The Changing Demographics of the Global Academic Workforce: Aging, Expansion, and Sex Differences in Science Across the OECD Countries, 1990-2020

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INSTITUTE FOR ADVANCED STUDIES IN SOCIAL SCIENCES AND HUMANITIES

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1. Introduction – Structure of This Speech

- The global academic workforce **leaving digital traces in their publications.**
  - From *publications* to *scientists*;
  - Scientists and *structured* Big Data.
- The **focus,** an **exploratory approach**.
- **Why age matters in science studies.**
  - Academic career research;
  - Academic cohorts;
  - Productivity and age;
  - *Academic* age and *biological* age.
- **Data, procedures, limitations & methodological choices**.
- **Results.**
  - Changing median age over time (1990-2020);
  - Snapshots 2020 vs. longitudinal data 1990-2020;
  - Disciplines, (countries) & gender;
  - Male to Female Ratio (MFR);
  - Zooming in on young scientists; zooming in on old scientists.
- **Final words** and **implications.**

2. The Global Academic Workforce Leaving Digital Traces…

- **Academics leave traces in their printed publications.**
- We can examine them. And **combine** them with biographical & administrative & related data, national & international. **Record linkage!**
- The academic workforce can be traced using **temporal, topical, geographical, and network analyses.**
- **Tracing academics & their careers:**
  - **over the years (longitudinal approach)** vs. **in points in time;**
  - **across countries (institutions; cities); as teams & as individuals;**
  - **as men & women; as juniors & seniors;**
  - across academic **disciplines.**
- **Remarkable level of detail and scale available: measuring the academic workforce with ever more precision possible!**
- **Structured (Big)** data preferred (Scopus raw data, WoS Core Collectio raw data, national registries of scientists, national CRIS systems data)
- We can study **huge** amounts of data **to discover patterns in how science operates - that would otherwise be just imperceptible.**

3. From *Publications* to *Individual Scientists* as a Unit of Analysis

- A major transition: from raw global metadata on **publications** (bibliometrics) to raw global metadata on individual **scientists** (global academic profession studies).
- **From millions of *publications* to millions or hundreds of thousands of *scientists* (and their characteristics).**
- The **individual scientist** as the **unit of analysis**.
- **Here: changing demographics of the global scientific workforce.**

4. The Academic Workforce & Structured Big Data: What to Explore?

- **What can be explored today at the scientist's level, at a scale unimaginable a decade ago?**
- **Research productivity & publication types** (e.g. article) and journal profile (e.g. top journals).
- **Collaboration & its major types** (international, national, institutional, solo; also same-sex, mixed-sex, solo).
- **Citations representing the influence** on the global academic community, or scholarly impact.
- **Academic mobility & its major types** (national and cross-national; also cross-sectoral: academia-industry etc.).
- **Research funding** (Acknowledgement sections in papers).
- **Academic credits, authorship** ("corresponding author" etc)
- Basically - *all* scholarly activities recorded in **publications metadata** (or in **administrative & biographical datasets**).
- **Studied by gender – and by age (academic seniority)!**
- **Studied both *statically* (e.g. 2020) and *dynamically,* over time (e.g. 2000-2020).**
- **Here: only demograhics (age & gender).**

5. Introductory Remarks: The Focus

- **The changing age profile of the global scientific workforce (38 OECD countries)**.
- **Traditional** focus on the "**graying of the academic profession**" (or the "aging of the professoriate"). Here: **scientists from all sectors**.
- **Probably the first comprehensive research focused on changes over time (1990-2020), across 26 disciplines, age groups, and gender.**
- Focus on the **global** dimension **(not: comparative cross-national)**.
- The **individual scientist** in focus, then aggregations.
- Final **sample: 5 million scientists.**
- **A cross-sectional (2020)** and a **longitudinal (1990-2020)** approach.

6. Introductory Remarks: Exploratory Approach

- The popular assumption (untested): **the academic profession is getting older** (= having ever larger cohorts of older scientists).
- **Unclear whether this assumption is universally justified,** correct across disciplines, countries.
- **We explore:**
  - **(1) the what:** what can be known about the **demographics of the scientific workforce globally**,
  - (2) **the where:** where the potential **data can be located,** and
  - (3) **the how:** how the global aging can be adequately **measured**.

7. Introductory Remarks: Long Careers in Science

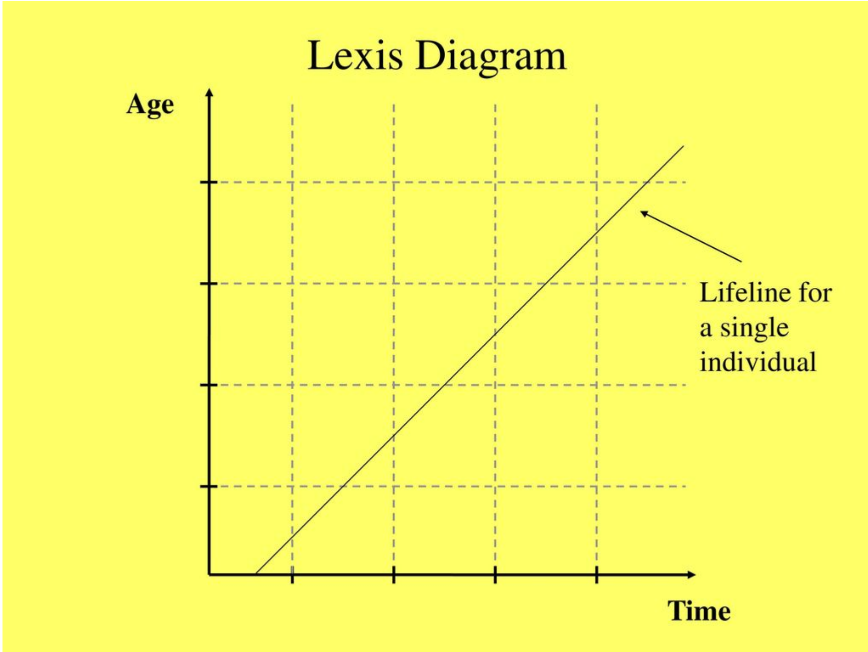
- **No comprehensive global account, past or current** (national-level studies e.g. Gu & Blackmore 2017 Australia; Savage & Olejniczak 2021 USA).
- **A major obstacle in global studies? Access to reliable data pertaining to scientists' age.**
- **We use academic age as a valid proxy of biological age**
  - Kwiek and Roszka, ”Academic vs. biological age in research on academic careers: a large-scale study with implications for scientifically developing systems, *Scientometrics,* 2022, a **whole national system**, 24 disciplines, N=21,000.
- **Careers in science are generally long**: o**nly a limited number stay on** in the science sector for decades; **a long period of training, followed by a long professional career ladder**.
- Our sample: all scientists who appeared **at least three times** in publications in **three different years** in the past three decades (incl. **once** in 2010-2020).

8. Age Matters: Age in Academic Career Research

- **Biological age has been an important sociodemographic factor in sociological and bibliometric studies of academic careers for more than half a century**
  - (Lehman 1953; Zuckerman & Merton 1973; Pelz & Andrews 1976; Kyvik 1990; Levin & Stephan 1991; Kyvik & Olsen 2008).
- **Six different hypotheses were suggested** (Kyvik & Olsen 2008: 441–442) to explain **reduced research performance of universities** with an **aging academic staff:**
  - **Three** hypotheses related to a **decline in productivity** (“the utility maximizing hypothesis”, “the seniority burden hypothesis”, and “the cumulative disadvantage hypothesis”), and:
  - **Three** hypotheses related to a **decline in creativity of research** (“the age decrement hypothesis”, “the obsolescence hypothesis”, and “the intellectual deadlock hypothesis”).

9. Age Matters: Cohorts & Academic Career Research

- **Some cohorts may be more research productive than others due to different competition levels in hiring** in their early years (and also due to different research funding opportunities at that time).
- **Scientists hired under different conditions** may **stay on in academia for decades**.
- **Academic cohorts may be more or less productive from the moment they have entered the academic profession.**
- Some cohorts may have always been characterized by low (or by high) productivity (Kyvik 1990).
- The academic careers of scientists are affected by **events that occur at the time of obtaining a PhD**: in other words, "**cohort matters**" (Stephan 2012).



10. Age Matters: Productivity in Academic Career Research (Country-Level Examples)

- **Norway** (N=11,500 scientists): **productivity increases with age, reaching a peak late in careers and declining thereafter** (Aksnes et al. 2011a).
- **Canada (Quebec)** (N=6,388 university professors) (Gingras et al. 2008): **productivity first increases sharply with age, and then increases at a slower pace at about 40**; it **reaches its peak at about 50**.
- **Spain**: Costas and Bordons (2010): **top researchers are younger than the other two research productivity classes** (low and medium classes).
- **Italy**: Abramo et al. (2016): **as age increases, there is a high decline in full professors' productivity**. However, **professors appointed at a young age are more likely to maintain or increase their productivity** than colleagues promoted at a later age.

11. Academic Age as a Proxy of Biological Age Thus Far

- **Biological age is generally unavailable for large-scale studies.**
- **However, the academic age (or the time elapsed from the first publication) is a good proxy for the biological age** (Robinson-Garcia et al. 2020; Milojević 2012; Nane et al. 2017).
- **The date of first publication in Scopus or Web of Science can be calculated and used** for research purposes for all scientists – at the level of institutions, cities, disciplines, journals, and countries.
- **Academic age** has been **rarely used** in research thus far: a **limited access to first publication data**.
- The **date of the first publication** was applied **less than 20 times.**
    - see, e.g. Milojević 2012; Radicchi & Castellano 2013; Nane et al. 2017; Robinson-Garcia et al. 2020; Aref et al. 2019; Simoes & Crespo 2020; Petersen 2015.
- Biological age has been studied through **two major proxies**:
    - (1) the **date of first publication** and
    - (2) the **date of receiving a PhD**.

12. Methodological Limitations & Biases

- The **data set bias** (Scopus or Web of Science come with their own linguistic, geographical, and disciplinary biases).
- **However, other data sets than global bibliometric sources cannot be easily used in *global* studies (beyond single institutions or single countries).**
- **Gender differences cannot be easily examined** without massive gender ascription to publication authors – done in big data sets.
  - Different probability levels in ascribing individual **names to gender** & individual **author IDs to real scientists**. **E.g. high percentages in Poland & Russia vs. low in China)**.
- Globally, **younger cohorts are generally more present in global data sets** than older cohorts, with implications for age structure biases.
- We study here **only *publishing* scientists (no other data sources available** for study **at a global level** with individual scientists as units of analysis).

13. General Approach

- We use **three dimensions to study demographics within 26 disciplines**:
  - The **current median age** (a snapshot, as of 2020) across disciplines;
  - The **shift in the median age over time** (years 1990-2020) across disciplines; and
  - The overall **number of scientists** & their **age distribution** across disciplines: in 2020 and in the 1990-2020 period.
- **Some disciplines were younger (and others were older) at the starting point of 1990.**
- And some disciplines **have larger increases in the median age** (and others have smaller increases) in 1990-2020.

14. Data and Procedures

- **The only large-scale data about the average age of the scientific workforce available today are aggregated**, cover the European Union only, and come from the Eurostat (Eurostat 2022, under the **Human Resources in Science and Technology HRSC section**).
- However, **the Eurostat dataset does not offer the microdata** at the level of individual scientists.
- **ICSR Lab // Kristy James: research metadata that power Elsevier's Scopus, a powerful computational platform.**
- **Lukasz Szymula, MA, doctoral student, ongoing research with MK (using ICSR Lab) on aging of the academic profession.**
- Major steps:
  - Step 1: List all **publications** by each author (lifetime)
  - Step 2: Determine the year of the author's **first publication** (any type)
  - Step 3: Obtain the **gender** of the researcher (0.85 probability)
  - Step 4: Calculate the **age** of the researcher at the time of publication.
  - Step 5: Determine the **discipline** of the publication (the mode of all cited references in all publications, lifetime, articles only)
  - Step 6: Include **filtering 1**: year 1990-2020
  - Step 7: Include **filtering 2**: 38 OECD countries
  - Step 8: Obtaining the results
    - After restriction on OECD countries: 11,074,331 scientists
    - **After cap on minimum 3 years of activity: 4.9 MIL scientists**
- All calculations performed on our final sample: **N = 4.9 MIL scientists**

ICSR Lab

Access rich datasets on a powerful computational platform, free for research use

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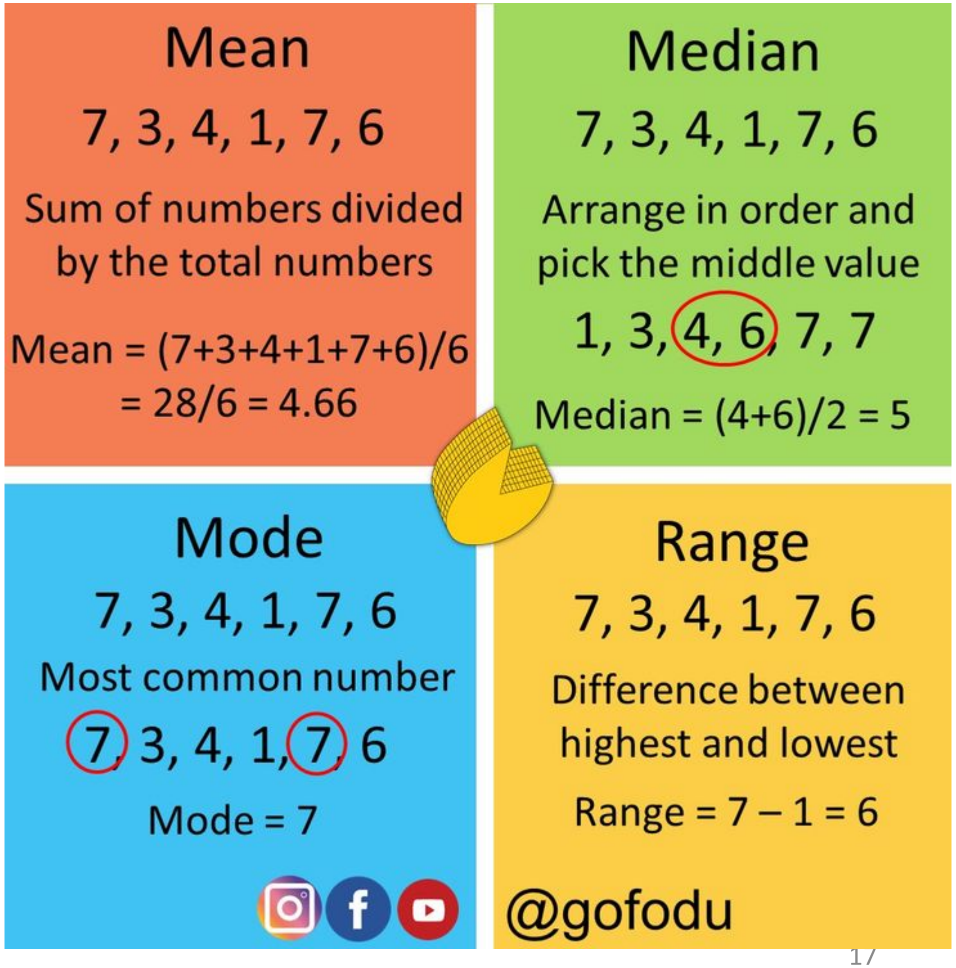
15. Methodological Choices

- **Only researchers with uniquely defined attributes** (gender, academic age, one scientific discipline & one country of affiliation).
- **Years of scientific activity confirmed by publications**.
  - Initial analyses (a sample of **33 MIL scientists) choosing 1 year** of scientific activity as the minimum criterion.
  - Final approach used: a smaller sample (5 MIL) resulting from **a 3-year minimum period of publication activity (in the 30 years studied,** including **at least one year in the last decade**).
- Admittedly, **the second approach reduced our sample.**
- **But our sample includes scientists with a more stable presence in science - and excludes episodic scientists (i.e. those who appeared in Scopus only once).**

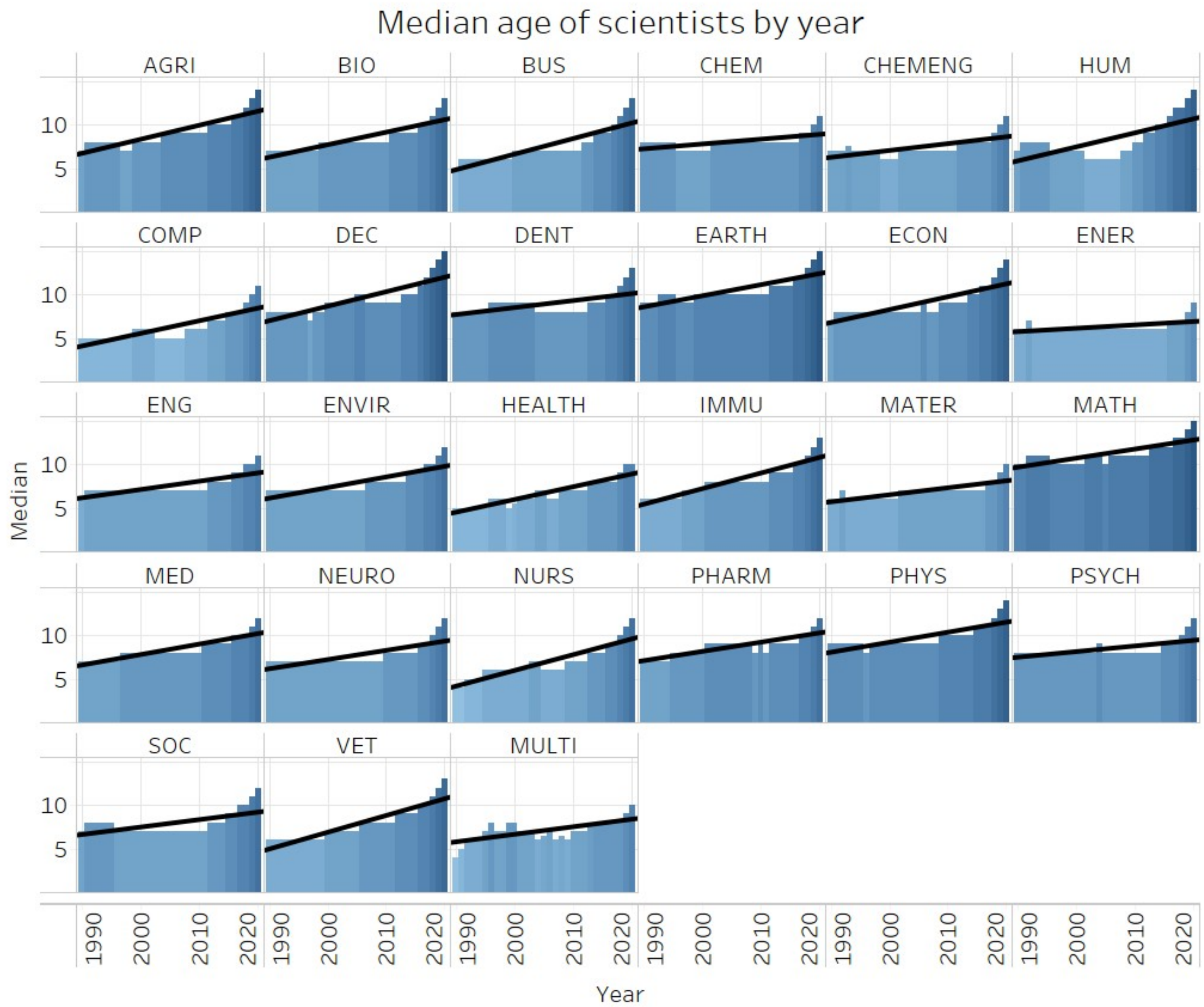
16. The Changing Median Age: a Single Measure

- From the **three measures of central value (the mean, the mode, and the median),** we have chosen the median.
- The **median** seems to work best for our research purposes.
- **The median age is a useful summary measure (unlike the mean, unaffected by extreme values).**
- The main **disadvantage:** the median age **reveals nothing about the details of the age distribution**: “contrasting age structures sometimes have the same median age” (Rowland 2003: 94).
- Therefore we also refer to **age pyramids**, and specifically to **the distribution of the youngest and the oldest cohorts**.

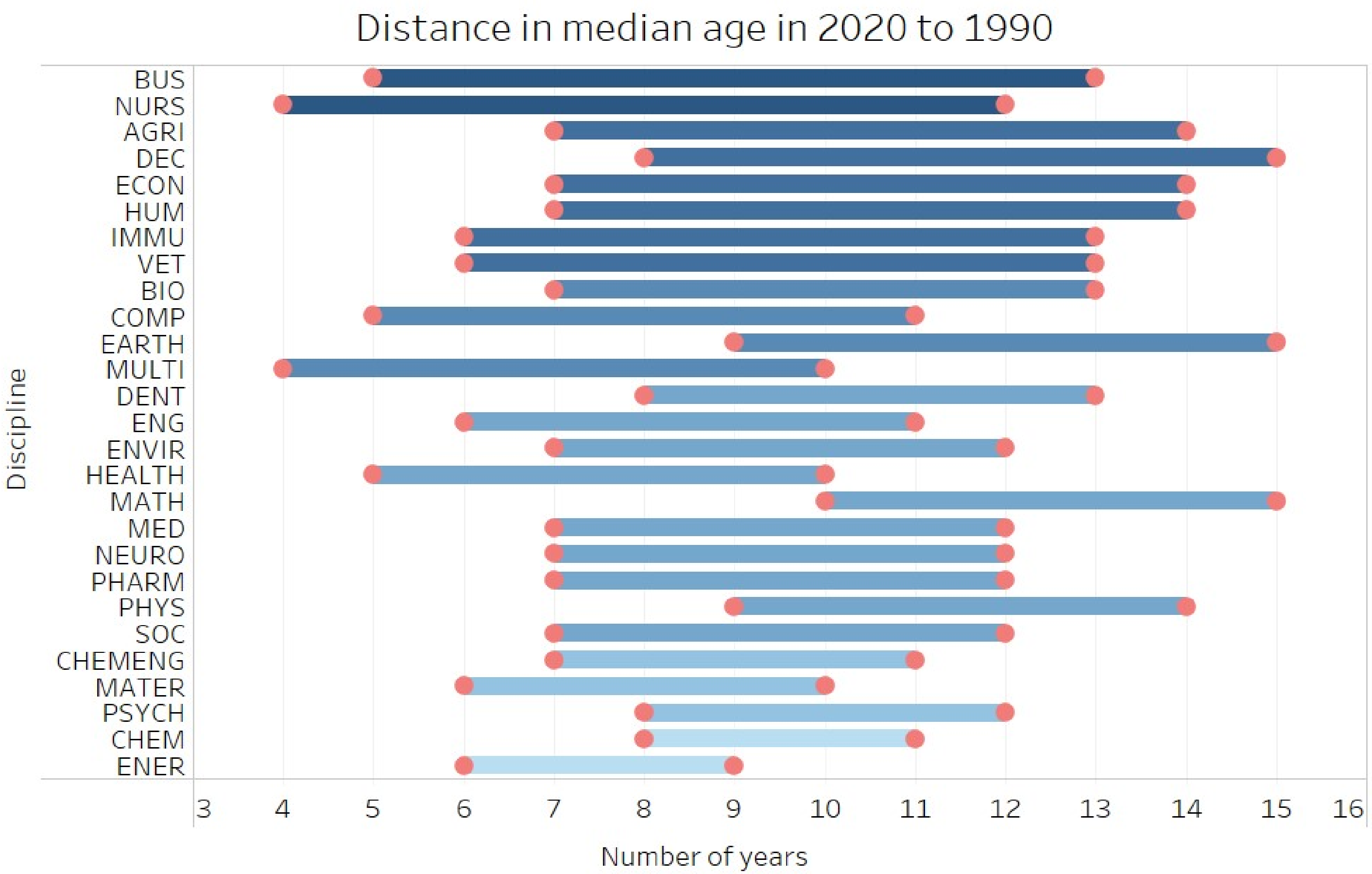



RESULTS

18. The Median Age of the Scientific Workforce, by Discipline, 1990-2020

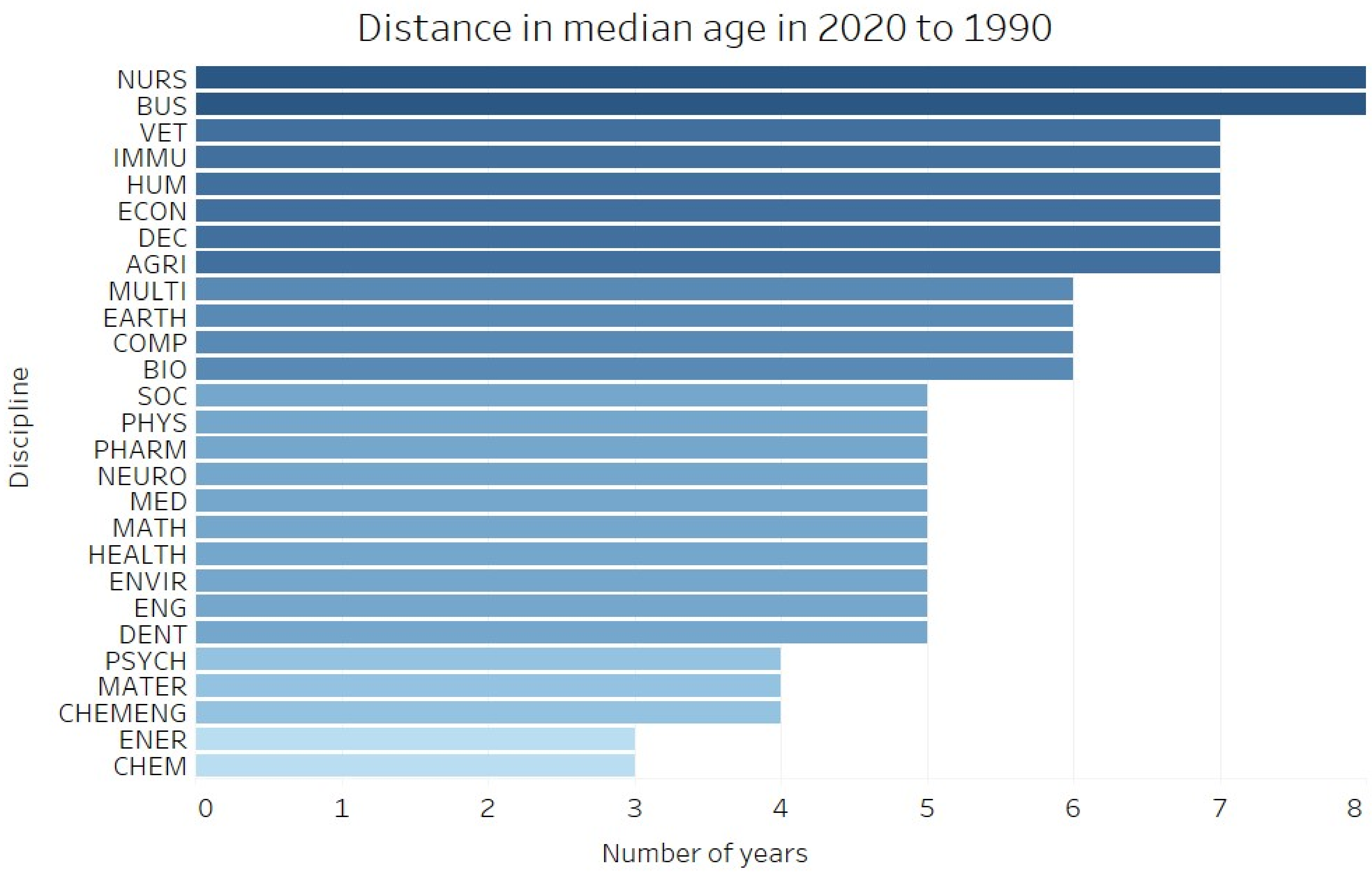


19. The Change in the Median Age between 1990 and 2020, by Discipline (the Difference between 1990 and 2020 Shown in Years)



- **Red points. Every discipline: the median age in 1990 (a starting point) and in 2020 (a point of departure).**
- Some disciplines **increased their median age much more than others**.
- Some disciplines had already higher median age at starting points.
- **The three largest disciplines (MED, BIO, ENG) noted increase from 6-7 years** to **11-12 years**.

20. The Change in the Median Age between 1990 and 2020, by Discipline (Difference Shown in Years)



- **Different speed of aging.**
- **The largest increase:** BUS business and economics (and small NURS): 8 years increase.
- **The smallest increase**: ENER and CHEM (3 years).
- **Consistently with popular beliefs, the median age of scholars active in BUS, HUM, and ECON is indeed increasing much faster than in other non-STEM disciplines (7-8 years).**
- **The largest discipline (MED)** is in the middle of aging disciplines (5 years)

21. The Trend: the Median Age in 1990-2020

- We have studied the trend of the median age in 1990-2020. **The analysis uses a linear trend in the form of y = ax+b** (in the most simplified form),
  - where ***a*** is a directional coefficient (indicating the average change from year to year),
- **In all disciplines, the median age increases from year to year - that is: all disciplines are aging. However, the speed of aging varies.**
- **Six disciplines are aging faster than 0.15 years per year** e.g. VET 0.19 (95% confidence interval 0.16-0.22) and IMMU 0.18 (0.15-0.21).
- **For 10 disciplines the directional coefficient *a* is 0.1-0.15** e.g. ECON 0.15 (0.11-0.19) and COMP 0.14 (0.11-018).
- **The slowest aging disciplines for which the directional coefficient *a* is less than 0.1** are ENG, SOC, DENT, MATER, CHEMENG, PSYCH and CHEM; the slowest aging is ENER (by 0.04 years per year).
- **The median age increases year-to-year on average by the value of the coefficient *a*.**

22. The Median Age: Trend Statistics

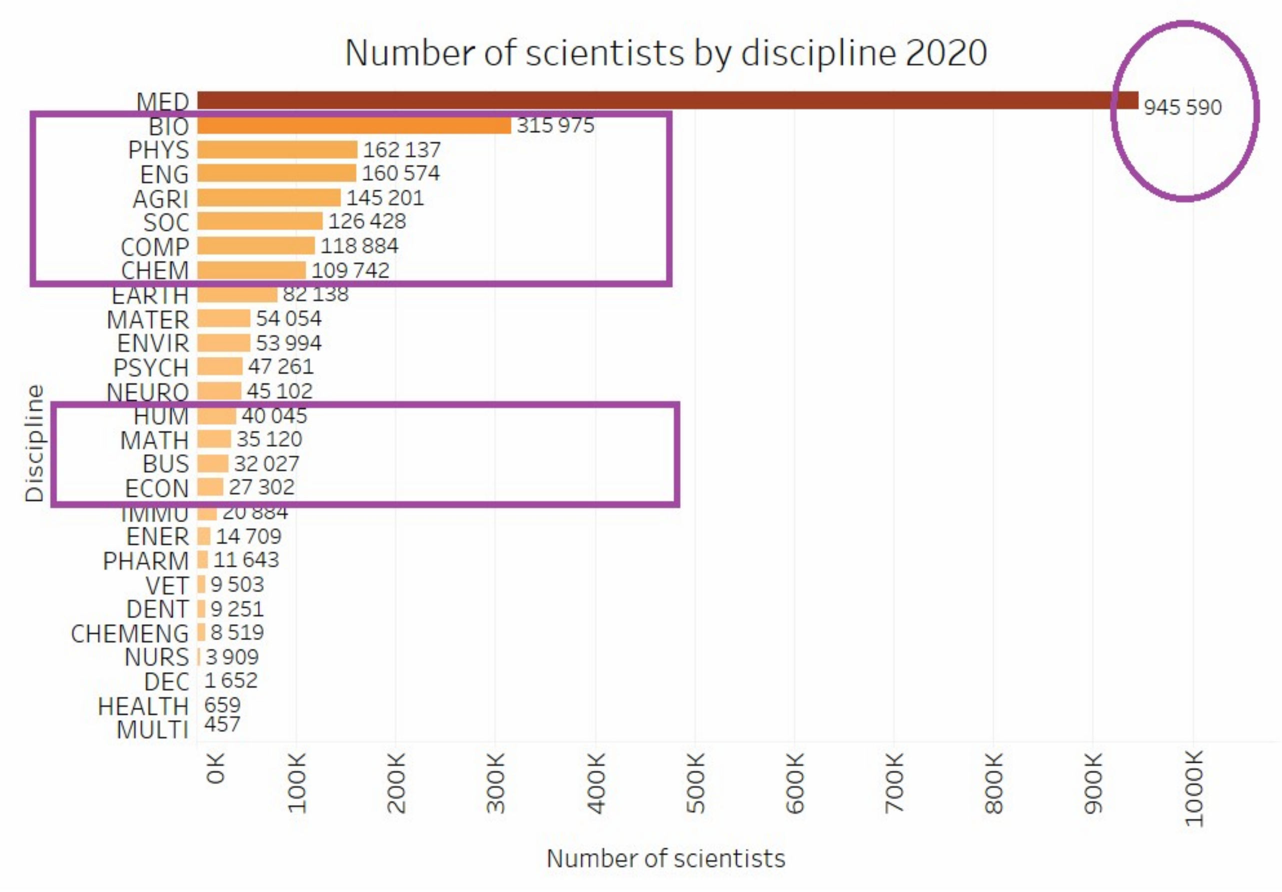
Table 1. Median age trends statistics

Academic disciplines	Coefficients - a						Coefficients - b				Quality measures	
	Value	StdErr	t-value	p-value	DG	GG	Value	StdErr	t-value	p-value	R-Squared:	Standard error:
AGRI	0.161	0.017	9.526	< 0.0001	0.126	0.195	6.683	0.295	22.659	< 0.0001	0.758	0.841
BIO	0.143	0.015	9.440	< 0.0001	0.112	0.174	6.240	0.265	23.562	< 0.0001	0.754	0.755
BUS	0.179	0.019	9.287	< 0.0001	0.139	0.218	4.804	0.336	14.302	< 0.0001	0.748	0.958
CHEM	0.055	0.014	4.047	0.000	0.027	0.083	7.204	0.238	30.219	< 0.0001	0.361	0.680
CHEMENG	0.078	0.016	4.940	< 0.0001	0.046	0.111	6.230	0.277	22.527	< 0.0001	0.457	0.789
COMP	0.145	0.019	7.695	< 0.0001	0.106	0.183	4.054	0.329	12.341	< 0.0001	0.671	0.937
DENT	0.080	0.020	3.961	0.000	0.039	0.122	7.667	0.354	21.672	< 0.0001	0.351	1.009
EARTH	0.127	0.017	7.385	< 0.0001	0.092	0.163	8.540	0.301	28.341	< 0.0001	0.653	0.859
ECON	0.147	0.019	7.561	< 0.0001	0.107	0.187	6.760	0.340	19.887	< 0.0001	0.663	0.969
ENER	0.039	0.012	3.178	0.004	0.014	0.064	5.710	0.213	26.840	< 0.0001	0.258	0.607
ENG	0.095	0.015	6.542	< 0.0001	0.065	0.125	6.121	0.254	24.093	< 0.0001	0.596	0.724
ENVIR	0.121	0.015	8.093	< 0.0001	0.091	0.152	6.083	0.262	23.223	< 0.0001	0.693	0.747
HUM	0.161	0.033	4.847	< 0.0001	0.093	0.229	5.813	0.580	10.028	< 0.0001	0.448	1.653
IMMU	0.179	0.014	12.661	< 0.0001	0.150	0.208	5.379	0.247	21.782	< 0.0001	0.847	0.704
MATER	0.080	0.012	6.976	< 0.0001	0.057	0.104	5.667	0.201	28.212	< 0.0001	0.627	0.573
MATH	0.104	0.016	6.576	< 0.0001	0.072	0.136	9.633	0.276	34.868	< 0.0001	0.599	0.788
MED	0.120	0.011	10.573	< 0.0001	0.097	0.143	6.552	0.198	33.014	< 0.0001	0.794	0.566
NEURO	0.105	0.017	6.171	< 0.0001	0.070	0.140	6.131	0.298	20.585	< 0.0001	0.568	0.849
NURS	0.181	0.017	10.506	< 0.0001	0.145	0.216	4.129	0.300	13.750	< 0.0001	0.792	0.856
PHARM	0.106	0.012	8.496	< 0.0001	0.081	0.132	7.054	0.218	32.360	< 0.0001	0.713	0.622
PHYS	0.115	0.016	6.970	< 0.0001	0.081	0.148	8.024	0.287	27.966	< 0.0001	0.626	0.818
PSYCH	0.065	0.015	4.169	0.000	0.033	0.096	7.452	0.270	27.570	< 0.0001	0.375	0.771
SOC	0.085	0.022	3.969	0.000	0.041	0.130	6.589	0.376	17.517	< 0.0001	0.352	1.073

23. Aging: Regression Models

- There is a **significant increasing trend in all disciplines.**
- **The quality of the resulting models varies**: the two models that best fit the empirical data have an R^2 of 0.85.
- The models do not tell us how much the academic staff in each discipline is aging, **but they do indicate that they are aging.**
- **The average R^2 coefficient is 0.61 (**at best an average fit).
- **The models are not suitable for prediction and only indicate the main direction of change and the speed of aging of the staff in each discipline.**
- An analysis of the confidence intervals of the directional coefficients indicates that **three rates of average annual aging can be distinguished:**
  - (1) 0.15-0.20; (2) 0.10-0.15; and (3) less than 0.10.
  - **The first group ages on average one year every 5-7 years, the second every 7-10 years, and the third every 10 years or more.**
  - **Slow aging - systematic aging in all areas.**
- **So: an evolution in science** in terms of the age of working scientists **rather than a revolution: the aging process is slow but inexorable**.

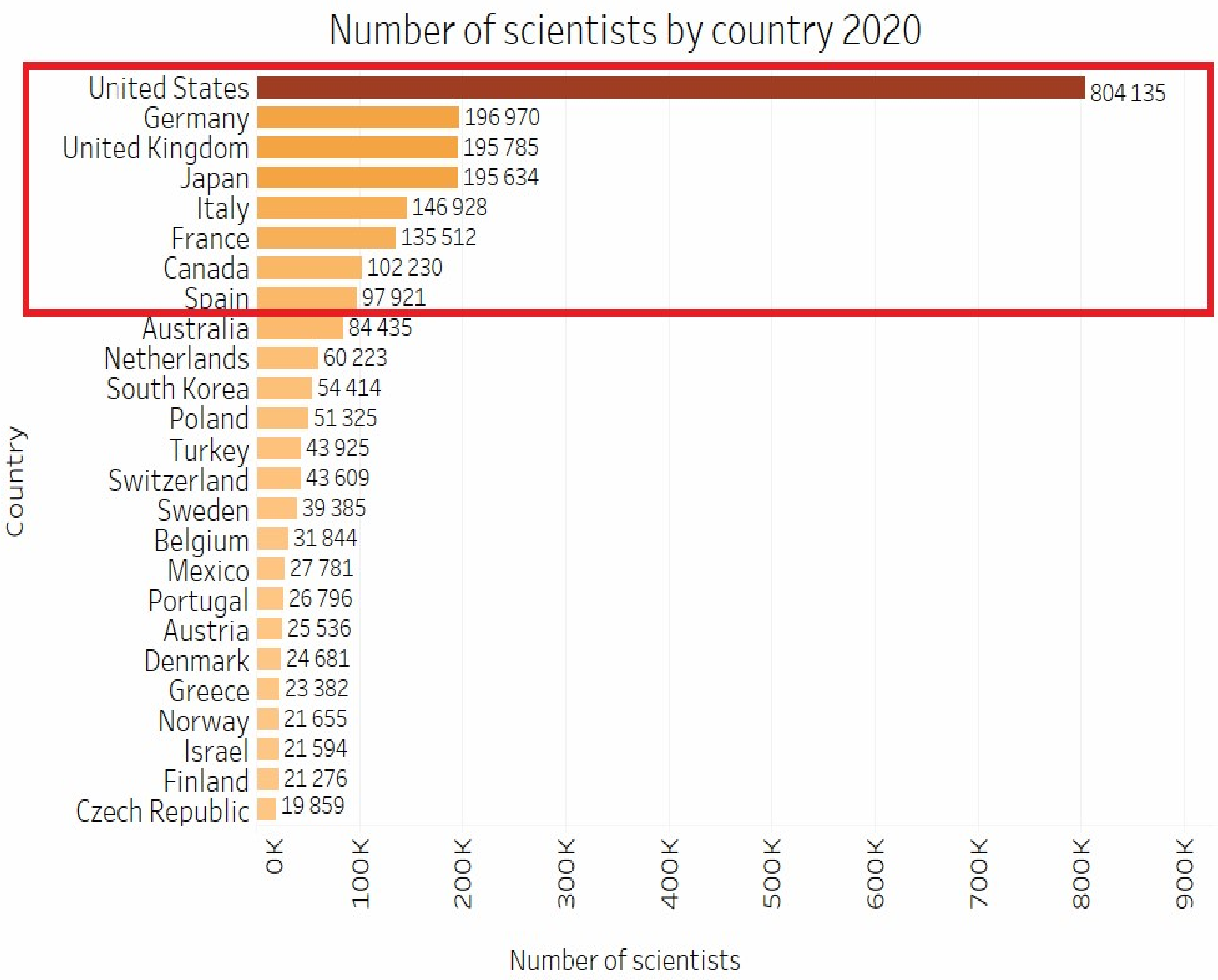
24. Snapshot 2020: the Total Number of Active Scientists, by Discipline



- The snapshot view of **where current research is located** and **how publishing scientists are distributed** among disciplines.
- **40% of the whole global scientific workforce is engaged in medical research!**
- In 2020 there were **950,000 scientists involved in medical research.**
- **The second discipline was biochemistry** with more than three times fewer publishing scientists (316,000 scientists), followed by **physics, engineering** (160,000), and **agriculture** (145,000).
- From among **non-STEM disciplines**, the largest is definitely **sociology (with 127,000);**
- All other non-STEM disciplines are much smaller in size, generally in the range of **30,000-50,000 scholars.**

25. Snapshot 2020: the Total Number of Active Scientists, by Country

- We are **not focused on publications and their numbers** (this type of data is easily available from bibliometric data sets).
- We are focused on individual **scientists**.
- **The absolute domination of the US research globally. 7 other major contributing countries to the global research enterprise.**
- **Only 8 (OECD) countries in the world had about 100,000 active scientists or more in 2020**.
- The **second group of countries included Australia, the Netherlands, South Korea, and Poland** with a number of scientists in the 50,000-100,000 range.
- The majority of OECD countries (23) had **no more than 30,000 publishing scientists in 2020.**



26. Men and Women Scientists: Disciplines (MFR)

- **We study sex differences using a male to female ratio (MFR): we divide the number of male scientists by the number of female scientists.**
- **MFR higher than 1 reflects a greater number of men in a discipline (or country).**
- **MFR lower than 1 reflects a greater number of women in a discipline (or country).**
- **The largest number and percentage of female scientists** are observed **in MED medical sciences**, followed by biochemistry, sociology, and agriculture.
- **Only four disciplines in which MFR is close to 1 or lower than 1:** SOC sociology and PSYCH psychology (and small IMMU immunology and VET veterinary).
- **The differences in the other non-STEM disciplines are substantial: in ECON economics, the FMR is 3.5** and in BUS business and economics and HUM humanities, 1.7.
- **SOC sociology: the number of men and women is almost equal** and PSYCH **psychology: a discipline in which women outnumber men**.

27. Men and Women Scientists: Disciplines and MFR

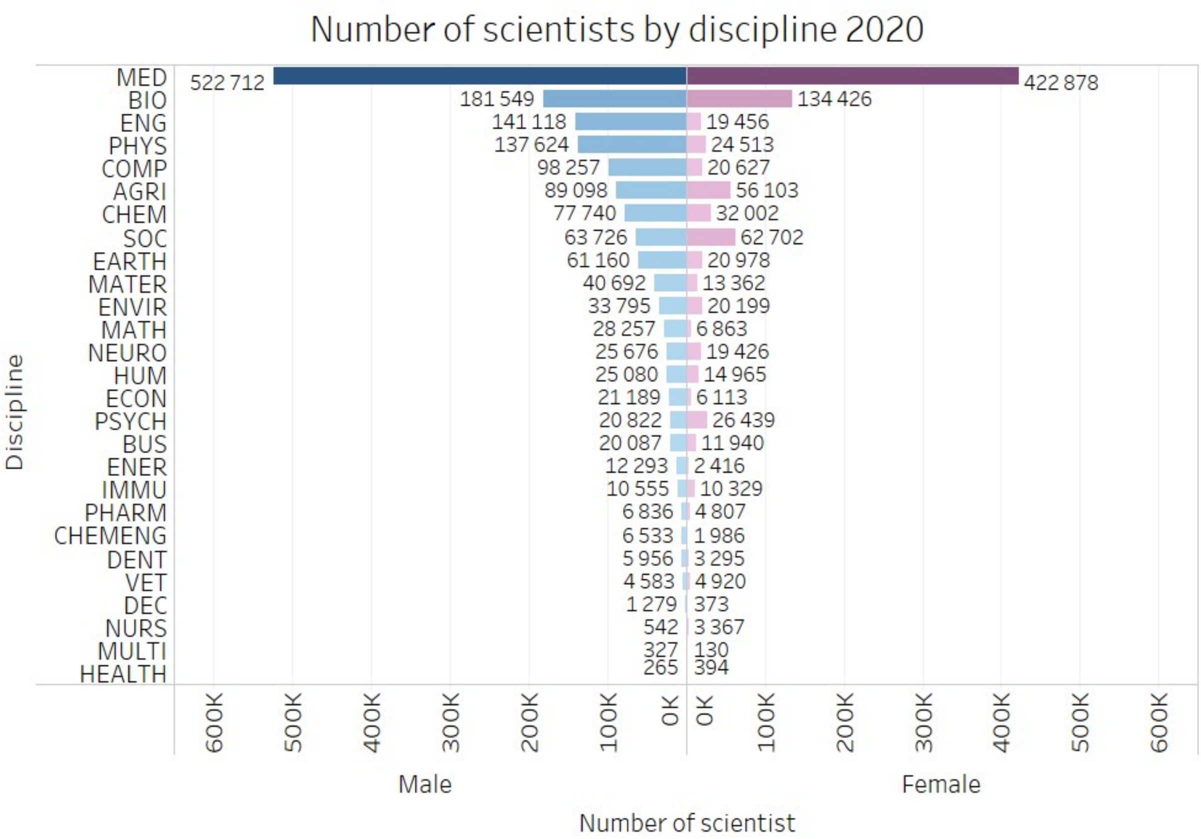


Table. The total number of scientists by discipline and gender, sorted by male to female ratio (MFR), 2020.

Discipline	Male	Female	Male to Female Ratio (MFR)
ENG	141 118	19 456	7.253
PHYS	137 624	24 513	5.614
ENER	12 293	2 416	5.088
COMP	98 257	20 627	4.764
MATH	28 257	6 863	4.117
ECON	21 189	6 113	3.466
CHEMENG	6 533	1 986	3.290
MATER	40 692	13 362	3.045
EARTH	61 160	20 978	2.915
CHEM	77 740	32 002	2.429
DENT	5 956	3 295	1.808
BUS	20 087	11 940	1.682
HUM	25 080	14 965	1.676
ENVIR	33 795	20 199	1.673
AGRI	89 098	56 103	1.588
PHARM	6 836	4 807	1.422
BIO	181 549	134 426	1.351
NEURO	25 676	19 426	1.322
MED	522 712	422 878	1.236
IMMU	10 555	10 329	1.022
SOC	63 726	62 702	1.016
VET	4 583	4 920	0.932
PSYCH	20 822	26 439	0.788
HEALTH	265	394	0.673

28. Men and Women Scientists: Countries & MFR

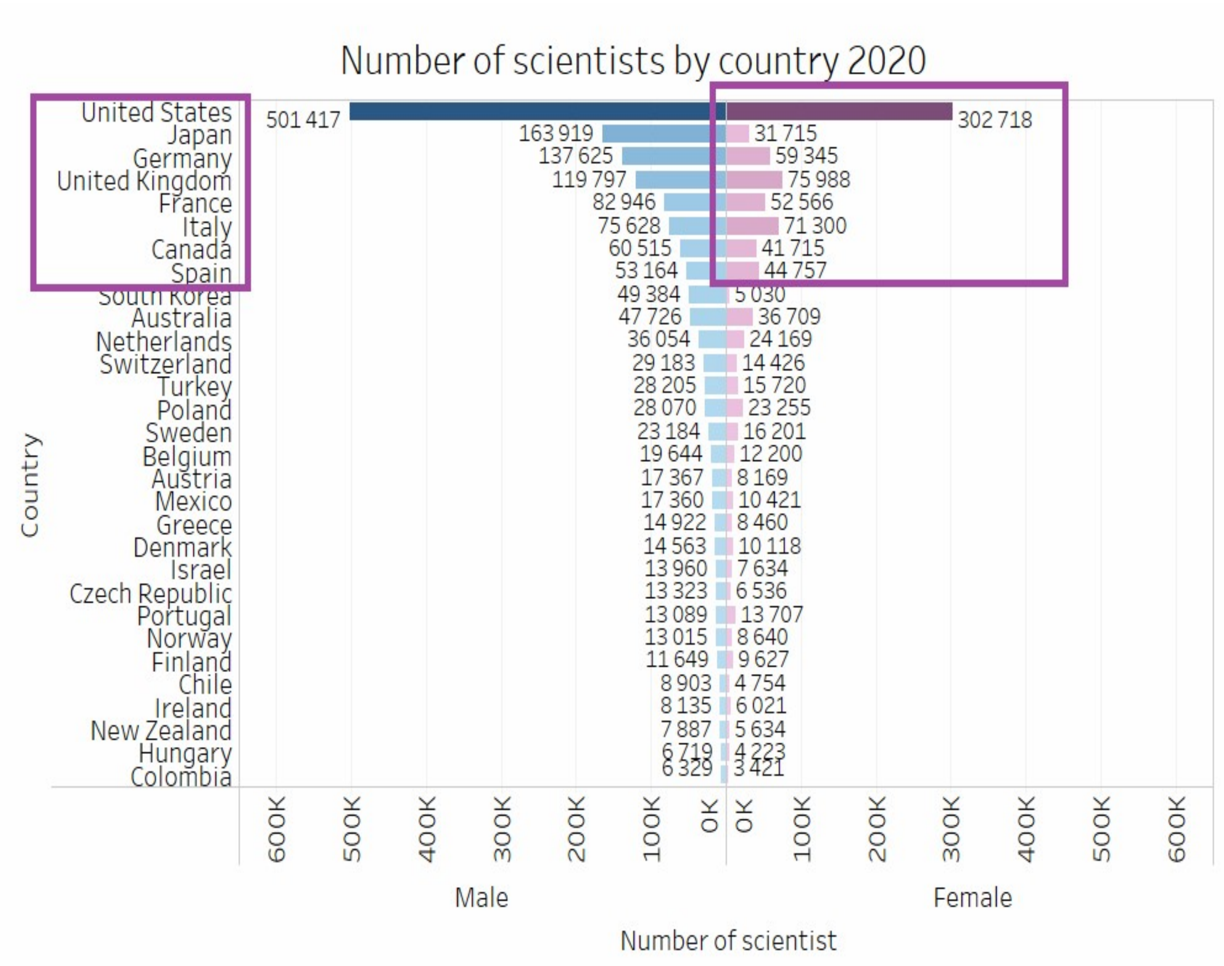


Table 10. The total number of scientists by country and gender, sorted by male/female ratio (MFR), 2020.

Country	Male	Female	Male to Female Ratio (MFR)
South Korea	49 384	5 030	9.818
Japan	163 919	31 715	5.169
Luxembourg	1 241	471	2.635
Germany	137 625	59 345	2.319
Austria	17 367	8 169	2.126
Czech Republic	13 323	6 536	2.038
Switzerland	29 183	14 426	2.023
Chile	8 903	4 754	1.873
Iceland	683	368	1.856
Colombia	6 329	3 421	1.850
Israel	13 960	7 634	1.829
Costa Rica	520	289	1.799
Turkey	28 205	15 720	1.794
Greece	14 922	8 460	1.764
Lithuania	2 257	1 335	1.691
Mexico	17 360	10 421	1.666
United States	501 417	302 718	1.656
Belgium	19 644	12 200	1.610
Hungary	6 719	4 223	1.591
France	82 946	52 566	1.578
United Kingdom	119 797	75 988	1.577
Slovakia	3 862	2 544	1.518
Norway	13 015	8 640	1.506
Netherlands	36 054	24 169	1.492
Canada	60 515	41 715	1.451
Denmark	14 563	10 118	1.439
Sweden	23 184	16 201	1.431
New Zealand	7 887	5 634	1.400
Ireland	8 135	6 021	1.351
Australia	47 726	36 709	1.300
Slovenia	2 775	2 288	1.213
Finland	11 649	9 627	1.210
Poland	28 070	23 255	1.207
Spain	53 164	44 757	1.188
Estonia	1 673	1 437	1.164
Italy	75 628	71 300	1.061
Latvia	1 058	1 098	0.964
Portugal	13 089	13 707	0.955

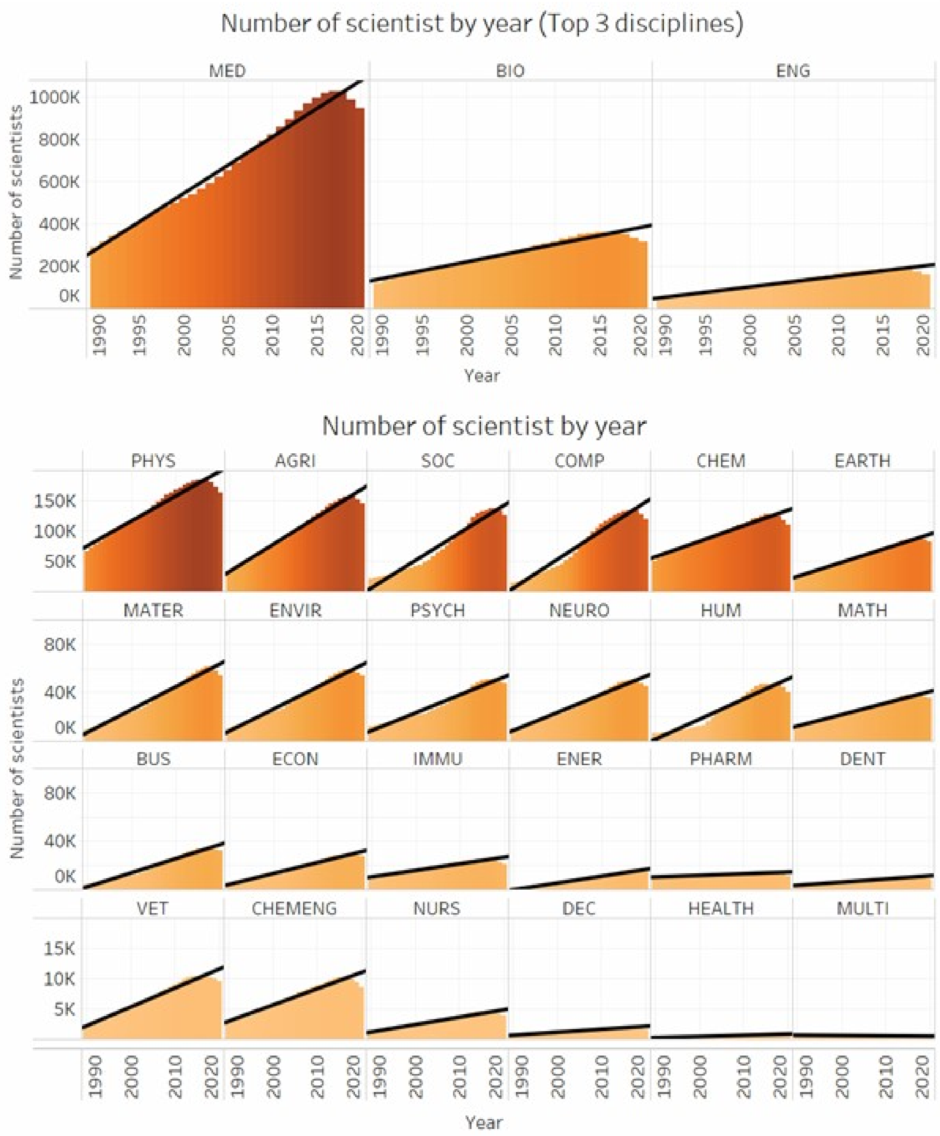
29. Men and Women Scientists: Countries & MFR

- **Where women scientists publishing in 2020 in the OECD area are globally concentrated?**
- **Three quarters (75%) in five countries: the United States (300,000 women), followed by the UK (76,000), Italy (71,000), Germany (59,000), and France (53,000).**
- **Almost a half (44.9%) of all female scientists globally - publish in Medical Sciences!**
- **Only in one third of countries the numbers are similar for men and women** (that is, the MFR is in the 1.00-1.20 range):
  - **Southern Europe** (Spain, Italy, Portugal),
  - **post-communist European** countries (Slovenia, Poland, Estonia, Latvia), and
  - **a single Scandinavian country** (Finland).
- **In Italy, the number of publishing man & women is almost equal.**
- **Germany and Japan clearly stand out: in their gender publishing patterns,** they are far away from the other largest systems.

30. The Global Scientific Workforce: Three Decades

- Figure 11 shows **the changing numbers of scientists by discipline**, with different scale of this increase.
- Table 11 (next slide) shows the changes in five year periods, with **the percentage change in 1990-2020**.
- **The overall picture needs several elements:**
  - **the numbers at the starting point (1990),**
  - **the numbers at the point of arrival (2020), and**
  - **the percentage change.**
- Again **medical sciences dominated the picture.**
- If we **remove medical sciences from the picture**, we can better see the changes in all the other disciplines.

Figure 11. The scientific workforce by discipline, 1990-2020.



31. The Global Scientific Workforce, Three Decades: Numbers & Disciplines

- An analysis of **the percentage change** shows that **the four largest disciplines increased by a factor of 2.5-2.6** (physics and biochemistry) and **by a factor of 3.3** (engineering and medical sciences).
- Disciplines which are **expanding faster** e.g.
  - computing (8.3),
  - business (7.1),
  - humanities (6.2) and sociology (6.2).
- However, **in nominal terms**, the number of scientists involved in **medical research increased by about 660,000**, in **biochemistry increased by about 200,000**. For sociology 106,000, humanities 34,000.

Table 11. The scientific workforce by discipline, 1990-2020.

Discipline	1990	1995	2000	2005	2010	2015	2020	Change 1990-2020 (in %)
AGRI	34 221	51 327	75 413	99 439	128 707	153 061	145 201	**424.30**
BIO	119 248	173 226	217 098	263 906	316 571	359 517	315 975	**264.97**
BUS	4 516	7 538	11 457	17 801	26 957	33 509	32 027	**709.19**
CHEM	49 603	67 558	82 340	96 596	111 725	126 738	109 742	**221.24**
CHEMENG	2 682	3 751	5 563	7 267	8 794	10 200	8 519	**317.64**
COMP	14 358	27 075	42 206	74 246	110 563	132 603	118 884	**827.10**
DENT	3 537	4 446	5 338	7 164	9 047	10 510	9 251	**261.55**
EARTH	25 005	33 753	45 360	59 428	72 881	85 659	82 138	**328.49**
ECON	5 861	8 151	11 574	16 756	23 356	28 627	27 302	**465.83**
ENER	1 718	2 591	4 015	6 705	10 586	15 241	14 709	**856.17**
ENG	48 082	71 403	94 038	129 137	162 498	184 381	160 574	**333.96**
ENVIR	10 730	16 219	23 965	34 313	45 932	57 278	53 994	**503.21**
HUM	6 491	8 586	12 176	24 935	36 818	47 077	40 045	**616.93**
IMMU	8 016	12 461	15 991	19 092	22 892	24 666	20 884	**260.53**
MATER	9 625	15 562	23 320	33 556	45 185	58 270	54 054	**561.60**
MATH	12 290	15 839	20 809	25 624	32 047	37 512	35 120	**285.76**
MED	287 046	405 615	517 898	653 499	821 196	992 234	945 590	**329.42**
NEURO	10 238	15 480	21 567	29 540	39 660	49 401	45 102	**440.54**
NURS	1 125	1 686	2 136	2 767	3 874	4 457	3 909	**347.47**
PHARM	8 642	11 100	11 599	12 189	13 541	14 065	11 643	**134.73**
PHYS	65 833	92 417	114 637	141 499	167 497	183 919	162 137	**246.29**
PSYCH	12 073	15 762	20 584	27 107	37 444	50 171	47 261	**391.46**
SOC	20 544	28 543	41 486	64 127	97 398	132 370	126 428	**615.40**
VET	2 079	3 249	5 087	7 030	8 988	10 343	9 503	**457.10**

32. New Academic Jobs – Where They Emerge?

- **Only in 6 disciplines more than 100,000 new unique scientists in 30 years.**
- **MED. Medical sciences rule globally!** More new scientists than in the top 2-6 ranks (shadowed); and much more than in the remaning 17 disciplines (ranks 7-26)!
- Followed by **BIO biochemistry, genetics, and molecular biology**.

Table. The scientific workforce by discipline: 1990, 2020, and the difference between 1990 and 2020.

Discipline	1990	2020	Difference
MED	287 046	945 590	658 544
BIO	119 248	315 975	196 727
ENG	48 082	160 574	112 492
AGRI	34 221	145 201	110 980
SOC	20 544	126 428	105 884
COMP	14 358	118 884	104 526
PHYS	65 833	162 137	96 304
CHEM	49 603	109 742	60 139
EARTH	25 005	82 138	57 133
MATER	9 625	54 054	44 429
ENVIR	10 730	53 994	43 264
PSYCH	12 073	47 261	35 188
NEURO	10 238	45 102	34 864
HUM	6 491	40 045	33 554
BUS	4 516	32 027	27 511
MATH	12 290	35 120	22 830
ECON	5 861	27 302	21 441
ENER	1 718	14 709	12 991
IMMU	8 016	20 884	12 868
VET	2 079	9 503	7 424
CHEMENG	2 682	8 519	5 837
DENT	3 537	9 251	5 714
PHARM	8 642	11 643	3 001
NURS	1 125	3 909	2 784

Figure 12. The changing numbers of scientists between 1990 and 2020, by discipline (MED included)

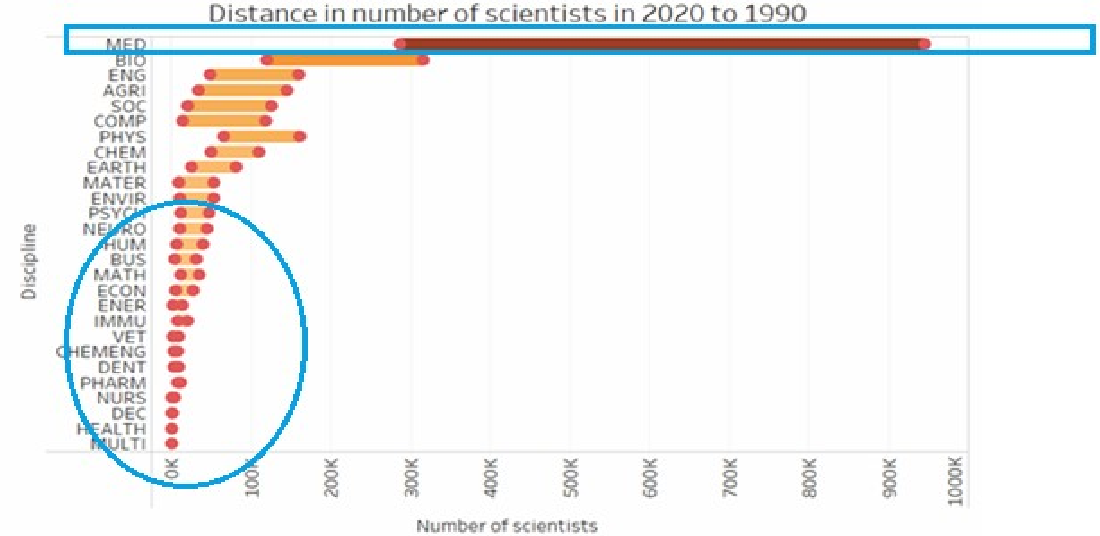


Figure 14. The changing numbers of scientists between 1990 and 2020, by discipline (MED excluded)

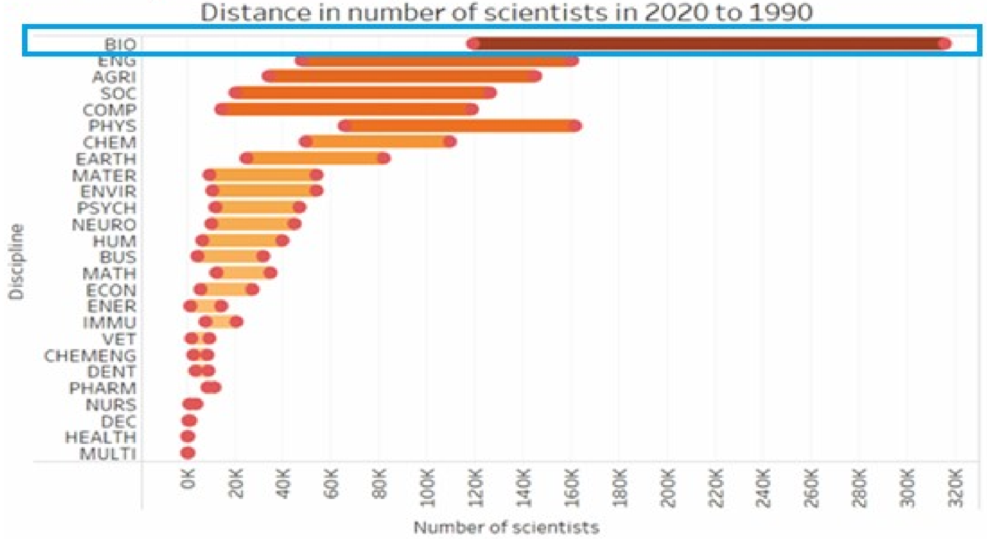


Figure 13. The difference in the number of scientists between 1990 and 2020 (MED included)

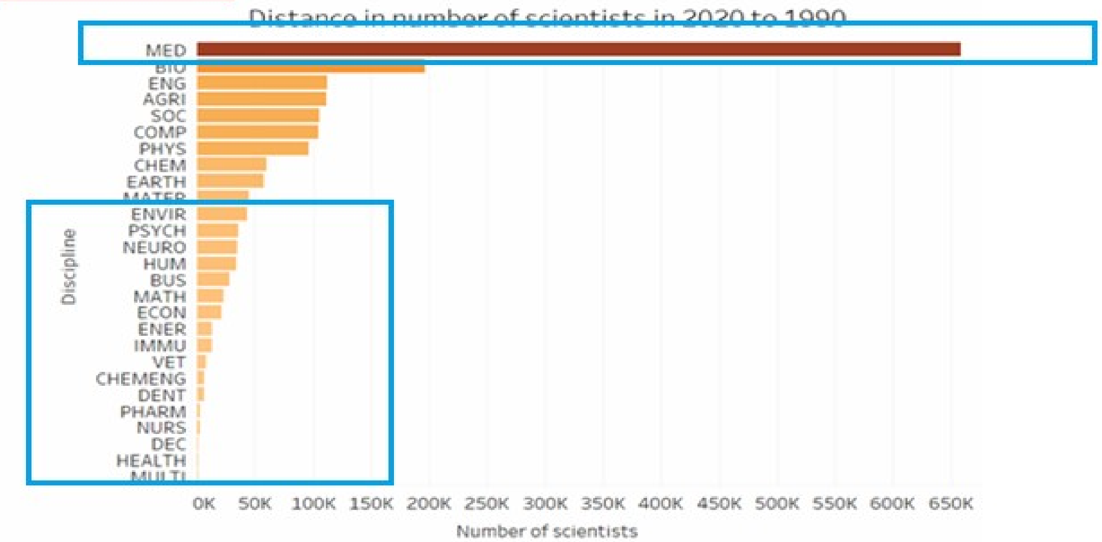
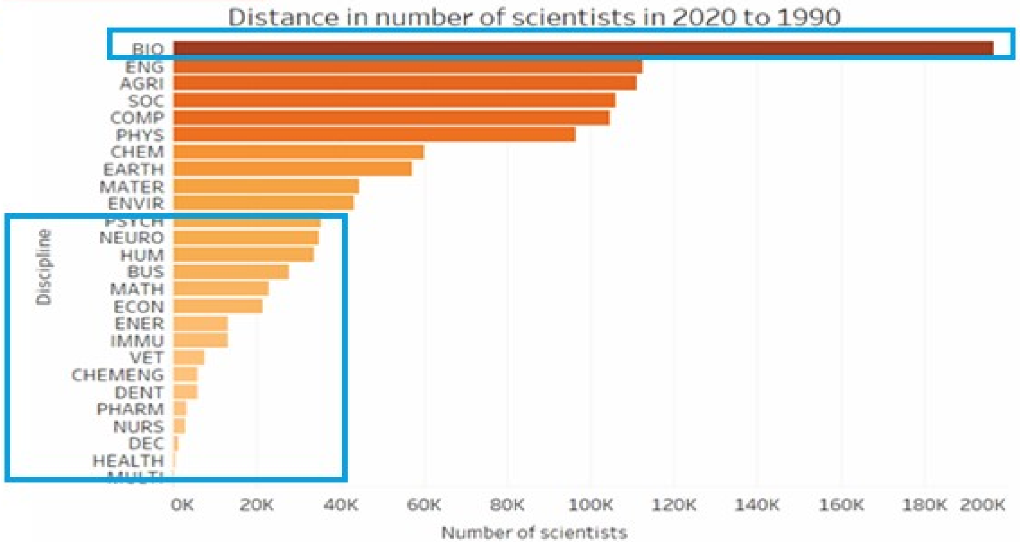
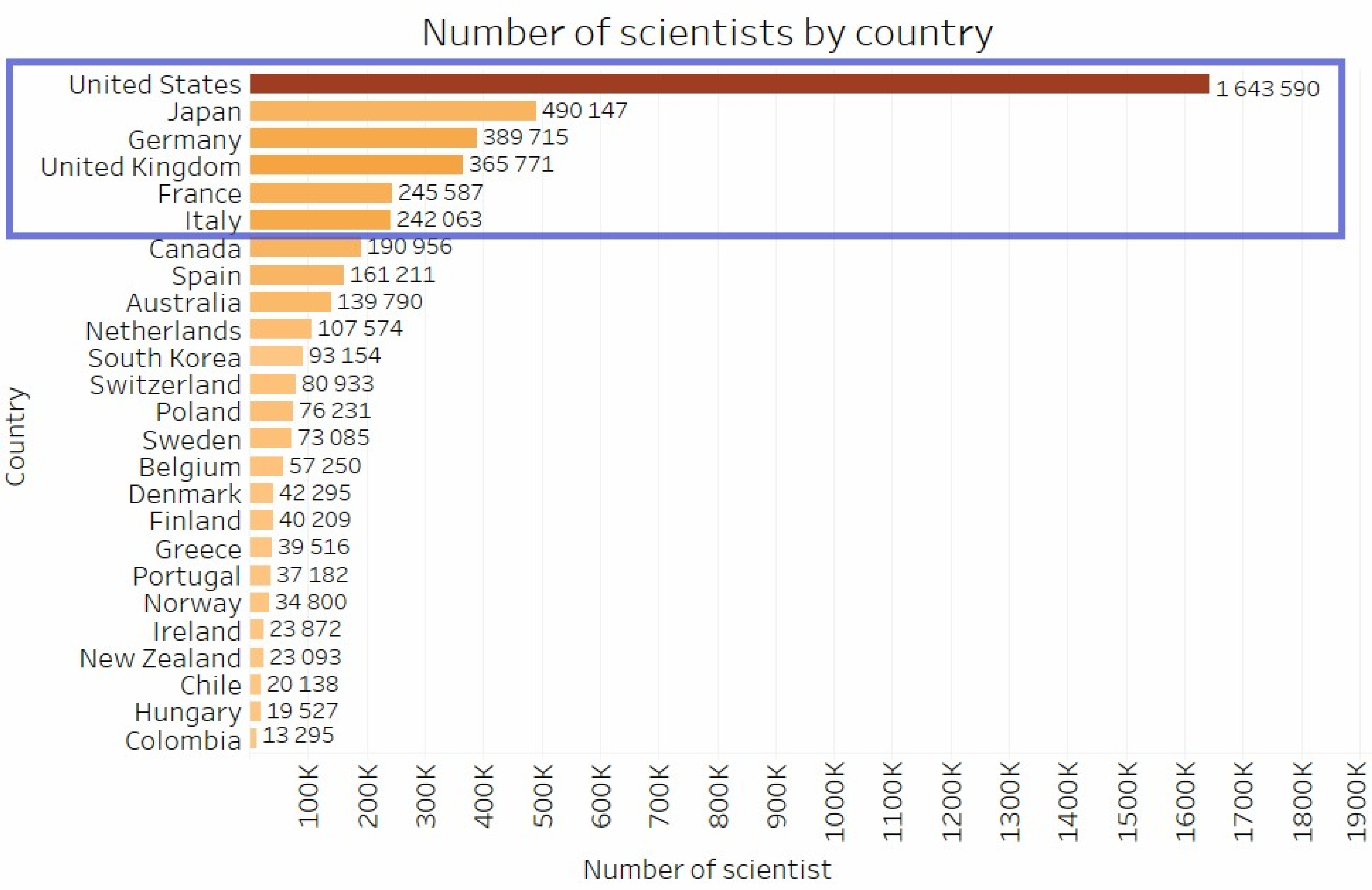


Figure 15. The difference in the number of scientists between 1990 and 2020 (MED excluded)

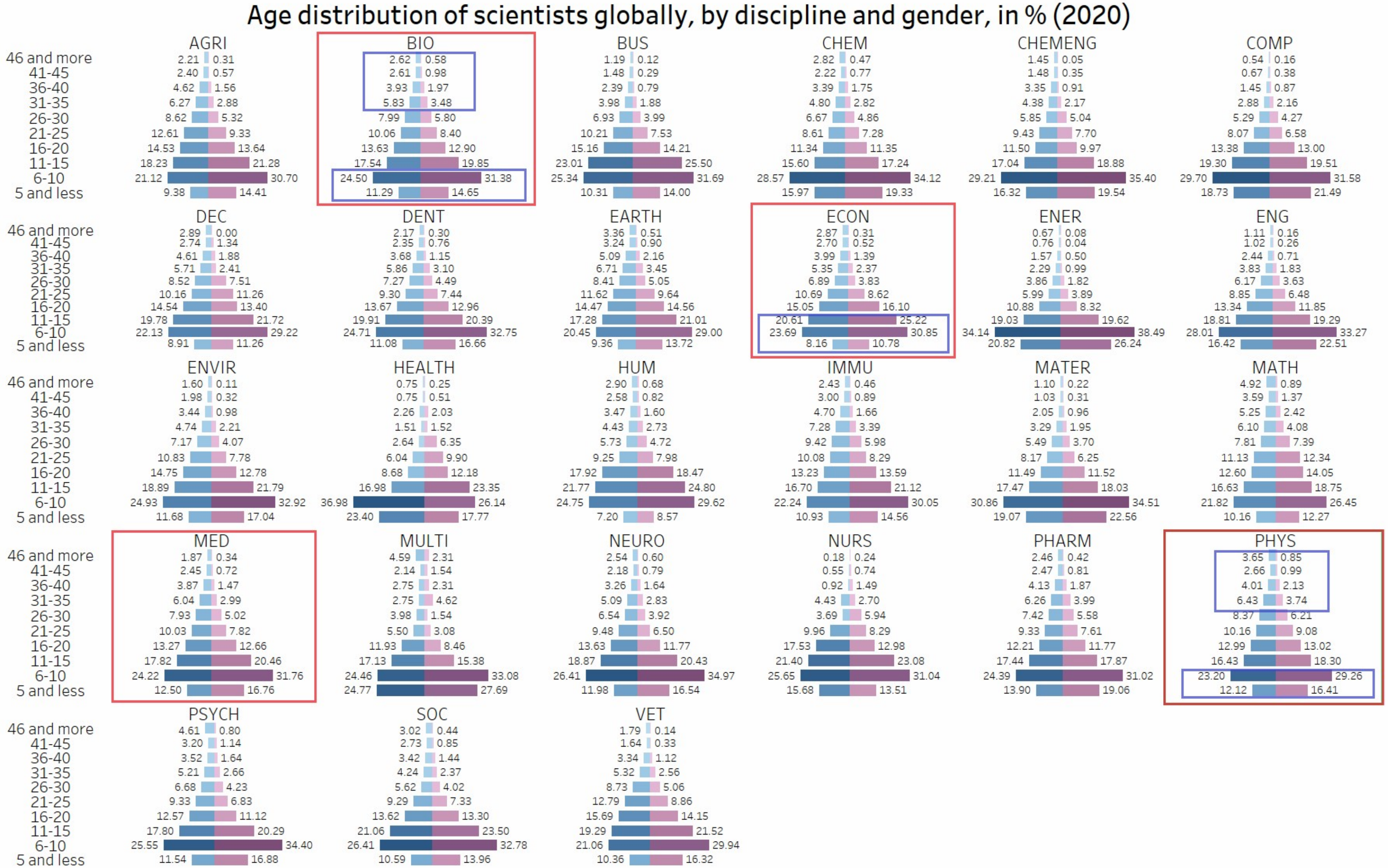


34. Scientists in 1990-2020, by Country

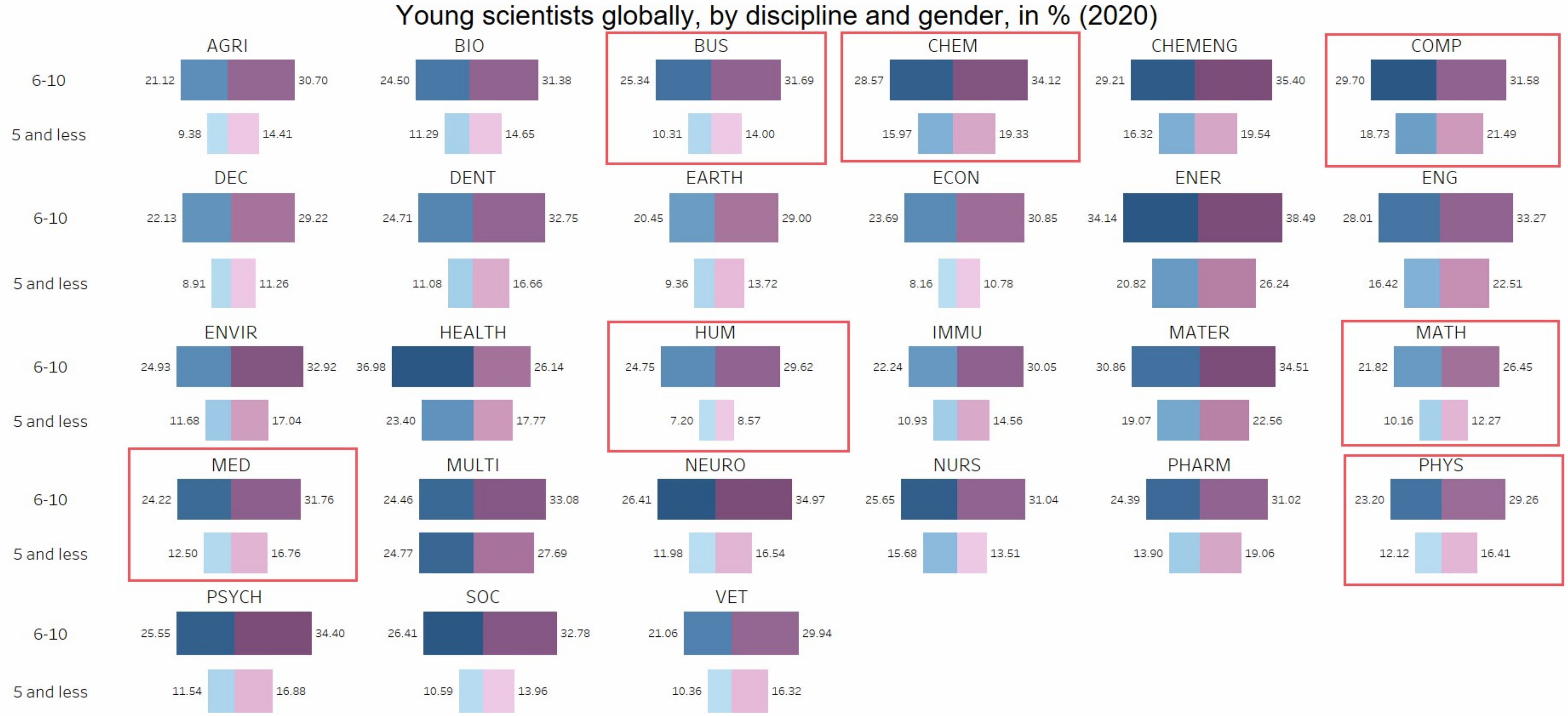
- **In terms of countries, about 73% percent of scientists in 1990-2020 came from the six top countries, including 35% from the United States.**
- **The differences are staggering**: 1.64 million scientists come from the USA.
- There are 10 countries with less than 10,000 scientists (omitted in Figure).
- There are **typical newcomers to global science in the list.**
- Consider e.g. **Poland**, with 76,000 scientists in 30 years - and as many as **51,000 in 2020 alone!**



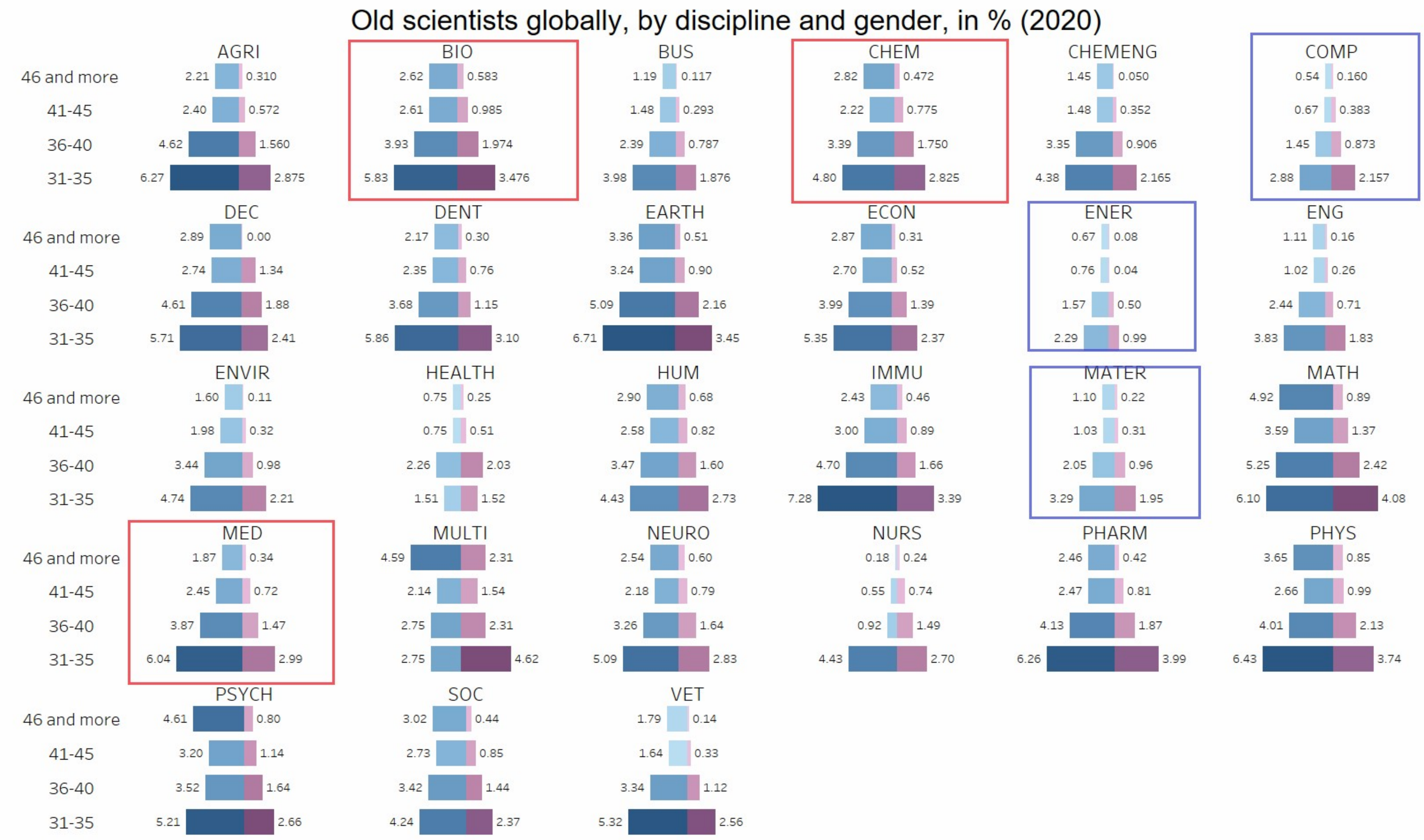
35. Distribution of Scientists by Age Group, Gender & Discipline (2020)



36. Zoom on Young Scientists (Academic Age 10 & Less), 2020



37. Zoom on Old Scientists (Academic Age > 30), 2020



38. Final Words & Implications (1/2)

- **Globalization of science** & new data sets – offer new opportunities to **examine scientists globally**.
- **New data sources and methodologies** pays off: new large-scale global pictures possible.
- **Age by itself** as an **important sociodemographic dimension** of the global academic workforce.
- New **raw (structured, commercial) Big Data useful in studying age profile and gender in science**.
- From **the publication** to **the scientists** as a unit of analysis (as a new approach).
- **Advantages and limitations** of the approach suggested: **a trade-off needed, new data come with their limitations, no perfect data today** (years-long criticism of bibliometrics pays off).
- **All disciplines are slowly aging** – but the speed of aging varies.
- Especially useful **zooming in on smaller subsamples**: e.g. selected disciplines, **young scientists**.

39. Final Words & Implications (2/2)

- Long-term trend: **more <u>young</u> women than <u>young</u> men scientists** across **all disciplines** – a **revolutionary** change, implications!
- **Productivity studies** (women less productive) vs. **demoghraphic studies** (more young women scientists): huge **untapped potential of female scientists!**
- **Ongoing concentration in global science:**
    - **Medical research** dominates globally: **40% of all scientists globally** (2020), including 44.9% of women.
    - **Three quarters (75%)** of women scientists globally concentrated in 7 countries (2020).
    - **Three quarters (73%) of scientists in 1990-2020 globally came from 6 countries**, one third (35%) from the USA.
    - **New jobs globally emerge in 6 disciplines** (min. 100,000 new unique scientists in 1990-2020 each), medical sciences on top (660,000 – more than the other 5 disciplines).
- The **global dimension** of the science workforce as important as a **traditional comparative cross-national dimension.**

- Thank you! (kwiekm@amu.edu.pl; Twitter: @Marek_Kwiek