14	4,1
	Australia	11	3,2
	India	9	2,6
	Russia	7	2,0
	Israel	6	1,7
	Hong Kong	4	1,2
	Japan	4	1,2
	South Africa	4	1,2
	rest of the world (*)	10	2,9
	Total	313	91,3
Missing	30	8,7	
TOTAL	343	100,0	

(*) 1 HCR for each of Argentina, Peru, Egypt, Brazil, Mexico, New Zeland, Venezuela, Algeria, Turkey and Chile



BSc studies of HCRs

- Only 32.7% of the HCRs completed their B.Sc. degree studies in the US, while 33.2% completed their first degree in Europe and a quite significant number (25.4%) have completed their B.Sc. studies in countries outside the US and Europe
- This could be an indication that “promising” undergraduate mathematics students are found equally in Europe and in the US and also in other countries outside the US and Europe



Table 5: Contingency table between the country of present affiliation of the HCRs and the country where the first degree of the HCRs was completed

			Country in which the B.Sc. Degree of the HCRs was obtained			TOTAL
			US	EU	Rest of the world	
Country of Present Affiliation of the HCRs	US	Count	107	50	61	218
		% within	49,1%	22,9%	28,0%	100,0%
	EU	Count	3	62	2	67
		% within	4,5%	92,5%	3,0%	100,0%
	Rest of the world	Count	2	2	24	28
		% within	7,1%	7,1%	85,7%	100,0%
TOTAL		Count	112	114	87	313
		% within	35,8%	36,4%	27,8%	100,0%

- The results indicate a significant transfer of mathematics researchers to the US from the rest of the world, when the first degree is taken into account
- Notice how diffuse the distribution of HCRs affiliated with US institutions is with respect to the country of their alma mater: only one in two were undergraduates in US universities



Birthplace of HCRs

Table 6: Frequencies and percentages of HCRs according to their country of birth

		FREQUENCY	PERCENTAGE (%)
Valid	US	108	31,5
	EU	129	37,6
	China/Taiwan	19	5,5
	Canada	11	3,2
	Australia	11	3,2
	Israel	9	2,6
	India	9	2,6
	Russia	8	2,3
	Japan	5	1,5
	Hong Kong	4	1,2
	South Africa	3	0,9
	Argentina	2	0,6
	New Zealand	2	0,6
	rest of the world (*)	12	3,5
	Total	332	96,8
Missing		11	3,2
TOTAL		343	100,0

(*) 1 HCR for each of Peru, Egypt, Brazil, Mexico, Venezuela, Algeria, Turkey, Chile, Tunisia, Vietnam, Pakistan and Rep Congo

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Birthplace of HCRs

- the majority of HCRs were born in Europe (37.6%), while 31.5% came from US, and the remaining 27.7% were born in countries in other parts of the world

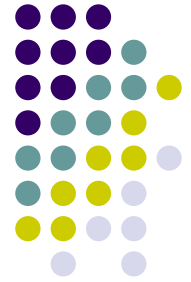




Table 7: Contingency table between the country of present affiliation and the country of birth of the HCRs

			Country of Birth of the HCRs			TOTAL
			US	EU	Rest of the world	
Country of Present Affiliation of the HCRs	US	Count	105	54	67	226
		% within	46,5%	23,9%	29,6%	100,0%
	EU	Count	1	72	3	76
		% within	1,3%	94,7%	3,9%	100,0%
	Rest of the world	Count	2	3	25	30
		% within	6,7%	10,0%	83,3%	100,0%
TOTAL		Count	108	125	95	332
		% within	32,5%	38,9%	28,6%	100,0%

- It is obvious that for the HCRs currently working in the US, less than half were native-born (46.5%), while the vast majority of researchers working in Europe or the rest of the world are native-born citizens
- the movement from Europe to the US (23.9%) heavily outnumbered the opposite movement (1.3%). Generally, the majority of HCRs working in US Universities and Institutions were born elsewhere (121 out of 226 researchers)



Table 8: Contingency table between the country of birth of the HCRs and the country where the first degree of the HCRs was completed

			Country in which the B.Sc. Degree of the HCRs was obtained			TOTAL
			US	EU	Rest of the world	
Country of Birth of the HCRs	US	Count	96	3	1	100
		% within	96,0%	3,0%	1,0%	100,0%
	EU	Count	7	107	3	117
		% within	6,0%	91,5%	2,6%	100,0%
	Rest of the world	Count	6	3	81	90
		% within	6,7%	3,3%	90,0%	100,0%
TOTAL		Count	109	113	85	307
		% within	35,5%	36,8%	27,7%	100,0%

- In relation to the movement of HCRs in the early steps of their life, we observe from Table 8 that moving between US, Europe and the rest of the world is retained at the minimum level



Table 9: Contingency table between the country of BS degree and the country of PhD degree of the HCRs

			Country in which the Ph.D. Degree of the HCRs was obtained			TOTAL
			US	EU	Rest of the world	
Country in which the B.Sc. Degree of the HCRs was obtained	US	Count	111	1	0	112
		% within	99,1%	0,9%	0,0%	100,0%
	EU	Count	23	91	0	114
		% within	20,2%	79,8%	0,0%	100,0%
	Rest of the world	Count	52	9	26	87
		% within	59,8%	10,3%	29,9%	100,0%
TOTAL		Count	186	101	26	313
		% within	59,4%	32,3%	8,3%	100,0%

- Almost all of the researchers who obtained their B.Sc. degree in the US continued their studies there (99.1%)
- In contrast, a highly significant number of European researchers (20.2%) left Europe to continue their Ph.D. studies in the US, while the majority of the researchers from other countries (59.8%) continued their Ph.D. studies in the US
- It is worth observing that none of the HCRs who did their undergraduate studies in Europe or the US chose to go to another continent for their Ph.D studies



HCRs and Top Institutions

- Our findings indicate a much higher concentration of HCRs in top mathematics institutions than in other scientific fields
- one might attempt to attribute this to the fact that hiring a top mathematician is less “expensive” for institutions than hiring an experimental scientist
- 20 of the top 24 Institutions in Mathematics ranked from the point of view of HCRs are in the USA, while only three are in Europe (University of Oxford, Pierre & Marie Curie University and University of Cambridge) and one is located in Israel (Tel Aviv University)

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HCRs and Top Institutions

Institution of Affiliation	HCRs	% of HCRs	non-native HCRs	% of non-native HCRs	native HCRs	% of native HCRs	BSs acquired in same country	% of BSs acquired in same country	BSs acquired elsewhere	% of BSs acquired elsewhere	PhDs acquired in same country	% of PhDs acquired in same country	PhDs acquired elsewhere	% of PhDs acquired elsewhere	Country
Stanford University	16	4,66%	8	50,0%	8	50,0%	8	50,0%	8	50,0%	16	100,0%	0	0,0%	USA
University of California, Berkeley (*)	14	4,08%	6	42,9%	7	50,0%	7	50,0%	5	35,7%	11	78,6%	3	21,4%	USA
University of Minnesota	10	2,92%	5	50,0%	5	50,0%	6	60,0%	3	30,0%	8	80,0%	2	20,0%	USA
Princeton University	10	2,92%	8	80,0%	2	20,0%	3	30,0%	7	70,0%	5	50,0%	5	50,0%	USA
Harvard University	8	2,33%	4	50,0%	4	50,0%	4	50,0%	4	50,0%	8	100,0%	0	0,0%	USA
New York University	7	2,04%	4	57,1%	3	42,9%	4	57,1%	3	42,9%	6	85,7%	1	14,3%	USA
Pierre & Marie Curie University (*)	6	1,75%	0	0,0%	5	83,3%	4	66,7%	0	0,0%	3	50,0%	2	33,3%	France
Massachusetts Institute of Technology	6	1,75%	4	66,7%	2	33,3%	1	16,7%	5	83,3%	5	83,3%	1	16,7%	USA
University of Oxford	6	1,75%	1	16,7%	5	83,3%	4	66,7%	2	33,3%	4	66,7%	2	33,3%	UK
Yale University (*)	6	1,75%	4	66,7%	1	16,7%	2	33,3%	3	50,0%	4	66,7%	2	33,3%	USA
Tel Aviv University	5	1,46%	2	40,0%	2	40,0%	2	40,0%	2	40,0%	2	40,0%	3	60,0%	Israel
University of Washington	5	1,46%	3	60,0%	2	40,0%	2	40,0%	3	60,0%	3	60,0%	2	40,0%	USA
Cornell University (*)	5	1,46%	2	40,0%	2	40,0%	1	20,0%	3	60,0%	3	60,0%	2	40,0%	USA
Georgia Institute of Technology	5	1,46%	4	80,0%	1	20,0%	1	20,0%	3	60,0%	3	60,0%	2	40,0%	USA
Rutgers University	5	1,46%	5	100,0%	0	0,0%	0	0,0%	5	100,0%	2	40,0%	3	60,0%	USA
Texas A&M University (*)	5	1,46%	1	20,0%	3	60,0%	4	80,0%	1	20,0%	5	100,0%	0	0,0%	USA
University of California, Davis	5	1,46%	4	80,0%	1	20,0%	1	20,0%	4	80,0%	3	60,0%	2	40,0%	USA
University of Maryland	5	1,46%	2	40,0%	3	60,0%	3	60,0%	2	40,0%	4	80,0%	1	20,0%	USA
Northwestern University	4	1,17%	1	25,0%	3	75,0%	3	75,0%	1	25,0%	4	100,0%	0	0,0%	USA
University of California, Los Angeles	4	1,17%	2	50,0%	2	50,0%	2	50,0%	2	50,0%	3	75,0%	1	25,0%	USA
University of Chicago	4	1,17%	4	100,0%	0	0,0%	2	50,0%	2	50,0%	3	75,0%	1	25,0%	USA
University of Texas at Austin	4	1,17%	3	75,0%	1	25,0%	1	25,0%	3	75,0%	2	50,0%	2	50,0%	USA
University of Wisconsin - Madison	4	1,17%	2	50,0%	2	50,0%	2	50,0%	2	50,0%	3	75,0%	1	25,0%	USA
University of Cambridge	4	1,17%	1	25,0%	3	75,0%	4	100,0%	0	0,0%	2	50,0%	2	50,0%	UK



HCRs and Top Institutions

- it is obvious that for the majority of the US Universities their HCRs come mostly from countries outside the United States.
- For instance, at Princeton University 8 out of the 10 HCRs come from countries outside the US, while at Rutgers University, all of the HCRs (5) were not born in US
- On the other hand, we observe the exact opposite effect when it comes to the three European institutions that complete the table. For example, in Pierre and Marie Curie University and the University of Cambridge, the majority of the HCRs are native-born citizens (5 and 3, respectively), while for the University of Oxford only one out of 5 was born elsewhere



Conclusions

- The results of the current study verify the widely held belief of a brain drain in mathematics from Europe and the rest of the world to the US, at least among those mathematicians who have become highly cited
- Moreover, it provides evidence supporting the view that this brain drain becomes more acute as the career of the HCRs evolves
- Focusing within this influential group of mathematicians we see that while only 6% of Europeans moved to the US for their undergraduate studies, the US drained 20% of European bachelors to do a PhD in the US. At the next level, 33.6% of European PhDs were attracted to faculty or research positions in the US



Conclusions

- The situation is worse for the HCRs born outside the US and Europe. The US drained 59.8% of non-European foreign bachelors to do a PhD in the US, while 55.2% of non-European foreign PhDs were attracted to faculty positions in the US
- On the other hand, the retention level of the HCRs in mathematics is high at every level in the US. The US has managed to retain 99% of their bachelors to do their PhDs and 90% of their doctors as faculty members in US Institutions
- These results, combined with other findings in this article, reveal that a significant number of HCRs working in the US has been scientifically “nurtured” elsewhere. The US is able to attract some of the best minds in mathematics from all over the world, and has found the means and conditions to keep them there



Conclusions

- If Europe wants to compete with the US, at least in mathematics, it should follow the example of the US and find ways of not only retaining its best scientists but also of attracting more from other parts of the world, including the US.
- The European Research Council established recently and the Starting and Advanced Research Grants awarded are certainly a step in the right direction