Declining global scientific mobility and persistent inequality in an expanding research system

Appendix

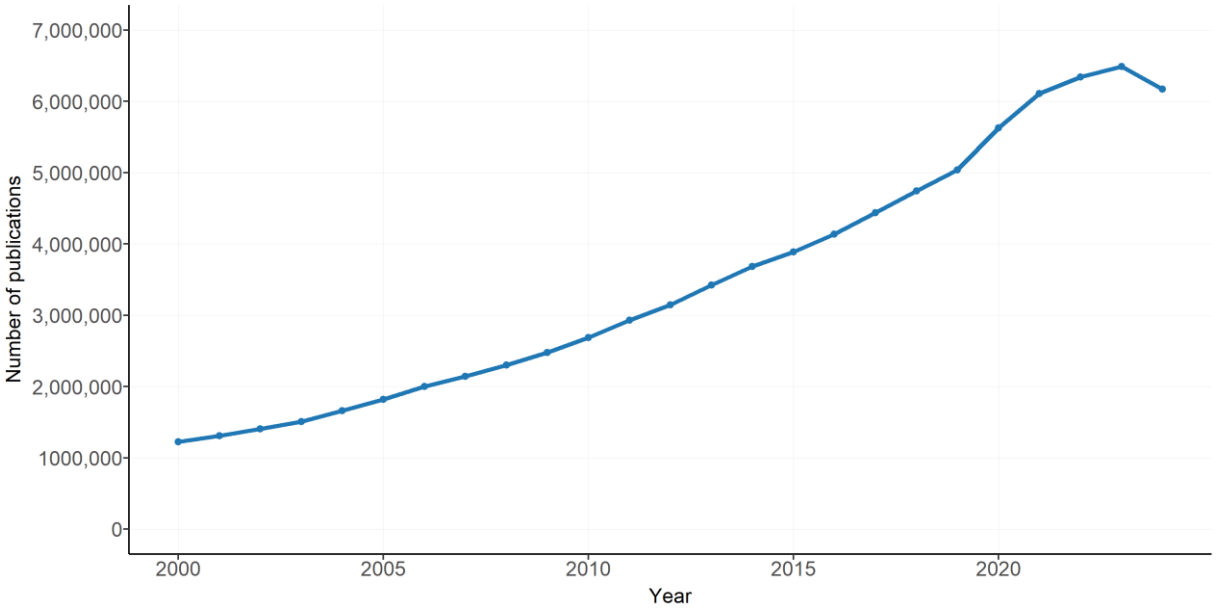

Figure A1. Trends in the annual number of distinct publications indexed in the Dimensions database, 2000–2024.

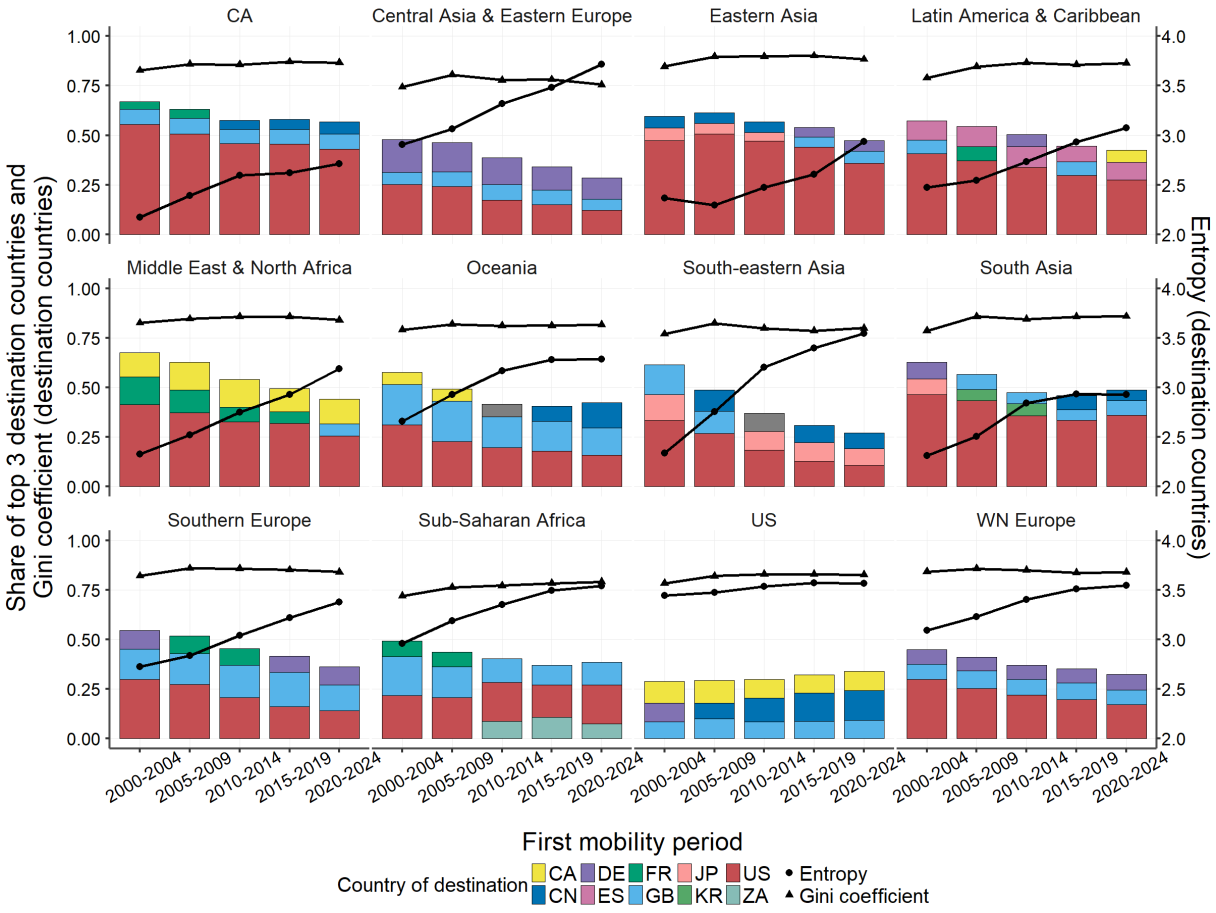

Figure A2. Top three destination countries (stacked bars) and country-level entropy (triangles) and Gini coefficient (circles) across five periods, by region of origin. The bars show the combined share of the three most common destination countries in each period. Higher entropy indicates a more diverse distribution across destination countries. Higher Gini indicates a more uneven distribution across destination countries.

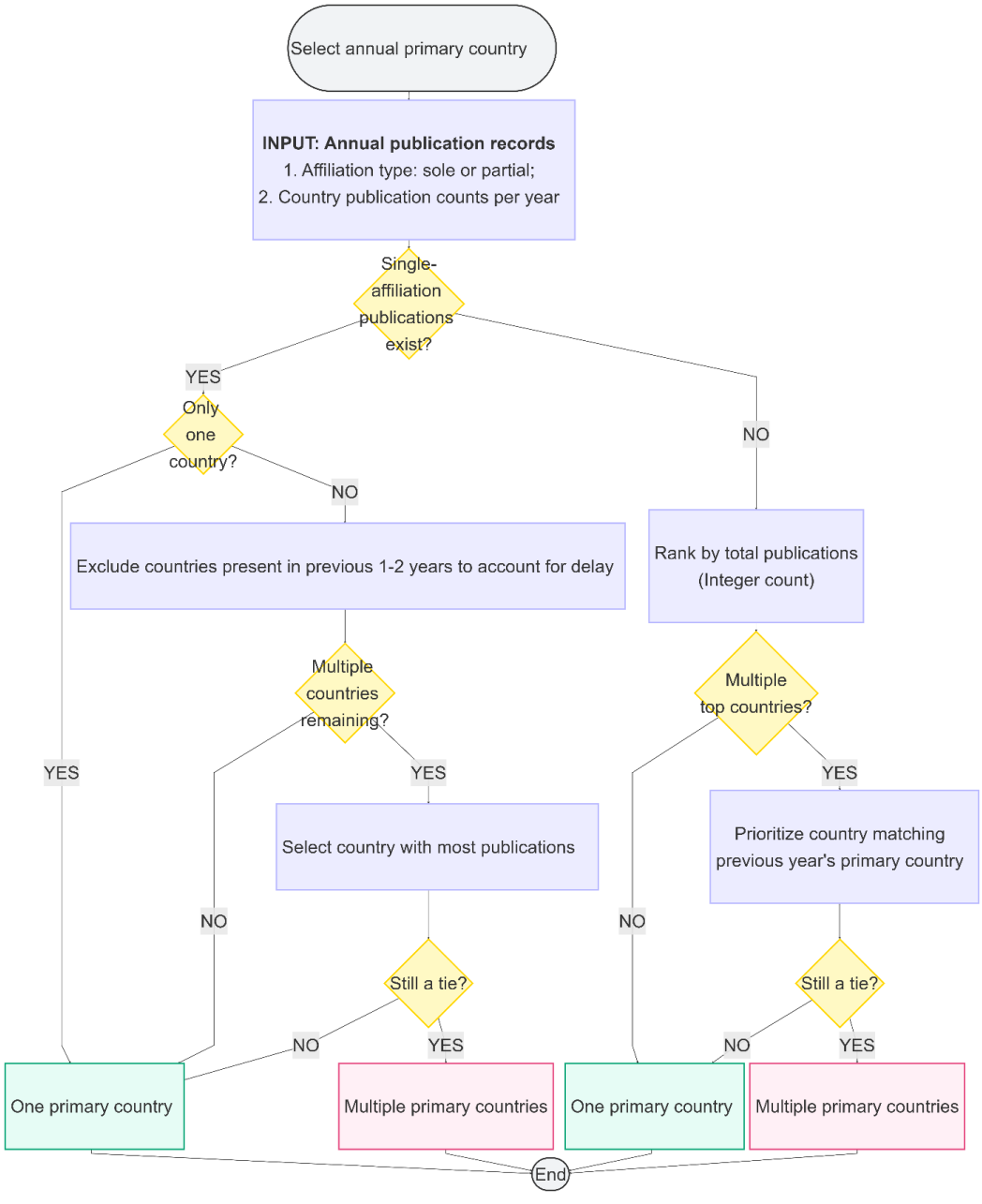

Figure A3. Methodology for selecting annual primary countries from publication data.

Table A1. Regional classifications and their corresponding country lists.

Region classification	Country name in the World Bank
CA	Canada
Central Asia & Eastern Europe	Armenia; Azerbaijan; Belarus; Bulgaria; Cyprus; Czechia; Georgia; Hungary; Kazakhstan; Kyrgyz Republic; Moldova; Poland; Romania; Russian Federation; Slovak Republic; Tajikistan; Türkiye; Turkmenistan; Ukraine; Uzbekistan
Eastern Asia	China; Hong Kong SAR, China; Japan; Korea, Dem. Rep.; Korea, Rep.; Macao SAR, China; Mongolia; Taiwan, China
Latin America & Caribbean	Antigua and Barbuda; Argentina; Aruba; Bahamas, The; Barbados; Belize; Bolivia; Brazil; British Virgin Islands; Cayman Islands; Chile; Colombia; Costa Rica; Cuba; Curacao; Dominica; Dominican Republic; Ecuador; El Salvador; Grenada; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Nicaragua; Panama; Paraguay; Peru; Puerto Rico; Sint Maarten (Dutch part); St. Kitts and Nevis; St. Lucia; St. Martin (French part); St. Vincent and the Grenadines; Suriname; Trinidad and Tobago; Turks and Caicos Islands; Uruguay; Venezuela, RB; Virgin Islands (U.S.)
Middle East & North Africa	Algeria; Bahrain; Djibouti; Egypt, Arab Rep.; Iran, Islamic Rep.; Iraq; Israel; Jordan; Kuwait; Lebanon; Libya; Malta; Morocco; Oman; Qatar; Saudi Arabia; Syrian Arab Republic; Tunisia; United Arab Emirates; West Bank and Gaza; Yemen, Rep.
Oceania	American Samoa; Australia; Fiji; French Polynesia; Guam; Kiribati; Marshall Islands; Micronesia, Fed. Sts.; Nauru; New Caledonia; New Zealand; Northern Mariana Islands; Palau; Papua New Guinea; Samoa; Solomon Islands; Tonga; Tuvalu; Vanuatu
South Asia	Afghanistan; Bangladesh; Bhutan; India; Maldives; Nepal; Pakistan; Sri Lanka
South-eastern Asia	Brunei Darussalam; Cambodia; Indonesia; Lao PDR; Malaysia; Myanmar; Philippines; Singapore; Thailand; Timor-Leste; Vietnam
Southern Europe	Albania; Andorra; Bosnia and Herzegovina; Croatia; Gibraltar; Greece; Italy; Montenegro; North Macedonia; Portugal; San Marino; Serbia; Slovenia; Spain
Sub-Saharan Africa	Angola; Benin; Botswana; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo, Dem. Rep.; Congo, Rep.; Côte d'Ivoire; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Gabon; Gambia, The; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; São Tomé and Principe; Senegal; Seychelles; Sierra Leone; Somalia; South Africa; South Sudan; Sudan; Tanzania; Togo; Uganda; Zambia; Zimbabwe
US	United States
Western & Northern Europe	Austria; Belgium; Denmark; Estonia; Faeroe Islands; Finland; France; Germany; Greenland; Iceland; Ireland; Isle of Man; Latvia; Liechtenstein; Lithuania; Luxembourg; Monaco; Netherlands; Norway; Sweden; Switzerland; United Kingdom

Table A2. Example of annual primary-country assignment and mobility identification.

Publication year	Primary country in previous publication year(s)	Single-affiliation publication counts	Multiple-affiliation publication counts	Decision rule	Primary country	Mobility event
2017	None	China = 2	–	First observed year; one single-affiliation country only	China	Entry year
2019	China	China = 3	–	One single-affiliation country only	China	No mobility
2020	China	Netherlands = 1, China = 1	–	Exclude old country (China); retain Netherlands	Netherlands	China → Netherlands
2021	Netherlands	–	Germany = 3, Netherlands = 2, US = 1	No single-affiliation recorded; choose top multi-affiliation country	Germany	Netherlands → Germany
2022	Germany	–	Germany = 2, US = 2	Tie in multi-affiliation counts; retain previous primary country	Germany	No mobility
2023	Germany	US = 2, UK = 2, Germany = 1	–	Exclude old country (Germany); tie remains between new countries	US and UK	Germany → US; Germany → UK

Example of the standardization framework for return rates

Table A3 presents a simplified example of the calculation of the jointly standardized annual return rate. Standardization is based on two dimensions: first-publication year (c) and years since leaving the country of origin by calendar year t (d). In this example, among researchers from the 2000 cohort, 100 left in 2001, of whom 20 returned in 2002 and 30 returned in 2003; 200 left in 2002, of whom 50 returned in 2003. Among researchers from the 2001 cohort, 150 left in 2002, of whom 35 returned in 2003.

Table A3. Worked example of the calculation of jointly standardized annual return rates, 2002-2003.

Calendar year (t)	Cohort (c)	Leaving year	Years since leaving (d)	$N_{t,c,d}$	$R_{t,c,d}$	$r_{t,c,d}$
2002	2000	2001	1	100	20	0.2
2003	2000	2001	2	80	30	0.375
2003	2000	2002	1	200	50	0.25
2003	2001	2002	1	150	35	0.2333

Fixed base weights were derived from the pooled reference population across 2002–2003. Thus, $\sum_t N_{t,2000,1} = 100 + 200 = 300$, $\sum_t N_{t,2000,2} = 80$, and $\sum_t N_{t,2001,1} = 150$. Base weights $W_{2000,1}$=300/530=0.5660, $W_{2000,2}$=80/530=0.1509, and $W_{2001,1}$=150/530=0.2830 The cell-specific return rate is defined as:

$$r_{t,c,d} = \frac{R_{t,c,d}}{N_{t,c,d}},$$

The jointly standardized annual return rate is then calculated as:

$$r_t^{std} = \sum_{(c,d)\in S_t} \widetilde{w}_{t,c,d} r_{t,c,d}\,, \qquad \widetilde{w}_{t,c,d} = \frac{w_{c,d}}{\sum_{(c,d)\in S_t} w_{c,d}}.$$

For 2002, only one (c, d) cell is observed, so $r_{2002}^{std} = r_{2002}^{raw} = 0.2$

For 2003, the standardized annual return rate is:

$$r_{2003}^{std} = 0.5660 \times 0.2500 + 0.1509 \times 0.3750 + 0.2830 \times 0.2333 = 0.2642.$$

For comparison, the raw annual return rate for 2003 is $r_{2003}^{raw} = 115/430 = 0.2674$.

Table A4. General overview of researchers' mobility types (2000–2024).

Type of international mobility	Number of researchers	Number of publications contributed	Ave. publications per researcher
Non-mobile	19,073,260 (94.7%)	45,990,556 (91.5%)	2.4
Mobile	1,065,526 (5.3%)	18,896,498 (37.6%)	17.7