Approaches to Educational Research Essay

Niall Douglas MBS MA BSc. Written January 2011. Word count: 1,525.

Research Question

Something I have always found of interest is why the cutting edge advancements in Mathematics seem to usually be achieved by Old World Europeans (i.e. including European Russia), and furthermore, that this apparent correlation has somehow not changed[1] to date despite the ongoing decline of European cultural and economic dominance during the past century. As a crude measure of this apparent phenomenon, I took a list of winners of the International Medal for Outstanding Discoveries in Mathematics[2] 1936-2010 and allocated a set of weights to each reflecting the countries of their schooling ages 0-10, 11-15 and 16-18 (see Appendix A). In order to account for population effects, I also divided the score by the approximate number of people per square kilometre[3]. The results are shown in Figure 1:

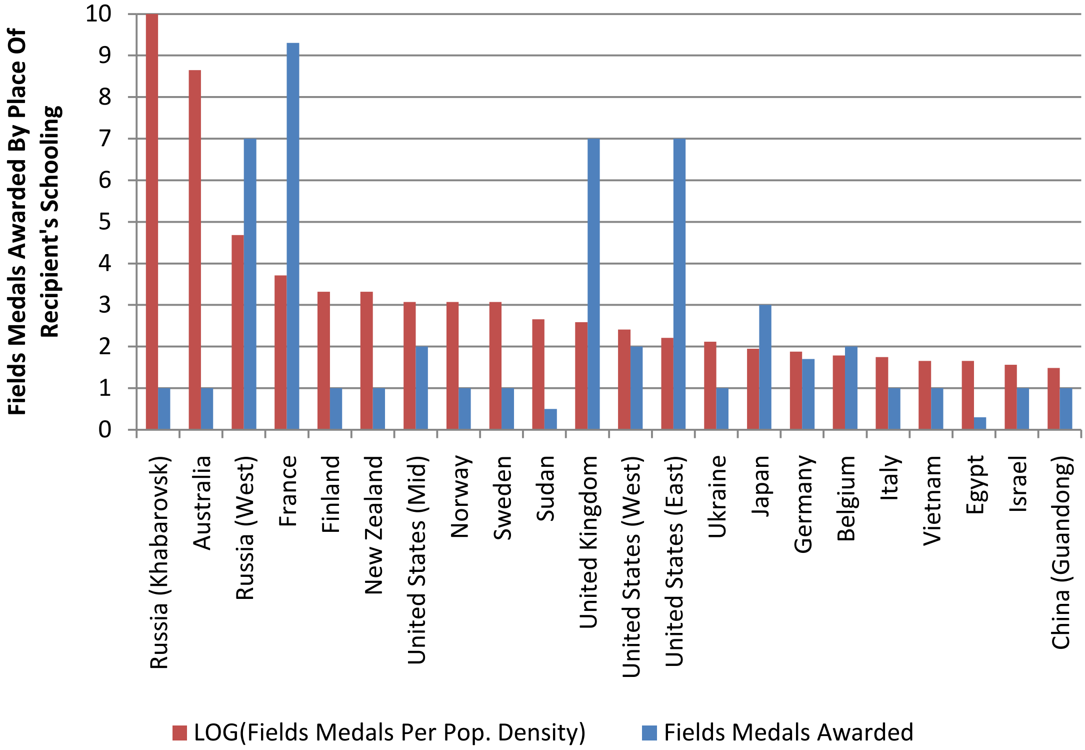

Figure 1: Number of Fields Medals Awarded By Place Of Recipient's Schooling[4]

Note the effect of the extreme emptiness of Eastern Russia and Australia on the adjusted scores, while Russia and France pull far ahead of the United Kingdom and United States. Also, note that Western Russia – when viewed as a map of European population densities (see Appendix B) – is contiguous with Europe, especially around its old capital

[1] To a statistically significant degree.

[2] Better known as the Fields Medal; its recipients are chosen by the International Mathematical Union for having significantly advanced the state of the art in mathematics but with the major proviso that the recipient must be under the age of forty. Despite its low cash prize, this is generally considered the highest honour that a mathematician can receive.

[3] Note that I used present day population densities, **not** those at the time of birth of the medal winner. Given the crudeness of the adjustment it probably doesn't hugely matter (though I have assumed rather than checked this).

[4] Note that the LOG(Fields Medals Per Pop. Density) has been scaled for clarity of display purposes such that the first item equals ten.

St. Petersburg, so I will henceforth call it "European Russia". Just to make the geographical relationship with Fields medals as presented in Figure 1 clear, this is the same population density weighted data classed by macro-geographical region in Figure 2:

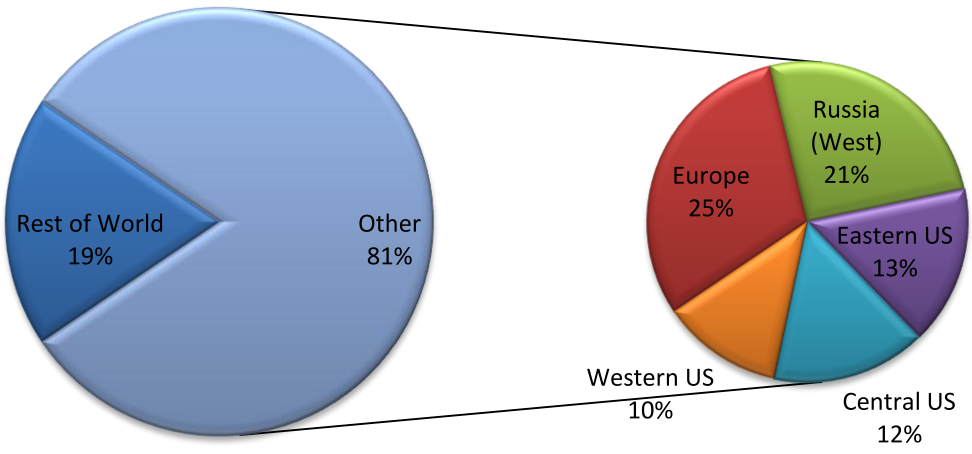

Figure 2: Fields Medals Awarded Classed By Macro-Regionality (with breakout adjusted for population density)

Interestingly, the ratios of total medals awarded, when adjusted for population density, is surprisingly uniform. However when looking more closely at the data (and while bearing in mind that there is a lag of approximately 35.5 years between a recipient's birth and receiving their award), it becomes clear that despite the United States' global pre-eminence since the 1950s, its receipt of Fields Medals went from very few to a clear peak around 1978 before rapidly dropping off (as shown by Figure 3). 1978 minus 35.5±1.2@99% equals 1941-1943 which surely is not a coincidence[5], but I have insufficient biographical data on the recipients to say more. Since 1987 it has received just two medals compared to eight by Europe and six by European Russia. This would suggest that something else is going on other than plain economic or social stability effects – there appears to be something special about Europe and mathematics.

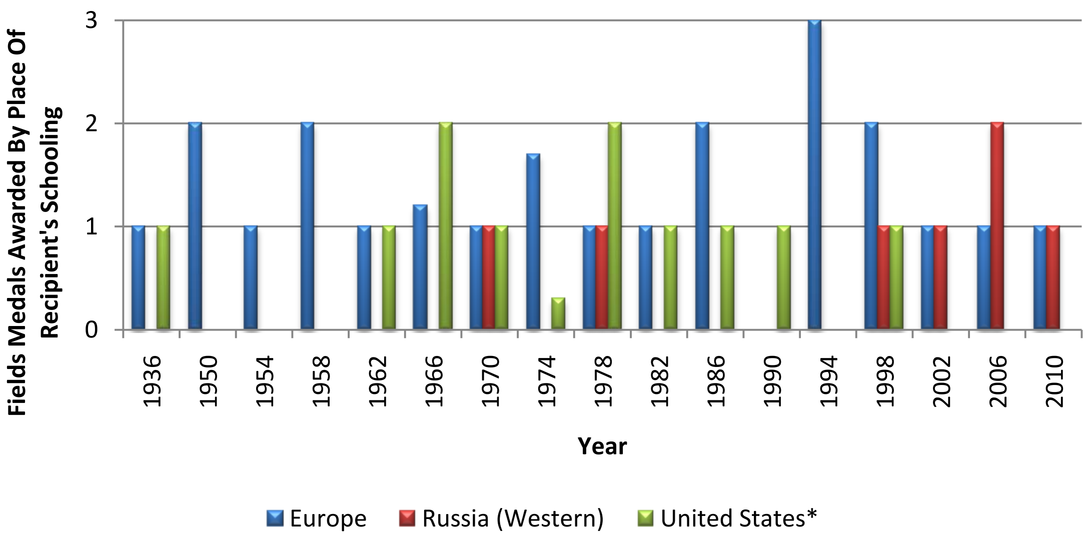

Figure 3: Fields Medals Awarded By Year

[5] The confidence interval at 99% is ±1.2 years. The coincidence refers to this period being the start of World War II – whether it was Europeans moving to the US in anticipation of the war, or that the parents of those of high calibre ended up encouraging their children into mathematics, or something else, I cannot say with the data I have.

Hypothesis: *is there something immanent to European patterns of thought and/or its structure of society which especially gives forth to advancing the cutting edge of mathematics?*

Research Approaches

This is a highly interesting research question, and one would have thought that it would have already been researched given how governments supposedly value the knowledge economy and its clusters of excellence. However, I have found very little research on this topic at all in the literature available to me – in fact, no one seems to even be asking the question regarding mathematics which is quite unlike the case with information technology or biotechnology[6].

Firstly, there is much which could be done statistically in drawing together multiple datasets to infer average regional social conditions during the birth and schooling of the recipients, and to improve the quality and resolution of the data presented above in order to greatly structure, narrow down and focus the scope of subsequent enquiries ("progressive focusing", Parlett, Hamilton, & Tawney (1976); Miles & Huberman (1984)). However, ultimately, due to its qualitative, contextual and trans-organisational social nature (Cohen, Manion, & Morrison, 2007, p. 170), the hypothesis is very much an *ethnographic* question and it is upon this I shall focus.

Ethnography seeks to gather empirical data on a human population through participant interaction and observation, and to construct an understanding of its phenomena (Malinowski, 1922). This means the holistic analysis of proactively acquired data (e.g. structured interviews, directed conversation, reflective practice) as well as passively acquired data with an attempt to determine what the participants think are the answers or main features to the hypothesis (Cohen, Manion, & Morrison, 2007, pp. 167-169). Unlike other kinds of research strategy, no definitive answer is typically expected: one moves from description and data to inference, explanation, suggestions of causation and theory generation (LeCompte, Preissle, Tesch, & Goetz, 1993, pp. 237-253).

Following the eleven stage planning process given on p. 171 of Cohen, Manion, & Morrison (2007), and for brevity in an ideal circumstance – i.e. if one had unlimited time, resources and money – one would begin Phase 1 by interviewing each winner of a Fields Medal or Abel Prize[7] as well as past and present members of the IMU selection committees ("finding informants"). One would interrogate them for their life history ("biographies") and those influences upon their life which they consider important (a "retrospective study"). One would then construct a sociograph (a map of the social links a person had and has) for each winner in an attempt to deconstruct the social structures and patterns which enabled each medal winner to make the breakthroughs that they did (i.e. determine the sociometry of the social space in order to determine points of overlap). These maps would surely yield nexus points of key people, places or institutions via triangulation ("corroboration of phenomenon from different sources"), so one would now expand the sampling to include these ("reputational case sampling").

After a sufficient number of iterations of this process, one should arrive at a reasonably accurate shortlist of places and institutions which historically have had a high probability of being involved with someone who advances the cutting edge of mathematics. Given one's unlimited resources, in Phase 2 one would now establish a programme of monitoring all those who flow through such places, following them up with periodic checks and possibly structured

[6] Searching Google Scholar for "Silicon Valley" returns many articles with citation counts in the thousands of which Saxenian (1996) is very famous in Management circles (Fallick, Fleischman, & Rebitzer (2006) is a good recent update of the research genre which has tried to focus on methods of replication). Similarly, "biotechnology cluster" returns plenty of well cited papers. Contrast this with searching for any of "math cluster", "mathematics cluster", "math center excellence", "math excellence" which returns nothing from management, business or economics – it does return a few items from education, but these are on teaching excellence which isn't on clusters of excellence. The closest I could find after twenty minutes of searching was a paper entitled "Factors contributing to the academic excellence of American Jewish and Asian students" by Fejgin (1995) which has nothing to do with development of cutting edge maths.

[7] A large cash prize of a deliberately similar amount to a Nobel Prize given to a mathematician for their life's work.

interviews to establish their career paths, who they are influencing and are being influenced by with periodic reconnection with those studied earlier in order to improve one's theory generation (LeCompte, Preissle, Tesch, & Goetz, 1993, pp. 237-253). After forty years or so one ought to start seeing some of the tracked individuals win a Fields Medal, thus allowing the reconsideration of all the data accumulated up until that point with a view to strengthening those methods which had proved best at identifying future winners ("reflective praxis", called "reflection-on-action" in Schön (1987)).

At this point one hopefully should be in a position to describe with some accuracy the recent state of development of advancers in cutting edge mathematics (a "grounded theory", Lincoln & Guba, 1985, p. 205). As shown in Figure 1 and Figure 3, the two long-lived historical clusters in Europe are in France and in Russia, however from an ethnographic perspective it is just as important to discover why top calibre people do **not** end up in positions where they can advance the cutting edge (LeCompte, Preissle, Tesch, & Goetz, 1993, pp. 250-251, 270). For example, in the US it could be that such people are funnelled into information technology and diverted away from mathematics – if this were the case it would invalidate the "patterns of thought" part of our hypothesis in favour of the "structure of society" part.

Problems with this research approach

One of the most persistent problems with any research involving people is gaining and retaining access to them. People can drop out of a study for many reasons ("mortality"), not least lack of free time or simply forgetting, and when your available sample pool is relatively small as it is here this could prove disastrous. On the other hand, ethnography has the least difficulty with this of all research sampling (Cohen, Manion, & Morrison, 2007, p. 175) and additionally, the small and collegiate pool of leading mathematicians has the advantage of each member being quite familiar with the affairs and backgrounds of the others.

There can be difficulties with gatekeepers such as secretaries or research heads who can dislike their charges being disturbed when they perceive they will gain nothing immediate from it (Flick, 2009, p. 57). A particular problem with Fields Medal winners is that they are high flyers who tend to job hop frequently because they are in such high demand (and can bore easily), often relocating themselves across continents[8] which can make maintaining relationships over time harder, not just for the researcher but also for the winner.

The question of whether there would be a halo effect is tough. For example, perhaps the winners are less important to advancing cutting edge mathematics than their (sometimes non-mathematical) associates[9]? A well designed research approach ought to be able to account for this however.

However, from my own personal experience, I believe that the winners themselves would be very interested in this research and would do what they could to help it along, not least because there are some very interesting maths involved which traverse a good chunk of present day cutting edge mathematical research (e.g. graph and colouring theory). Also, there is a robust historical tradition of mathematicians having studies performed on them on how and why they excel at mathematics e.g. Toulouse's study of Henri Poincaré (1910). For this reason I did not elect to

[8] This characteristic of large relocations is something I noticed when compiling the Fields Medal data. Interestingly, if you were schooled in France or Russia you almost are guaranteed to win your Fields Medal in the same country (i.e. those countries are highly sticky) whereas if you were schooled in other parts of the world then you are likely to win your Fields Medal whilst working in the United States (and if not, then after you win the Medal the recipient tends to relocate to the US within two years). This French and Russian property of stickiness to a cluster is likely highly significant in their self-propagation.

[9] There is form for this: it has been noted within the profession itself that major advances often come from pairs of mathematicians where one is creative but disorganised, whereas the other is rather more dull but disciplined. Often the latter, being the person to have laboured on the logical proof when writing the academic paper, receives the majority of the credit and perhaps rightly so. Still, the mathematics community has often noted itself that the major advance still needs the crazy guy with the whacky ideas, and interestingly often this person is very bad at mathematics (i.e. makes many mistakes).

perform a critical ethnography (one concerned with the exposure of oppression and inequality) as I do not perceive power relations to be dominant (Carspecken & Apple, 1996, p. 4 ff.).

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Appendix A: Data for Fields Medal Winners

Source for winners: http://en.wikipedia.org/wiki/Fields_medal. Birth years and schooling history retrieved from Wikipedia article for each medal winner.

Weights were assigned as follows: 0.5 for schooling 0-10 (primary), 0.3 for schooling 11-15 (early secondary), 0.2 for schooling 16-18 (late secondary).

Sources for population densities: http://en.wikipedia.org/wiki/List_of_U.S._states_by_population_density, http://en.wikipedia.org/wiki/European_Union_statistics, http://en.wikipedia.org/wiki/European_Russia, http://en.wikipedia.org/wiki/List_of_sovereign_states_and_dependent_territories_by_population_density.

Year	Name	Birth year	Age	Weight	School Nationality	Latitude	Longitude	Population Density (people/km^2)	Adj. Weight
1936	Lars Valerian Ahlfors	1907	29	1	Finland	60.169812	24.93824	16	62.50
1936	Jesse Douglas	1897	39	1	United States (New York)	40.058324	-74.405661	159.8	6.26
1950	Laurent Schwartz	1915	35	1	France	48.856667	2.350987	111	9.01
1950	Atle Selberg	1917	33	1	Norway	59.912726	10.746092	20	50.00
1954	Kunihiko Kodaira	1915	39	1	Japan	35.689488	139.691706	336	2.98
1954	Jean-Pierre Serre	1926	28	1	France	48.856667	2.350987	111	9.01
1958	Klaus Roth	1925	33	1	United Kingdom	51.500152	-0.126236	246	4.07
1958	René Thom	1923	35	1	France	48.856667	2.350987	111	9.01
1962	Lars Hörmander	1931	31	1	Sweden	59.332788	18.064488	20	50.00
1962	John Milnor	1931	31	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1966	Paul Cohen	1934	32	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1966	Alexander Grothendieck	1928	38	0.5	Germany	52.523405	13.4114	231	2.16
				0.5	France	48.856667	2.350987	111	4.50
1966	Michael Atiyah	1929	37	0.5	Sudan	15.550101	32.532241	16	31.25
				0.3	Egypt	30.064742	31.249509	79	3.80
				0.2	United Kingdom	51.500152	-0.126236	246	0.81
1966	Stephen Smale	1930	36	1	United States (Michigan)	44.314844	-85.602364	67.77	14.76
1970	Alan Baker	1939	31	1	United Kingdom	51.500152	-0.126236	246	4.07
1970	Heisuke Hironaka	1931	39	1	Japan	35.689488	139.691706	336	2.98
1970	Sergei Novikov	1938	32	1	Russia (Western)	55.755786	37.617633	50	20.00
1970	John G. Thompson	1932	38	1	United States (Kansas)	39.011902	-98.484246	13.3	75.19
1974	Enrico Bombieri	1940	34	1	Italy	41.895466	12.482324	195	5.13
1974	David Mumford	1937	37	0.7	United Kingdom	51.500152	-0.126236	246	2.85
				0.3	United States	40.058324	-74.405661	159.8	1.88
1978	Pierre Deligne	1944	34	1	Belgium	50.8503	4.35171	344	2.91
1978	Charles Fefferman	1949	29	1	United States (Maryland)	39.045755	-76.641271	225.1	4.44

1978	Grigory Margulis	1946	32	1	Russia (Western)	55.755786	37.617633	50	20.00
1978	Daniel Quillen	1940	38	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1982	Alain Connes	1947	35	1	France	48.856667	2.350987	111	9.01
1982	William Thurston	1946	36	1	United States (Washington D.C.)	39.045755	-76.641271	159.8	6.26
1982	Shing-Tung Yau	1949	33	1	China (Guandong)	6.742645	13.952637	486	2.06
1986	Simon Donaldson	1957	29	1	United Kingdom	51.500152	-0.126236	246	4.07
1986	Gerd Faltings	1954	32	1	Germany	52.523405	13.4114	231	4.33
1986	Michael Freedman	1951	35	1	United States (California)	36.778261	-119.417932	91.5	10.93
1990	Vladimir Drinfel'd	1954	36	1	Ukraine	4.659589	13.952637	78	12.82
1990	Vaughan Jones	1952	38	1	New Zealand	-36.84846	174.763332	16	62.50
1990	Shigefumi Mori	1951	39	1	Japan	35.689488	139.691706	336	2.98
1990	Edward Witten	1951	39	1	United States (Maryland)	39.045755	-76.641271	225.1	4.44
1994	Jean Bourgain	1954	40	1	Belgium	50.8503	4.35171	344	2.91
1994	Pierre-Louis Lions	1956	38	1	France	48.856667	2.350987	111	9.01
1994	Jean-Christophe Yoccoz	1957	37	1	France	48.856667	2.350987	111	9.01
1994	Efim Zelmanov	1955	39	1	Russia (Khabarovsk)	77.307784	223.242188	2.5	400.00
1998	Richard Borcherds	1959	39	1	United Kingdom	51.500152	-0.126236	246	4.07
1998	Timothy Gowers	1963	35	1	United Kingdom	51.500152	-0.126236	246	4.07
1998	Maxim Kontsevich	1964	34	1	Russia (Western)	55.755786	37.617633	50	20.00
1998	Curtis T. McMullen	1958	40	1	United States (California)	36.778261	-119.417932	91.5	10.93
2002	Laurent Lafforgue	1966	36	1	France	48.856667	2.350987	111	9.01
2002	Vladimir Voevodsky	1966	36	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Andrei Okounkov	1969	37	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Grigori Perelman	1966	40	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Terence Tao	1975	31	1	Australia	-33.859972	151.211111	2.9	344.83
2006	Wendelin Werner	1968	38	0.2	Germany	52.523405	13.4114	231	0.87
				0.8	France	48.856667	2.350987	111	7.21
2010	Elon Lindenstrauss	1970	40	1	Israel	32.059925	34.785126	365	2.74
2010	Ngô Bảo Châu	1972	38	1	Vietnam	21.033333	105.85	259	3.86
2010	Stanislav Smirnov	1970	40	1	Russia (Western)	55.755786	37.617633	50	20.00
2010	Cédric Villani	1973	37	1	France	48.856667	2.350987	111	9.01

Appendix B: World Population Density

Source: http://commons.wikimedia.org/wiki/File:World_population_density_1994.png