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Project Working Paper 1[1]

R&D 20 Background Briefing: Nations, Universities, Value Generation, and Value Capture

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Posted May 12, 2020 (Working Draft)[2]

Contents

Introduction: Where to for Global Universities and Global Innovation?

What is the purpose of the research university in 2020, particularly in relation to country-level R&D intensity, value generation, and value capture? How can it best focus on serving its students, local community, nation-state, and the international stakeholders? How can it balance the need to import and export talent and ideas across borders, while maintaining national security and showing economic and social benefits to its immediate surroundings?

From the 1940s to the 1960s, Vannevar Bush and Clark Kerr suggested and implemented major advances in the reach of (mostly, but not exclusively, US) universities as engines of economic growth and long-term advancers of new knowledge. Are their mid-20th century (or, with Kerr, as recent as the

[1] Information about the Global Innovation and National Interests Project is available at https://www.brginstitute.org/project-description. Opinions expressed are those of the author and not of the project or BRG Institute.

[2] Some minor updates and corrections were added to the briefing paper on December 23, 2020.

final edition of *The Uses of the University* in 2001)[3] concepts still relevant in 2020, and in countries outside of the Anglo-American academic tradition?

This paper first explores the concept, and underlying metrics, of a group of the twenty-plus most research-intensive nations, referred to as the R&D 20. This section, with a focus on university contributions to research intensity, runs for about twenty pages, followed by about ten pages of consideration of university value generation and value capture. Together, these narratives provide data and discussion relevant to further assessments of international R&D activities.

As of May 2020, this briefing is a time capsule, in that it was drafted in late February and early March of 2020. This was prior to the onset of COVID-19 and its resulting changes on global life and institutions, R&D included. At that time, some possibilities of COVID-19 were known. However, they are not discussed to the extent to which the pandemic has had impacts understood as of late April 2020. As such, this briefing represents metrics and analysis of research, development and innovation activity immediately prior to the 2020 pandemic.

Part I: An R&D 20 of Research-Intensive Nations

Specific to an R&D 20 concept, while university research and development exists globally, a high concentration of activity, in quantitative and qualitative terms, centers in about twenty countries, as will be defined. Of course, there is no official "R&D 20" list, and as such, a group of twenty will include some and exclude others.

For instance, in sheer quantitative terms, nations such as Italy and Spain rank above New Zealand, and are comparable to Canada, in total R&D expenditures, and as a GDP percentage and per capita. Canada and New Zealand, however, have more Top 500 universities per capita, and large numbers of foreign students (particularly from Asia).

Certainly, metrics vary, as do country-level strengths in R&D, as well as the university systems for conducting R&D and producing graduates, within each country. What will be proposed are a core group, and a supplemental group, of R&D-intensive nations, and those with some degree of intensity and interesting stories to tell.

The world average of R&D as a percentage of GDP is around 1.68 percent, according to UNESCO.[4] An assessment can be started by compiling a "two percent club" of nations spending more than two percent of GDP on research and development, to find seventeen countries, with Israel, South Korea, and Switzerland having the highest concentrations.[5]

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3 https://books.google.com/books?id=OeeZAAAAQBAJ&dq=inauthor:%22President+Emeritus+and+Former+Chancellor+and+Professor+Emeritus+Clark+Kerr%22

4 http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en#

5 Ibid. and https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm (All figures are rounded to three decimal places. As of February 2020, 2017 is the latest year with non-provisional data available for most countries.)

Data consistency to generate an R&D 20 is an issue, as it is with many international indicators. For instance, UNESCO does not include 2017 figures for Singapore, however, OECD shows Singapore in 2017 at under two percent of GDP, while both OECD and UNESCO show the country above two percent for 2016, but at 2.1 and 2.2 percent, respectively. Israel and South Korea, among others, appear to release provisional data with fluctuations, prior to final numbers appearing in international datasets.[6]

That stated, some countries clearly show at the top of the rankings. In addition, the UK is absent on the list. As of 2018, the UK is the only nation in the top five by total GDP (the others are the US, China, Germany, and Japan) not to reach two percent of total GDP spent on R&D.[7] Its 2017 estimate comes in at 1.67 percent, per UNESCO. The country does have a goal for reaching 2.4 percent by 2027,[8] however Brexit puts that aspiration partially at risk, as approximately 14 percent of UK R&D funding comes from international sources (whether directly funded by EU sources or not, the regulatory changes and uncertainties from Brexit could potentially impact all external funding).[9]

By examining total R&D spending, other highlights emerge in this R&D 20 version.[10] Table 2 indicates the US and China as spending around $500 billion each on R&D in 2017, followed by Japan at $170 billion, Germany at $131 billion, and South Korea at $90 billion.

Via looking at R&D GDP per capita (Table 3) some consistency appears with the percentages and total spend, such as in Israel, South Korea, and Switzerland, while larger countries with low ratios, notably India and Russia, disappear, and smaller states (Singapore and Luxembourg) gain prominence.[11]

Higher Education Rankings

The above tables show figures for all sectors, not specifically in a university context. In that regard, some metrics within the higher education sector are also worth examining.

Quacquarelli Symonds (QS) and Times Higher Education (THE), both in the UK, and the Academic Ranking of World Universities (ARWU, in China) provide annual rankings, with varied methodologies, of 1,000 global research universities. In general, these three are three heavily relied-upon international ranking systems (among others), so run a simple average of country distributions in their lists will be run.

Much attention goes towards "Top 100" status. For purposes of this briefing, at a national level, it is important to consider a wider range in universities, beyond an elite global tier (which does not cover

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[6] https://mfa.gov.il/mfa/aboutisrael/economy/pages/economy-%20sectors%20of%20the%20economy.aspx and https://en.yna.co.kr/view/AEN20191218008400320

[7] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?most_recent_value_desc=true&view=map

[8] https://www.ukri.org/about-us/increasing-investment-in-r-d-to-2-4-of-gdp/

[9] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2017

[10] UNESCO. (https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm for Taiwan, with 12% adjustment per https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1&year1=201001&year2=201701)

[11] http://data.uis.unesco.org/index.aspx?queryid=74 (Taiwan data from https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm and https://eng.stat.gov.tw/point.asp?index=9)

most of a country's higher education sector, and in which the US and the UK normally predominate in most rankings). ARWU, QS, and THE each rank 1,000 institutions, to varied degrees of individual versus group numbering systems the lower down one reaches in the rankings. As such, employing a "Top 500" approach will make visible the extent of the upper half of internationally-oriented, research-intensive tertiary institutions among different countries. The results, sorted by the average count, and cross-measured by a ratio of people in each country for every Top 500 institution, are shown below.[12]

More than twenty countries are included in this data set, because of the interesting examples of New Zealand, Austria, Denmark, and notably, Finland, with strong concentrations of higher-ranked institutions amidst low country-level populations. The results, shown in Table 4, indicate a strong concentration in the US, with 115 of top-500 ranked institutions, followed by the UK at 48, and China and Germany each with 33 universities in the aggregate rankings.

Publication Rankings

Another metric is the *Nature Index*, which consists of weighted authorship shares (accounting for multi-author papers) in the natural sciences. Certainly, a fraction of academic journal authorship occurs outside of university settings, however, that should not discourage use of this measure as an assessment of the relative production of research in scientific and engineering fields among universities in a given country. Table 5 presents the data for 2017 to 2018.[13] The US has by far the largest number of authorship shares, at around 20,000, followed by China at around 9,000 in 2017, and Germany at around 4,400. While the US and Germany, and the UK, in fourth place, remained relatively flat between 2017 and 2018, China's count noticeably increased to over 11,000 in 2018.

It is also possible to review citations, per the *Scimago Journal and Country Rank*. When sorted by total citations by country, this metric can indicate quality of research outputs and their impact in the international R&D community (even if not exclusively in STEM fields or from university sources).[14] Here, the US clearly leads, a nearly 300 million citations for publications between 1996 and 2018, followed by the UK at 77 million, Germany at 61 million, and China at 48 million. Table 6 displays the full results.

Student Counts

China has the largest number of tertiary students in the world, at about 44 million as of 2017, followed by India at 33 million, the US at 19 million, and Brazil at 8 million.[15] Although this measure does not indicate presence in research universities (versus teaching colleges and vocational institutes, for instance) it still correlates with the volume of a country's population going through the range of formal

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[12] http://www.shanghairanking.com/ARWU-Statistics-2019.html, https://www.topuniversities.com/university-rankings/world-university-rankings/2020, https://www.timeshighereducation.com/world-university-rankings/2020/world-ranking and https://data.worldbank.org/indicator/SP.POP.TOTL
[13] https://www.natureindex.com/annual-tables/2019/country/all#note-adjustment
[14] https://www.Scimagojr.com/countryrank.php?order=ci&ord=desc
[15] http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en#

education mechanisms necessary to power an economy with R&D intensity. Table 7 shows the top twenty countries.

For total research doctorates awarded per year, metrics are rev the International Standard Classification of Education (ISCED) 2011 standard for international reporting.[16] Ideally, this would include a percentage of STEM degrees, however, academic discipline metrics between countries involve inconsistencies, mixed categories, and incomplete datasets, so that aspect has been left out for data quality. In the ISCED 2011, Level 8 includes PhD-equivalent degrees, such as DSc, DPhil, and LLD, but excludes professional doctoral degrees, such as in law and medicine.[17] Table 8 shows the top twenty in simple numerical terms, led by the US at about 71,000, followed by China at 59,000 (as of 2018), and Germany and the UK at 28,000 each.[18]

The percent of population with a bachelors degree indicates the relative success levels of universities at producing graduates capable of further study and professional-level careers, and the top twenty global countries in that metric are presented below.[19] An important point, fully shown in Table 9, is that in every country, a majority of the national population (and with only seven exceptions, a two-thirds majority) does not have a university-level degree. The UAE leads at about 46 percent with an undergraduate qualification, followed by Israel at 35 percent, and Lithuania, Taiwan, Georgia and the UK each at around 34 percent. The US share is 33 percent.

R&D in Business

For context, it is useful to briefly discuss R&D performed in business. Finding a low percentage of a country's R&D efforts in higher education, and a high percentage in business, usually correlates to a stronger ability of a country's universities to produce graduates capable of managing and performing R&D in industrial and corporate settings. That is, such distribution leans towards later stages of commercialization and product development.[20] Table 10 shows Israel has the highest share in the business sector, at 85 percent, followed by Japan and Taiwan at 78 percent. The lowest of the top twenty countries, Poland, has a 65 percent share in corporate settings.

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[16] https://stats.oecd.org/Index.aspx?DataSetCode=EDU_GRAD_FIELD# and https://mhrd.gov.in/sites/upload_files/mhrd/files/statistics-new/AISHE2015-16.pdf and http://en.moe.gov.cn/documents/statistics/2018/national/201908/t20190812_394213.html and https://files.eric.ed.gov/fulltext/EJ1087314.pdf

[17] http://uis.unesco.org/sites/default/files/documents/isced-2011-operational-manual-guidelines-for-classifying-national-education-programmes-and-related-qualifications-2015-en_1.pdf (Para. 247) and https://www.oecd-ilibrary.org/education/isced-2011-operational-manual/isced-2011-level-8-doctoral-or-equivalent-level_9789264228368-13-en and http://uis.unesco.org/en/isced-mappings

[18] https://stats.oecd.org/Index.aspx?DataSetCode=EDU_GRAD_FIELD# and http://en.moe.gov.cn/documents/statistics/2018/national/201908/t20190812_394213.html and https://mhrd.gov.in/sites/upload_files/mhrd/files/statistics-new/AISHE2015-16.pdf and https://files.eric.ed.gov/fulltext/EJ1087314.pdf

[19] http://data.uis.unesco.org/ and https://english.moe.gov.tw/cp-86-18943-e698b-1.html

[20] http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en#

The R&D 20

To arrive at an R&D 20, based on the "two percent" table (Table 1), and considering the successive data, (1) the UK is added, for its overall spend and highly ranked universities, and (2) Singapore is included for its per capita spend and *Nature Index* ranking. Iceland is removed for its small size. These changes bring the count to 18.

For the last two, Australia is first selected, for its GDP contribution approaching two percent, university rankings, and high *Nature Index* ranking. The final R&D 20 member is more subjective, but largely between Italy and Canada. Canada is chosen for its higher percentage of GDP spent on R&D (approximately 1.6 and 1.4 percent, respectively), *Nature Index* score, and a greater concentration of Top 500 universities and population with an undergraduate degree. Both Italy and Canada appear to have relatively low levels of R&D spending per capita, and R&D performance in the private sector, but are still above other countries in most rankings. The below groupings summarize the results.

Group A. The R&D 20: Leaders in Research and Development Intensity

1. **Australia** leads in relative intensity of inbound tertiary exchange students, with 28 inbound for every domestic student headed outbound. The country has seen marginally declining total R&D intensity in recent years, from over two percent to slightly less than two percent.

2. **Austria** performs well in most metrics, notably with over three percent of GDP allocated to R&D. It did experience a decline in authorship counts in the *Nature Index* of about nine percent from 2017 to 2018, resulting in a ranking of 22, behind Taiwan and ahead of Brazil.

3. **Belgium** also fares well in most measures, although it is lower in R&D spending per capita relative to neighboring countries such as Denmark and Germany. A high percentage of its population has a university degree, and its *Nature Index* measure grew year over year. Powell and Dusdal (2017) found that its integrated research university system, as opposed to a dual research institute and university system in France and Germany, resulted in higher per capita output than the latter two countries (as measured by publications).[21]

4. **Canada**, in addition to the comments above about R&D performance, has relatively low levels of R&D activity in the business sector, however, the country has a high percentage of inbound foreign students, and strong citation impacts in Scimago.

5. **China** has risen enormously in R&D totals and R&D intensity, and appears on a path to overtake the US as the country with the largest total spend on R&D, and as the world's largest producer of doctoral degrees. The country has launched ambitious initiatives to create domestic R&D, such as Made in China 2025, and to recruit international R&D, such as the Thousand Talents Program. Substantial economic growth has occurred in the last forty years, raising per capita income in the

[21] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5686278/

country from about $300 in 1980 to over $10,000 USD in 2019 (in current prices).

6. **Denmark** has strong rankings overall, with R&D more than three percent of GDP, and growth in its *Nature Index* profile. The country has well-integrated systems of higher education and workforce training.

7. **Finland** has the most favorable ratio of Top 500 universities to population, and, interestingly, one of the less favorable ratios of university faculty to students.

8. **France** shows high R&D intensity overall, if slightly lower in metrics such as spending per capita in comparison to other Western European countries. The country has a differentiated higher education and research sector, with both universities and *grandes écoles*, the latter of which, such as CNRS, perform much of the country's R&D, often in conjunction with university facilities and personnel.[22]

9. **Germany**, as Kerr and others have described, pioneered the graduate-oriented research university as currently defined. It has strong R&D metrics in most areas, ranking third globally for total spend. Some extended comments from Willetts are in order:

   "Under West Germany's constitution universities were the responsibility of the individual Lander and, to stop the federal Government subverting this, it was specifically forbidden from funding them directly. The only way the national government could fund research was via separate federal institutes until they amended the Constitution in 2015 to permit federal funding of university-based research as part of their effort to boost their universities through the Excellence Initiative.

   "Now Germany conducts more of its research, which is of exceptional quality, in its network of Max Planck, Leibniz, Helmholz, and Fraunhofer research institutes with a range of distinct missions ranging from pure to applied research."
   "The German university still does a lot of R&D, funded by the state governments or by research-intensive companies. So a state (a Land) with a big agricultural sector may well sponsor agricultural research in its local university."[23]

10. **Israel** statistically ties with South Korea for R&D spending as a percent of GDP. The country has an exceptional start-up network, focused on close collaborations between higher education, government, and industry. University quality is a concern, with the number of senior research faculty per 100,000 people declining from about 130 to 60 between 1970 and the present.[24] *Start-up Nation* (2011) reports that the tech transfer entity from Hebrew University, "Yissum earns over $1 billion annually in sales of Hebrew-University-based research."[25]

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[22] Ibid.
[23] Willetts, 2017, pp. 92-93.
[24] http://taubcenter.org.il/endangered-species-declining-supply-senior-faculty-members-israels-universities/
[25] Senor and Singer, p. 211.

11. **Japan** performs well in practically all quantitative metrics above. A concern is the commercialization potential for university research, with a 2015 study (Ito, Kaneta, and Sundstrom), noting, "Japanese universities currently possess, arguably, too many patents and also receive relatively low income from patents, resulting in significant pressure on their budgets. The number of Japanese spin-offs created fell significantly between 2005 and 2010, since when the number has remained at around 50 per year."[26]

12. The **Netherlands** has strong university and publication rankings, and an inbound student surplus of about 78,000. Its R&D intensity does appear to be dropping below two percent of GDP. The country also features well-organized coordination between R&D enterprises, including universities.[27]

13. **Norway** has good indicators overall, but lower than other Nordic countries. It also has almost 9,000 more outbound than inbound international students each year. A 2017 paper noted of a recent drop in university commercialization due to a policy reform: "Upon the reform, Norway moved toward the typical US model, where the university holds majority rights. Using comprehensive data on Norwegian workers, firms, and patents, we find a 50% decline in both entrepreneurship and patenting rates by university researchers after the reform. Quality measures for university start-ups and patents also decline."[28]

14. **Singapore** has high R&D per capita, although its R&D as a percentage of GDP appears at risk of falling below two percent (showing at 1.95 in OECD 2017 data). It has a high net inbound international student ratio, and ranks at 28 in the Scimago index for citations.

15. **South Korea** provides a major success story of R&D policy as catalyst for national development in the last fifty years. However, it does have about 35,000 fewer inbound than outbound international students, and a *Nature* article pointed out shortcomings in its universities, such as, "At public universities, tenure and promotion decisions are often based in part on evaluations that count papers by fractional contribution: a four-author paper, for example, would earn a scientist a small fraction of the credit of a single-author one."[29]

16. **Sweden** is fourth in R&D as a percent of GDP, and has a "professor's privilege" approach to IP, whereby the university does not own or control patent rights for research.[30]

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[26] https://innovation-entrepreneurship.springeropen.com/articles/10.1186/s13731-016-0037-9

[27] https://www.rathenau.nl/en/science-figures/policy-and-structure/infrastructure-knowledge/dutch-knowledge-infrastructure and https://www.utwente.nl/en/bms/cheps/research/CHEPSWorkingPaperSeries/chepswpseries201804.pdf

[28] https://www.kellogg.northwestern.edu/faculty/jones-ben/htm/University%20Innovation%20and%20the%20Professors%20Privilege.pdf

[29] https://www.nature.com/news/why-south-korea-is-the-world-s-biggest-investor-in-research-1.19997

[30] https://link.springer.com/article/10.1007/s11024-018-9348-2 and http://ejlt.org/article/view/567/755

17. **Switzerland** has universities that rank highly in measures of international orientation; however, it also have restrictive post-graduate immigration policies. A 2019 article specified, "Graduates, especially in the so-called MINT subjects (mathematics, information technology, natural sciences, technology), could also be in high demand in Switzerland. But only 10-15% of students from countries outside the EU and EFTA get a job in Switzerland after their studies, according to estimates by Economiesuisse, the Swiss Business Federation."[31]

18. **Taiwan** provides another case study for successful national development through industry-university collaboration, as Sainsbury describes.[32] A recent Carnegie Endowment article, notes of a risk and an opportunity here:

    "Taiwan's education system is producing insufficient technical talent while concentrating the talent pool that it does produce into legacy fields connected to semiconductor design, such as electrical engineering. (…)
    "A model of sorts already exists in Taiwan's semiconductor industry. As public funding declines, industry players have agreed to furnish matching funds for university professors and laboratories. This government-industry match funding model could be extended to next-generation fields."[33]

19. The **UK** is described by Willetts as follows: "England's strong powerful autonomous institutions protect freedom of enquiry and promote intellectual diversity within them. They are world-class centers of research. And they compete vigorously with each other. But their very strength can also look to an economist like producer power, with insufficient attention to their students and little competitive challenge from alternative ways of doing things. The challenge I wrestled with as minister and which runs through this account is how to protect their autonomy and strengthen them and their finances whilst opening them up to more challenge and putting them under more pressure to do a better job of educating their students."

    Sainsbury further notes academic-corporate connections are "almost exclusively limited to R&D activities and R&D personnel" in contrast to more extensive curricular, internship, and research linkages in Germany.[34]

20. The **US** remains, for now, the global leader in research and development by most measures. Weaknesses, however, include a stratified university system, with both elite global universities and regional institutions with fewer resources (particularly in regard to research) charging high tuition rates (sometimes with means-tested discounting, but not consistently so).

Group B. The R&D 20-Plus: Strong Performance in Notable Metrics

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[31] https://www.swissinfo.ch/eng/labour-market_non-eu-graduates-struggle-with-swiss-job-access/44959126
[32] Sainsbury, 2020, pp. 99-102.
[33] https://carnegieendowment.org/2020/01/29/assuring-taiwan-s-innovation-future-pub-80920
[34] Sainsbury, 2020, p. 74.

21. **Brazil** is tenth in total R&D spending, fourth in total tertiary enrollment and seventh in doctoral graduates worldwide, the highest in Central in South America in each category. It has four universities in the averaged top 500, and ranks 23rd in the *Nature Index*.

22. **Czechia** (officially the Czech Republic) has about 1.67 percent of GDP spending on R&D (the highest in Eastern Europe), and it has a high number of inbound tertiary students (about 31,000 more inbound than outbound students). It graduates about 22,000 STEM students annually.[35]

23. **Iceland** has strong R&D measures for a small island nation with a single research university. R&D as a percentage of GDP has grown from 1.75 percent in 2013 to 2.18 percent in 2018. With under 400,000 people, it places at 43 in the *Nature Index*, above Pakistan. The country's Policy and Action Plan for Science notes, "Strong universities are essential for Iceland's competitiveness in the future, to foster inventive enterprises that compete on the international market and to ensure that young people are willing to live and work here."[36]

24. **India** has high overall spending on R&D, although low per capita (about $46 USD PPP per UNESCO) and as a percentage of GDP (approximately 0.61 percent, per the World Bank). Although second in the world in total number of tertiary students, it has a relatively low corresponding number of doctorates granted.

25. **Italy** has high total R&D spending, although lower as a percent of GDP. It places highly in the Scimago ranking. It also has a variant of "professor's privilege" allowing for faculty ownership of IP.

26. **New Zealand** has a relatively low level of total R&D intensity, at about 1.37 percent. However, in the last thirty to forty years, the country has (1) diversified from a heavily agricultural economy towards a large services sector (including scientific and technical areas),[37] (2) hosts high numbers of foreign students, and (3) is planning a nationwide overhaul of vocational education.[38]

27. **Russia** is ninth in total R&D spending, fifth in granted doctorates, seventh in total tertiary enrollment, and eighteenth in the *Nature Index*. R&D comprises about 1.1 percent of total GDP.

28. **Saudi Arabia** has high tertiary attainment levels, with about 25 percent of the population with a bachelors degree, and a large-scale scholarship program for young adults to complete studies abroad. It also has a university-focused approach to international research collaborations, in which higher education institutions in the country fund and engage with partner universities around the world. As an example, Saudi universities provided over $50 million in funding to US colleges and universities between 2013 and 2019, according to the US Department Education's Section 117

[35] https://www.czechinvest.org/getattachment/Grunde-zu-investieren/Strong-focus-on-R-D/Research-Development-in-the-Czech-Republic.pdf
[36] https://www.government.is/lisalib/getfile.aspx?itemid=58e09fff-ac4b-11e8-942a-005056bc4d74
[37] https://www.stats.govt.nz/experimental/which-industries-contributed-to-new-zealands-gdp
[38] https://conversation.education.govt.nz/conversations/reform-of-vocational-education/

report.[39] Overall R&D intensity is low, at under one percent of GDP.

29. **South Africa** leads the African continent in R&D spending as a percentage of GDP, at 0.82 percent. The country further has plans to increase this amount to 1.5 percent, along with national IP reforms in 2018 and a country-level commitment to prioritize innovation capacity building.

30. **Spain** ranks at fourteen in total spending, and eleven in both the *Nature Index* and the Scimago ranking. Atkinson and Foote (2019) noted government funding for R&D as a percentage of GDP declined slightly from 2011 to 2017, but less so than in France, Taiwan, the UK, and the US.[40]

31. **Turkey** has high overall spending (low per capita) in R&D, about half that of Spain. It also has a high number of students enrolled in higher education, and ranks 20th in total number of patent filings worldwide (although, at about 8,000 applications in 2018, it does not compare with the top three, China, the US, and Japan, which had 1.54 million, 597,000, and 313,000 respectively that year).[41]

Data Interpretation and Next Steps

Within the R&D 20, variances exist in total amount, intensity, and allocation of R&D activity among universities, governments, and companies. However, it is not possible to discount the importance of tertiary institutions in any R&D 20 nation, as no other type of entity provides the same connections to open international knowledge, or the talent generation that advanced economies require.

As of late 2019 and early 2020, a seeming period of nationalism has challenged the open and international nature of universities, through concerns of espionage and propaganda, trade wars, restrictions on migration of international talent and intellectual property, and de-internationalization projects such as Brexit.

This noted, university R&D dynamics continue as they have for years. First, in 2010, former Yale president Richard Levin wrote of Asian universities in the *New York Times*: “Having made tremendous progress in expanding access to higher education, the leading countries of Asia are focused on an even more challenging goal: building universities that can compete with the finest in the world. The governments of China, India, Singapore and South Korea are explicitly seeking to elevate some of their universities to this exalted status because they recognize the important role that university-based scientific research has played in driving economic growth in the United States, Western Europe and Japan.”[42]

Second, the *Times of Israel* quoted economist Dan Ben-David on talent migration in late 2019: “’The problem is when it becomes one-sided and the flow is primarily outward. When 4.5 academics leave

[39] https://studentaid.gov/data-center/school/foreign-gifts
[40] https://itif.org/publications/2019/10/21/us-funding-university-research-continues-slide
[41] https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2019.pdf (page 33)
[42] https://www.nytimes.com/2010/04/21/opinion/21iht-edlevin.html

Israel for each one that has returned then this becomes a problem. When we stopped building universities at the level of the Technion, Hebrew University and Tel Aviv University, though our population has more than doubled since the 1970s, then we have a problem. When the stock of Israeli doctors abroad continues to increase while the stock of foreign-born doctors in Israel continues to decline, then this no longer a full two-way street.'"[43]

Third, the COVID-19 pandemic in 2020 has highlighted the dependence of Australian universities on foreign students. The *Guardian* reports, "International students contributed $34bn to the Australian economy last year, and the sector faces major losses from students cancelling enrolments. The travel ban has left nearly 100,000 Chinese students with valid visas stranded outside of Australia, according to the latest figures from the Department of Home Affairs."[44]

Part II: Value Generation and Value Capture Considerations

One approach to value generation and value capture is to conceptualize three main ways that universities contribute to the industrial strategies of their home countries, as organized in the following sub-sections.

Value Generation from Domestic Investment in University R&D

This group of activities includes investment and expenditure mechanisms such as competitive research funding grants, cooperative research agreements, and other government contracts to universities.

It also includes government financial support for students, particularly in tuition and salary support for doctoral students in the sciences and engineering.

China, Japan, and the US, for example, provide high levels of financial support per higher education student, relative to other countries as a percentage of GDP per capita. The table below shows performance in this realm by a sample of countries in our groups (specifically, those countries providing data to UNESCO for this metric).[45] The high relative variance among countries comes across as striking, and suggests two points. First, as David Sainsbury advises in *Windows of Opportunity*, "There is no magic recipe that says take one great university, add in large amounts of venture capital, sprinkle with sunshine and an entrepreneurial culture, and a high-tech cluster will spring up."[46]

That is, there is more than one approach to university funding as a means of advancing R&D and national development. Second, and more importantly, such variances should not be used as evidence

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[43] https://www.timesofisrael.com/startup-nation-sees-brain-drain-as-national-priorities-sidelined/
[44] https://www.theguardian.com/world/2020/feb/07/universities-deny-plans-to-put-international-students-in-coronavirus-quarantine
[45] UNESCO Institute for Statistics, as presented by the World Bank, https://data.worldbank.org/indicator/SE.XPD.TERT.PC.ZS and from NCES, https://nces.ed.gov/programs/coe/indicator_cmd.asp, China MOE, Taiwan Statistical Information Network, and Index Mundi.
[46] Sainsbury, 2020, p. 90.

that funding can simply be cut to match countries with lower values, as this metric excludes national- and regional-level context, such as non-governmental funding for students, costs of living, and tuition levels and payment structures.

Comparative national spending levels on students can inform policy conversations on how to optimally generate value for national economic development via investments in undergraduate and graduate-level university students. Table 11 indicates a range in government spending per tertiary student as a ratio to GDP, ranging from 49 percent in India, 46 percent in South Africa, and 43 percent in Sweden, to 18 percent in Israel, 17 percent in Australia, and 15 percent in South Korea.[47]

In a shift to looking beyond student-level funding, towards overall university research spending as a percentage of GDP, Denmark ranks highest, followed by Switzerland and Sweden. Among the R&D 20, China spends the least as a percentage of GDP, at less than half of the relative amount of US, as the next lowest country (refer to the middle column).[48]

By comparing the percent of GDP allocated to business R&D, every country in the sample has greater R&D spending in business than in university settings, but with large variances in the ratios (refer to the right columns). Although countries with higher overall R&D intensity vary, such as the Nordic countries as contrasted with Israel and Korea, less intensive countries tend to have lower multiples of academic R&D spent in industry. Table 12 shows the data from 28 compared countries.

Three lessons appear from the data.

First, funding formulas and value generation strategies differ by country, and there is no ideal ratio between higher education R&D and business R&D, except seemingly for more of total GDP allocated to commercial R&D.

Second, universities seem to provide a relative bargain, in that despite media reports and public perceptions of large and unaccountable university research budgets, in all countries shown below, universities cost less as R&D performers than businesses do.

Third, Israel and South Korea stand out not for their intensity of academic R&D, but for high concentration in industrial sectors. They rank as the two most intensive R&D countries on a GDP basis because of the funding commitments of the companies located within their borders.

Finally, in regard to value generation, statistics for university faculty should be considered. Table 13 ranks a sample of countries (those with available data) on the number of students for each teacher at the tertiary level.[49] Japan and Austria are lowest in a sample of about twenty countries, each with about one instructor for seven students. Turkey is a noticeable outlier, with forty-seven students per faculty member.

[47] http://data.uis.unesco.org/Index.aspx?queryid=183#
[48] http://data.uis.unesco.org/
[49] World Bank, https://data.worldbank.org/indicator/SE.TER.ENRL.TC.ZS with verification from UNESCO (e.g. ensuring accuracy for Turkey and India figures), http://data.uis.unesco.org/index.aspx?queryid=180

Although the figures do not correspond exactly to research faculty, this is nonetheless a metric of how many professors and other academic staff are available to train future R&D practitioners (and to collaborate with current practitioners in government and in industrial labs). Interestingly, although the most intensive R&D countries in general have low ratios, Finland is a notable exception. Again, teaching and research methods can vary, so this is not a pure indicator of value generation among countries, but rather of the spread of one component in that generation.

Value Capture from Domestic Activity at Research Universities

While value generation involves inputs, value capture consists of outputs (economically "captured" by the host country), including IP licensing, startups and university spin-out companies, as well as the career-long know how of university graduates and their contribution to national economies.

An interesting comparison appears in the US, with its 1980 Bayh-Dole Act, which allows universities to assert ownership (and licensing rights) of government-funded inventions, and Canada, which has no comparable national law.[50]

In practice, Canadian institutions appear to operate in similar ways to American counterparts, by claiming ownership. A 2016 op-ed in *University Affairs* explained: "In Canada, universities assign IP in their own individual ways, with most resembling the arrangements made in the US. There are only two to my knowledge that assign 100 percent of the IP to the inventor. They are the University of Waterloo and Dalhousie University. This type of arrangement presumes that the inventors themselves will look after the protection of their IP and move it to commercialization on their own with less than full support from the university. In the case of Dalhousie, if substantial support is provided to the inventor, the IP is split with the university."[51]

In many countries, universities have become a source for considerable potential and earned commercialization revenue from IP licensing activities.[52]

A more significant value that nations can capture from universities, however, is not from licensing IP. University IP tends towards early-stage and by design does not serve the same purposes as ready-to-ship IP outputs from companies. Instead, it is important for universities to focus on their graduates as their main sources of value capture for a nation's economy (and government and society).

First, the *NSF Science and Engineering Indicators* report provides a snapshot of annual first-degree graduates in S&E fields in select R&D 20 countries.[53] Such statistics offer a reminder of the sheer volume of university contributions to a country's workforce. China and the US produce by far the largest

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[50] https://www.law.cornell.edu/cfr/text/37/401.14 and https://www.robic.ca/wp-content/uploads/2017/05/068.129E-FP-H2011.pdf

[51] https://www.universityaffairs.ca/opinion/from-the-admin-chair/universities-require-transparent-intellectual-property-guidelines/ (Also see http://www.sfu.ca/sfublogs-archive/departments/cprost/uploads/2012/10/IP-Policy-Introduction-January-2010FINALCombined.pdf for a chart of university IP policies in Canada from 2010.)

[52] https://www.wipo.int/sme/en/documents/academic_patenting.html

[53] https://ncses.nsf.gov/pubs/nsb20197/data Table S2-15.

numbers of S&E graduates, at 1.7 million and over 700,000, respectively, with Japan next at under 200,000, as of 2016 (2015 for China).

Second, the IP, know-how and new product development from university graduates inside and outside of the academy (that is, not just through university IP licensing) contributes to national value capture. Mariana Mazzucato's revelatory 2013 work (revised in 2015), *The Entrepreneurial State*, famously shows a chart of iPhone components, with each constituent part naming the government entity that funded or invented the underlying blockbuster commercial technology. For instance, lithium-ion batteries emerged from US Department of Energy funding, GPS from the US Navy, HTML from CERN, and SIRI from DARPA (which also began the internet itself).[54]

It is conceivable to extend Mazzucato's idea by showing the university alumni who contributed to iPhone R&D, from basic to applied research, to ultimate design and commercialization, not to mention manufacturing, supply chain, and marketing and sales, and future iterations. In addition, diagrams could be built out of all of the university researchers who collaborated with government and industry as co-authors, advisors, and other knowledge partners, in the multi-decade evolution of the smartphone.

Value Capture from the Foreign Activities of Research Universities

This group of activity encompasses the degree to which a country's government, market, or civic mechanisms capture innovation, or opportunities for economic growth, from R&D done outside the country's borders. Many of the nations which have been most successful at economic development over the last fifty years have had this activity as a major focus of their tech-based industrial policy.

Obtaining returns on foreign effort and investment, in monetary, knowledge-based, and cultural terms, can involve both locations outside of the host country, and foreign students and researchers within the host country (as both actions can be thought of as foreign activities and exports).

Foreign-located activities can involve research partnerships, international branch campuses, and temporary outbound student and research exchange. Foreign activity within the host country encompasses inbound foreign students and researchers (either temporary or long-term) and their contributions to the university and nation.

The Institute of International Education provides information on the number of inbound foreign students in select R&D 20 countries.[55] This data is presented in Table 15. The US has, by far, the most inbound students, at nearly 1.1 million as of 2018, and more than twice the number of the second highest, the UK. Australia has the highest percentage of international students relative to the total student count, at about 32 percent.

When considering the inbound-to-outbound balance of international students in host countries from UNESCO data, the US appears as the largest net exporter, which is to say that it receives the most net

[54] Mazzucato, 2015, p. 116. Also see Sainsbury, 2020, p. 216.
[55] https://www.iie.org/en/Research-and-Insights/Project-Atlas/Explore-Data/Infographics/2019-Project-Atlas-Infographics

foreign inbound students, at almost 900,000 per year. China is the largest net importer, as it sends almost 800,000 more students abroad than come to China to study each year.[56] Table 16 presents the data across R&D 20 countries.

In most cases, as a percentage and as a sheer quantity, international students comprise a significant number of overall higher education students. Many R&D 20 countries have work visa programs for recent international S&E graduates, further providing contributions to national economies from what are, essentially, exports of education to foreign citizens within the host country.

The above figures do not include full- and part-time online students, nor students participating with faculty and fellow students in varied levels of synchronous and asynchronous engagement in online open courses.

International branch campuses (IBCs) represent another model of university value capture in foreign settings. A 2019 report from World Education Services (WES) indicated about 250 such campuses globally, up from about 50 in 1995, with the most IBCs in China and the UAE, with approximately thirty each.[57] The US and UK constituted the largest "sending" countries, with about eighty and forty IBCs, respectively.

IBCs represent potential revenue streams for universities, as well as branding and name recognition abroad, and increased prestige domestically, for their home institutions. Although they seldom have extensive R&D operations, they nonetheless provide a pipeline for students, researchers, and faculty towards further engagement with the central university's research enterprise efforts.

David Willetts notes of successes of UK IBCs, writing, "The University of Nottingham has led the way with excellent campuses in China and in Malaysia. Liverpool University has also got a well-regarded campus in China, and a few other universities have also done this, though it does require a lot of work."[58]

Interestingly, Liverpool University was an early provider of online degrees. Via a partnership started in 2000 with a private-sector partner, Laureate, the university had awarded taught masters and doctorates to 12,000 students in over 170 countries as of 2019.[59]

While branch and virtual campuses can serve as a financial and recruitment tool for research universities, they do not always succeed in the long-run. WES notes, "of the more than 30 US IBCs established in Japan in the 1980s, only one, Temple University, Japan Campus, remains today"[60]

There has also been dramatic growth in international research collaborations, and co-authored papers by international authors, in recent decades. The NSF's 2020 *Science & Engineering Indicators* report

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[56] http://data.uis.unesco.org/Index.aspx?queryid=172 and http://data.uis.unesco.org/Index.aspx?queryid=171
[57] https://wenr.wes.org/2019/05/the-complex-environment-of-international-branch-campuses
[58] Willetts, 2017, p. 317.
[59] https://www.liverpool.ac.uk/aqsd/collaborative-provision/laureate/
https://www.kaplanpathways.com/about/news/university-of-liverpool-partners-with-kaplan-open-learning/
[60] WES, ibid.

demonstrates the rise of internationally-authored papers across science and engineering fields worldwide since the mid-1990s. This data is shown in Table 17.[61] International articles grew from 12 percent of the total count in 1996, to 22 percent in 2018. The total output of publications in the same period increased from under one million in the mid-1990s to more than 2.5 million in the late 2010s.

For international authorships by country, the US, UK, Germany, and China had the highest number collaborations with other countries, as of the latest UNESCO data, covering 2008 to 2014. Table 18 shows the top twenty countries in this metric.[62]

In commercial partnerships, IP licensing, and startups, as business has become more international, so have university collaborations with industry. A biotech startup, for instance, could have an academic co-founder in Europe, a main office in Silicon Valley, and labs in Asia.

The 2019 Nobel Prize in Chemistry, for the invention of lithium-ion (Li-ion) batteries, offers an example of partnerships across institutions and countries. The award went to one researcher in Japan and two in the US (both of whom conducted prior work in the UK). From initial experiments at Exxon in the 1970s, Sony commercialized Li-ion in Japan in the early 1990s, and today, Li-ion manufacturing in the US has a $5 billion market value, and provides essential power for cell phones, laptops, and electric vehicles. This technology would not have been possible without decades of international scientific collaboration, including at universities, to develop it.

With such levels of international collaborations and exchanges, the lines of foreign and domestic can become blurred. The trend is clear that global R&D is becoming increasingly an international enterprise, and, specifically, that university academic staff will work across borders as part of their efforts in both research and instruction.

University operations often span instruction, teaching, and outside engagement. In 1945, Vannevar Bush, in *Science: The Endless Frontier* emphasized that higher education institutions “must furnish both the new scientific knowledge and the trained research workers”.[63]

Writing seventy-five years ago, Bush further recognized the importance of universities in facilitating international knowledge transfer. *The Endless Frontier* proposed an agency, which would become the US National Science Foundation, with remit including coordination of functional areas naturally housed at tertiary educational institutions: “To support international cooperation in science by providing financial aid for international meetings, associations of scientific societies, and scientific research programs organized on an international basis.”[64]

[61] https://ncses.nsf.gov/pubs/nsb20206/international-collaboration
[62] https://en.unesco.org/sites/default/files/tab_usr15_s10_publications_collaboration_en.pdf
[63] https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm
[64] Ibid.

In a sample of 11 countries, including China and the US, higher education accounted for 49 percent of basic research expenditures, 22 percent in applied research, and two percent in the development stage.[65] Figure 1 presents this data.

It is Important to accompany these metrics with an explainer that the R&D functions of advanced industrialized countries could not operate effectively without this contribution of universities. Attempting R&D without this share of university basic research would be comparable to chemical engineering unable to use half of the elements in the periodic table.

The later stages of R&D depend on basic research. Again, there are no iPhones, solar panels, or pharmaceuticals without their underlying components and concepts. Universities form an essential financial and technical link in the lifecycle of R&D.

Immigrants comprise a substantial portion of the overall population in many R&D-intensive countries, but not in all such nations.[66] While the US counts more than 50 million foreign-born residents, the figure in China is under one million. Table 19 presents this data set.

Given the international mobility of researchers, and the contribution of universities to a national talent pool, the ability of a country to retain R&D staff should correlate to university value capture in technical personnel. Table 20 shows the number of researchers per million people in the top twenty countries in this metric.[67]

Universities or governments could model economic competition restrictions on export controls for commercialization-related activities such as applied research collaborations, IP licensing, and spinout companies. This could conceivably be based on international rankings of countries in IP protections and economic transparency and best business practice criteria, with countries in groups, or those under a certain threshold subject to additional fees or restrictions.

Two such rankings are presented, as example mechanisms that could be used in such economic competition and fair play measures. The first, the *Peddling Peril Index*, from the Institute for Science and International Security, evaluates countries on the following: International Commitment ("preventing strategic commodity trafficking"), Legislation, Ability to Monitor and Detect Strategic Trade, Ability to Prevent Proliferation Financing, and Adequacy of Enforcement.[68]

The second, the *U.S. Chamber International IP Index*, ranks the following: "the IP infrastructure in each economy based on 45 unique indicators, which are critical to the growth of effective IP systems. The indicators span 8 categories of IP protection: patents, copyrights, trademarks, trade secrets, commercialization of IP assets, enforcement, systemic efficiency, and membership and ratification of

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65 http://data.uis.unesco.org/Index.aspx?DataSetCode=SCN_DS&lang=en# Countries in the sample: China, Czechia, Iceland, Italy, Japan, Netherlands, Republic of Korea, Russia, Spain, UK, US

66 https://www.un.org/en/development/desa/population/migration/publications/migrationreport/migreport.asp and, for Taiwan, https://thediplomat.com/2019/01/how-taiwanese-think-about-immigration/

67 https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6?end=2018&start=1996&view=chart

68 https://isis-online.org/ppi/detail/peddling-peril-index-for-2019/

international treaties."[69]

The rankings are shown in Table 21, sorted by a simple average score of the two measures. Some countries are not included in the IP Index, so they are noted in a separate list at the end of the table. The US and the UK rank first, with China and Russia ranking lowest in the sample.

Conclusion: Expectations for Universities in the R&D 20

Current university and university-affiliated research enterprises have of all of the following: lab and technical facilities, publication counts, working know-how, dynamic capabilities (in number and in scope), proprietary and open affiliated entities, international collaborations, and engagements with academic, government and local and global industries.

They are expected to provide internships and organized practical experiences for students, increasingly complex grants and contracts for researchers, and gigabyte-level cloud-storage folders of work visa forms (and requisite attachments) for foreign graduates hoping to stay on at nearby startups rather than return to their home countries.

These purposes come at a time with simultaneous expectations and demands for transparency, international partnerships, local and national benefits, general optimization, and metrics reporting all of the above, amidst seemingly less assured and more competitive funding sources.

A comparative indicator of economic growth in the last four decades merits consideration as well. While all countries in the sample have shown economic growth, a few stand out. The only instances in the sample to exceed GDP per capita growth of over 1,000 percent since 1980 are in Asia, and China presents a clear outlier, with an increase above 3,000 percent per capita over forty years. In 1980, the GDP per capita in China was less than three percent of that in the United States. As of 2019, that ratio had grown to about 15 percent. The metrics in Table 22 come from the IMF.[70]

[69] https://www.theglobalipcenter.com/ipindex2019-chart/

[70] https://www.imf.org/external/datamapper/NGDPDPC@WEO/OEMDC/ADVEC/WEOWORLD

Appendix: Comparative Data Tables on R&D Performance

Figure 1. Research by type

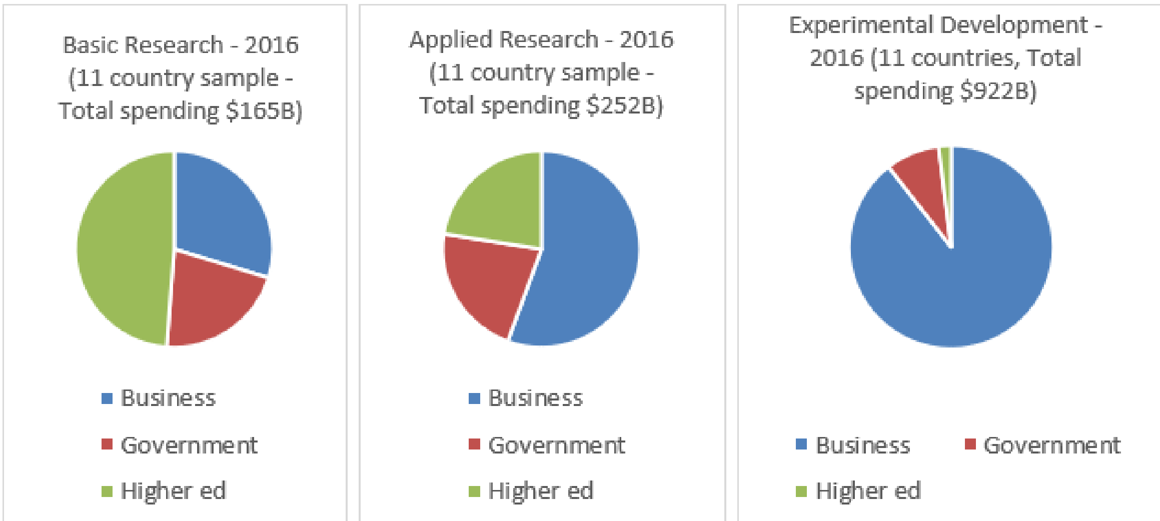

Table 1. Nations with R&D expenditures greater than two percent of GDP in 2017 (UNESCO and OECD)

Rank (Average)	**Country**	UNESCO 2017	OECD 2017	**Resulting Average: Estimated R&D as % of GDP**	Variance: OECD vs. UNESCO, 2017 data (rounded)
1	**Israel**	4.576	4.545	**4.560**	-0.031
2	**Korea, South**	4.553	4.553	**4.553**	0.000
3	**Switzerland**	Not included	3.373	**3.373**	N/A
4	**Sweden**	3.312	3.397	**3.354**	0.085
5	**Taiwan**	Not included	3.295	**3.295**	N/A
6	**Japan**	3.205	3.213	**3.209**	0.008
7	**Austria**	3.159	3.157	**3.158**	-0.002
8	**Denmark**	3.103	3.046	**3.074**	-0.057
9	**Germany**	3.035	3.038	**3.036**	0.002
10	**US**	2.802	2.788	**2.795**	-0.014
11	**Finland**	2.762	2.757	**2.760**	-0.005
12	**Belgium**	2.606	2.702	**2.654**	0.096
13	**France**	2.189	2.185	**2.187**	-0.003
14	**Iceland**	2.179	2.145	**2.162**	-0.034
15	**China**	2.129	2.104	**2.116**	-0.024
16	**Norway**	2.113	2.093	**2.103**	-0.020
17	**Netherlands**	2.002	1.991	**1.996**	-0.011

Table 2. Total R&D spending by country (UNESCO)

Top 20 rank	Country	Year	Total GERD (General expenditures in R&D) in current PPP$
	World Total	*2017*	*$ 2,192,381,201,326.92*
1	US	2017	$ 543,249,000,000.00
2	China	2017	$ 499,099,117,129.16
3	Japan	2017	$ 170,900,736,316.29
4	Germany	2017	$ 131,339,461,049.18
5	Korea (South)	2017	$ 90,979,631,227.59
6	France	2017	$ 64,672,100,921.38
7	India	2018	$ 62,715,994,256.11
8	UK	2017	$ 49,345,308,636.08
9	Russia	2017	$ 41,868,011,829.74
10	Brazil	2017	$ 41,120,996,294.33
11	Italy	2017	$ 33,542,892,227.26
12	Canada	2018	$ 27,682,642,211.27
13	Spain	2017	$ 21,914,133,774.15
14	Turkey	2017	$ 21,729,494,505.30
15	Netherlands	2017	$ 18,563,587,767.04
16	Switzerland	2015	$ 17,854,924,821.28
17	Sweden	2017	$ 17,201,413,636.63
18	Israel	2017	$ 15,391,501,014.45
19	Austria	2017	$ 14,966,432,460.62
20	Belgium	2017	$ 14,582,744,079.20

Table 3. R&D per capita (UNESCO)

Top 20 rank	Country	Year	R&D spending per capita (USD)
1	Switzerland	2015	$ 2,152.03
2	Singapore	2016	$ 1,964.97
3	Israel	2017	$ 1,867.03
4	Republic of Korea	2017	$ 1,780.55
5	Sweden	2017	$ 1,736.66
6	Austria	2017	$ 1,696.89
7	United States	2017	$ 1,671.10
8	Denmark	2017	$ 1,670.52
9	Taiwan	2017	$ 1,667.50
10	Germany	2017	$ 1,588.94
11	Luxembourg	2017	$ 1,362.15
12	Japan	2017	$ 1,340.37
13	Norway	2017	$ 1,307.06
14	Finland	2017	$ 1,277.06
15	Belgium	2017	$ 1,276.98
16	Iceland	2017	$ 1,208.53
17	Netherlands	2017	$ 1,090.61
18	France	2017	$ 997.37
19	Australia	2013	$ 994.62
20	United Arab Emirates	2018	$ 976.63

Table 4. Top 500 university rankings (QS, ARWU, THE)

Top 20+	Country	# in QS 2020 Top 500	# in ARWU 2020 Top 500	# in Times Higher Ed 2020 Top 500	Average # in Top 500	2018 population (World Bank)	In-country population per Top 500 university
1	US	89	137	121	**115.7**	327,167,434	2,828,537
2	UK	50	36	58	**48.0**	66,488,991	1,385,187
3	Germany	29	30	40	**33.0**	82,927,922	2,512,967
4	China	24	58	17	**33.0**	1,392,730,000	42,203,939
5	Australia	26	23	30	**26.3**	24,992,369	949,077
6	France	17	29	20	**22.0**	66,987,244	3,044,875
7	Italy	12	16	27	**18.3**	60,431,283	3,296,252
8	Canada	17	18	18	**17.7**	37,058,856	2,097,671
9	Japan	17	14	13	**14.7**	126,529,100	8,626,984
10	Netherlands	13	12	13	**12.7**	17,231,017	1,360,343
11	South Korea	15	11	11	**12.3**	51,635,256	4,186,642
12	Spain	12	13	6	**10.3**	46,723,749	4,521,653
13	Sweden	8	11	11	**10.0**	10,183,175	1,018,318
14	Switzerland	8	8	10	**8.7**	8,516,543	982,678
15	Russia	16	4	5	**8.3**	144,478,050	17,337,366
16	Belgium	7	7	8	**7.3**	11,422,068	1,557,555
17	Finland	8	5	6	**6.3**	5,518,050	871,271
18	Austria	5	6	7	**6.0**	8,847,037	1,474,506
19	Taiwan	11	3	3	**5.7**	23,576,705	4,160,595
20	Hong Kong	6	5	6	**5.7**	7,451,000	1,314,882
21	Denmark	5	5	6	**5.3**	5,797,446	1,087,021
22	India	9	1	6	**5.3**	1,352,617,328	253,615,749
23	New Zealand	8	4	4	**5.3**	4,885,500	916,031
				Averages	**19.0**	168,878,092	15,710,874

Table 5. Nature Index rankings

Top 20 Countries	Country	Share 2017	Share 2018	2017 to 2018 Change
1	US	19859.38	20061.64	202.26
2	China	9228.70	11183.75	1955.05
3	Germany	4424.83	4472.62	47.79
4	UK	3672.59	3667.40	-5.19
5	Japan	3088.25	2987.34	-100.91
6	France	2234.45	2151.96	-82.49
7	Canada	1563.41	1585.29	21.88
8	Switzerland	1351.55	1382.67	31.12
9	South Korea	1293.86	1322.84	28.98
10	Australia	1097.22	1235.78	138.56
11	Spain	1104.01	1130.23	26.22
12	Italy	1037.41	1003.79	-33.62
13	India	960.68	929.22	-31.46
14	Netherlands	915.51	910.60	-4.91
15	Sweden	605.31	616.63	11.32
16	Israel	587.71	600.77	13.06
17	Singapore	598.33	597.81	-0.52
18	Russia	409.49	451.95	42.46
19	Belgium	403.89	408.60	4.71
20	Denmark	361.23	397.32	36.09

Table 6. Scimago citation rankings

Top 20 (Citations)	Country	Citable documents	Citations (for documents published from 1996 to 2018)	Citations per document
1	US	10,701,848	297,655,815	24.66
2	UK	2,935,537	77,355,297	22.43
3	Germany	2,787,096	61,262,766	20.29
4	China	5,785,424	48,833,849	8.27
5	Japan	2,630,141	42,767,077	15.55
6	France	1,969,558	42,219,660	19.91
7	Canada	1,569,064	39,431,612	22.60
8	Italy	1,587,823	32,252,528	18.49
9	Australia	1,204,470	27,018,516	19.83
10	Netherlands	872,993	25,586,850	26.46
11	Spain	1,262,302	23,570,723	17.13
12	Switzerland	648,991	19,461,396	27.38
13	Sweden	604,085	16,383,158	24.98
14	India	1,551,015	15,035,059	9.00
15	South Korea	1,067,096	14,306,940	12.95
16	Belgium	486,066	12,126,138	22.85
17	Brazil	888,530	10,225,275	10.90
18	Denmark	357,963	10,115,806	25.73
19	Taiwan	633,680	8,757,902	13.30
20	Israel	344,498	8,735,337	23.20

Table 7. Total tertiary enrollment (UNESCO)

Top 20 countries	Country	Total tertiary enrollment (2017)
1	China	44,127,509
2	India	33,374,107
3	US	19,014,530
4	Brazil	8,571,423
5	Indonesia	7,944,099
6	Turkey	7,198,987
7	Russian Fed.	5,886,641
8	Mexico	4,430,248
9	Japan	3,853,034
10	Philippines	3,589,484
11	Argentina	3,140,963
12	Rep. of Korea	3,136,395
13	Germany	3,091,694
14	Egypt	2,914,473
15	Bangladesh	2,763,254
16	France	2,532,831
17	Colombia	2,446,314
18	UK	2,431,886
19	Spain	2,010,183
20	Pakistan	1,941,478

Table 8. Doctoral-level degrees granted (OECD and alternative sources for China, India, Taiwan)

Top 20 countries	Country	Year	Doctoral-level degrees granted
1	United States	2017	71,042
2	China	2018	59,638
3	Germany	2017	28,404
4	United Kingdom	2017	28,143
5	Russia	2017	27,338
6	India	2015-2016	24,171
7	Brazil	2017	21,609
8	Spain	2017	20,049
9	Japan	2017	15,674
10	Korea	2017	14,316
11	France	2017	13,583
12	Italy	2017	9,399
13	Mexico	2017	9,310
14	Australia	2017	9,242
15	Canada	2017	8,003
16	Turkey	2017	6,045
17	Netherlands	2017	4,747
18	Taiwan	2013	4,048
19	Switzerland	2017	4,150
20	Sweden	2017	3,586

Table 9. Population with undergraduate degrees or higher (UNESCO)

Top 20 countries	Country	% of Population with bachelors degree or higher (2017 or latest year)
1	United Arab Emirates	46.56%
2	Israel	35.00%
3	Lithuania	34.54%
4	Taiwan	34.35%
5	Georgia	34.02%
6	UK	33.92%
7	US	33.44%
8	Belgium	32.17%
9	Australia	31.39%
10	Ireland	31.16%
11	Bermuda	31.11%
12	Denmark	30.98%
13	Singapore	30.71%
14	Netherlands	29.41%
15	Latvia	29.33%
16	New Zealand	28.10%
17	Norway	28.07%
18	Cyprus	26.62%
19	Saudi Arabia	25.98%
20	Canada	25.75%

Table 10. R&D performed in business (UNESCO)

Top 20 countries	Country	Time	% of total GERD (R&D) performed by business enterprise
1	Israel	2016	85.64%
2	Japan	2016	78.75%
3	Taiwan	2017	78.74%
4	Republic of Korea	2016	77.74%
5	China	2016	77.46%
6	United Arab Emirates	2016	76.60%
7	Slovenia	2016	75.70%
8	Hungary	2016	74.14%
9	Bulgaria	2016	73.26%
10	Thailand	2016	72.95%
11	US	2016	72.58%
12	Ireland	2016	72.20%
13	Austria	2016	70.21%
14	Belgium	2016	70.05%
15	Sweden	2016	69.58%
16	Germany	2016	68.16%
17	UK	2016	67.08%
18	Belarus	2016	66.84%
19	Finland	2016	65.84%
20	Poland	2016	65.67%

Table 11. Government spending per tertiary student, as % of GDP per capita (UNESCO)

Rank in sample	Country	2016 Government expenditure per student, tertiary (% of GDP per capita)
1	India (2013)	49.17
2	South Africa (2017)	46.77
3	Sweden	43.25
4	Denmark (2014)	43.13
5	Norway	39.82
6	United Kingdom	37.99
7	Austria	36.24
8	Netherlands	35.78
9	Germany	33.58
10	Brazil (2015)	33.28
11	Belgium	32.13
12	Canada	31.55
13	Iceland	27.31
14	New Zealand	25.20
15	Italy	24.33
16	Singapore (2017)	24.17
17	Spain	21.82
18	Czech Republic	20.34
19	Russian Federation	19.82
20	Israel	18.18
21	Australia	17.86
22	Korea, Rep.	15.02

Table 12. University R&D as GDP percentage, with comparison to industrial R&D (UNESCO)

Rank in sample	Country	Year	GERD - performed by higher education as a percentage of GDP	GERD - performed by business enterprise as a percentage of GDP	Business R&D multiple of higher education R&D
1	Denmark	2017	**1.01%**	1.97%	1.95
2	Switzerland	2015	**0.90%**	2.39%	2.66
3	Sweden	2017	**0.86%**	2.35%	2.74
4	Norway	2017	**0.70%**	1.12%	1.59
5	Austria	2017	**0.70%**	2.22%	3.16
6	Finland	2017	**0.70%**	1.80%	2.57
7	Iceland	2017	**0.66%**	1.38%	2.08
8	Australia	2016	**0.65%**	1.03%	1.57
9	Canada	2018	**0.64%**	0.81%	1.27
10	Singapore	2016	**0.63%**	1.30%	2.07
11	Netherlands	2017	**0.59%**	1.17%	1.97
12	Belgium	2017	**0.54%**	1.76%	3.25
13	Germany	2017	**0.52%**	2.09%	4.01
14	Israel	2017	**0.52%**	3.91%	7.56
15	France	2017	**0.45%**	1.42%	3.13
16	UK	2017	**0.39%**	1.12%	2.85
17	Republic of Korea	2017	**0.39%**	3.62%	9.36
18	Japan	2017	**0.39%**	2.53%	6.56
19	US	2017	**0.36%**	2.04%	5.61
20	Czechia	2017	**0.35%**	1.13%	3.20
21	New Zealand	2015	**0.35%**	0.63%	1.83
22	Italy	2017	**0.33%**	0.83%	2.54
23	Spain	2017	**0.33%**	0.66%	2.03
24	Turkey	2017	**0.32%**	0.55%	1.70
25	South Africa	2016	**0.27%**	0.34%	1.27
26	China	2017	**0.15%**	1.66%	10.79
27	Russian Federation	2017	**0.10%**	0.67%	6.67
28	India	2018	**0.04%**	0.27%	6.61

Table 13. Tertiary student-faculty ratio (UNESCO)

Rank in sample	Country name	Pupil-teacher ratio, tertiary, 2017
1	Japan	6.88
2	Austria	7.18
3	Germany	7.59
4	Norway	8.56
5	Switzerland	8.73
6	Russian Federation	9.86
7	United States	12.02
8	Spain	12.03
9	Sweden	12.28
10	Netherlands	12.74
11	Singapore	13.34
12	Korea, Rep.	14.28
13	United Kingdom	15.56
14	New Zealand	15.96
15	Belgium	16.95
16	Brazil	19.24
17	Finland	19.84
18	Saudi Arabia	20.04
19	Italy	20.12
20	India	24.44
21	Turkey	47.44

Table 14. Granted S&E first degrees (UNESCO)

Rank in sample	Country	2016 Granted S&E undergraduate degrees
1	China (2015)	1,716,413
2	United States	768,291
3	Japan	178,891
4	United Kingdom	169,832
5	Germany	155,533
6	Korea, Rep.	146,438
7	France	129,028
8	Taiwan	80,504
9	Canada	77,834
10	Australia	55,093
11	Netherlands	28,577
12	Israel	23,380
13	Sweden	19,241
14	Switzerland	17,371
15	Austria	15,809
16	Finland	12,918
17	Denmark	12,791
18	New Zealand	12,450
19	Belgium	10,702

Table 15. Inbound foreign tertiary students by country (IIE)

Rank in sample	Country	Inbound foreign tertiary students, 2018	Percentage of total tertiary enrollment
1	United States	1,094,792	5.50%
2	United Kingdom	506,480	21.00%
3	China	489,200	1.10%
4	Australia	371,885	32.00%
5	Canada	370,710	18.30%
6	France	343,386	12.80%
7	Germany	265,484	9.50%
8	Japan	188,384	5.10%
9	Netherlands	76,462	10.70%
10	New Zealand	61,402	15.20%
11	Sweden	35,862	10.40%
12	Finland	30,807	10.40%

Table 16. Inbound and outbound international tertiary students (UNESCO)

Country	Net inbound tertiary students (2017)	Inbound to outbound ratio (2017)
US	898,332	11.38
UK	400,482	12.36
Australia	367,707	28.25
Russia	193,999	4.42
France	169,001	2.89
Canada	160,593	4.25
Germany	136,678	2.12
Japan	132,606	5.18
Netherlands	77,851	5.22
New Zealand	47,911	11.05
Switzerland	39,034	3.72
Czechia	31,102	3.36
Singapore	29,489	2.24
Saudi Arabia	*(5,966)*	*0.93*
Norway	*(8,746)*	*0.51*
Iran	*(31,485)*	*0.40*
Korea (South)	*(34,603)*	*0.67*
Brazil	*(38,170)*	*0.35*
India	*(285,330)*	*0.14*
China	*(770,982)*	*0.17*

Table 17. International authorship (NSF)

Year	Total S&E articles (worldwide)	Co-authored with international institutions	International articles as percent of total	Relative increase in international percentage above 1996 level
1996	972,746	120,323	12.37%	
1997	1,008,481	128,684	12.76%	3.16%
1998	1,017,971	135,492	13.31%	7.60%
1999	1,023,842	138,116	13.49%	9.06%
2000	1,071,952	145,362	13.56%	9.63%
2001	1,108,034	143,083	12.91%	4.40%
2002	1,155,683	159,002	13.76%	11.23%
2003	1,216,799	199,195	16.37%	32.35%
2004	1,328,748	219,381	16.51%	33.48%
2005	1,493,822	244,097	16.34%	32.10%
2006	1,574,326	262,099	16.65%	34.59%
2007	1,667,152	283,230	16.99%	37.35%
2008	1,755,850	300,282	17.10%	38.26%
2009	1,857,115	324,359	17.47%	41.20%
2010	1,948,805	344,357	17.67%	42.85%
2011	2,051,840	371,037	18.08%	46.19%
2012	2,110,004	401,031	19.01%	53.65%
2013	2,179,056	431,857	19.82%	60.22%
2014	2,264,127	463,722	20.48%	65.58%
2015	2,294,092	485,274	21.15%	71.01%
2016	2,377,180	514,666	21.65%	75.03%
2017	2,465,689	543,064	22.02%	78.06%
2018	2,555,959	575,857	22.53%	82.14%

Table 18. International article collaborations (UNESCO)

Top 20 rank	Country	Total publication count, 2008 to 2014	Total international collaboration publication count, 2008 to 2014	Int'l % of total
1	United States	2,151,180	749,287	34.8%
2	United Kingdom	582,678	325,807	55.9%
3	Germany	608,713	320,067	52.6%
4	China	1,137,882	277,145	24.4%
5	France	438,755	238,170	54.3%
6	Canada	357,500	180,314	50.4%
7	Italy	366,894	168,632	46.0%
8	Spain	309,076	147,698	47.8%
9	Japan	523,744	142,163	27.1%
10	Australia	269,403	138,976	51.6%
11	Netherlands	202,703	118,246	58.3%
12	Switzerland	157,286	108,371	68.9%
13	Sweden	136,603	84,276	61.7%
14	Korea, Rep. of	298,768	82,513	27.6%
15	Belgium	115,353	74,806	64.8%
16	India	314,669	67,146	21.3%
17	Brazil	232,381	65,925	28.4%
18	Austria	81,174	53,248	65.6%
19	Denmark	85,311	52,635	61.7%
20	Poland	144,090	49,019	34.0%

Table 19. Immigrant population figures (UN)

Country	Immigrant Population, 2017, from UN	Approximate % (of country total population) comprised of immigrants
Australia	7,035,560	27.92%
Austria	1,660,283	18.43%
Belgium	1,268,411	11.01%
Canada	7,861,226	21.01%
China	999,527	0.07%
Denmark	656,789	11.25%
Finland	343,582	6.21%
France	7,902,783	12.13%
Germany	12,165,083	14.57%
Israel	1,962,123	23.03%
Japan	1,151,865	0.91%
Korea, Rep.	2,321,476	4.53%
Netherlands	2,056,520	11.90%
New Zealand	1,067,423	22.32%
Singapore	2,623,404	45.20%
Sweden	1,747,710	17.41%
Switzerland	2,506,394	29.17%
Taiwan	770,000	3.26%
UK	8,841,717	13.09%
US	49,776,970	15.13%

Table 20. Researchers per million people (World Bank via UNESCO)

Top 20 rank	Country	Researchers in R&D (per million people), 2016 or latest data
1	Israel (2012)	8341.65
2	Denmark	7846.66
3	Sweden	7154.53
4	Korea, Rep.	7086.45
5	Iceland	6640.46
6	Finland	6531.48
7	Norway	6077.57
8	Japan	5209.37
9	Austria	5136.78
10	Germany	4861.74
11	Belgium	4780.52
12	Netherlands	4776.84
13	Luxembourg	4667.99
14	United Kingdom	4357.93
15	Canada	4263.76
16	United States	4245.27
17	Ireland	4214.64
18	Portugal	4004.54
19	Slovenia	3914.26
20	Hong Kong SAR, China	3741.26

Table 21. PPI and IIP rankings

Rank in Sample	Country	*Peddling Peril Index* (PPI) points (higher is better)	*U.S. Chamber International IP Index* 2019 (higher is better)	Simple average score
1	US	1019	42.66	530.8
2	UK	1018	42.22	530.1
3	Sweden	987	41.03	514.0
4	Germany	969	40.54	504.8
5	Australia	966	36.06	501.0
6	Singapore	959	37.12	498.1
7	Netherlands	926	40.07	483.0
8	Spain	904	37.07	470.5
9	France	896	41.00	468.5
10	South Korea	897	36.06	466.5
11	Italy	884	36.58	460.3
12	Canada	883	29.88	456.4
13	New Zealand	882	30.63	456.3
14	Switzerland	854	37.25	445.6
15	Japan	818	39.48	428.7
16	Israel	821	29.89	425.4
17	India	713	16.22	364.6
18	Brazil	688	18.25	353.1
19	Taiwan	677	28.05	352.5
20	Turkey	650	21.09	335.5
21	Saudi Arabia	583	16.47	299.7
22	China	537	21.45	279.2
23	Russia	452	19.46	235.7
I	Austria	927	Not ranked	N/A
II	Czechia	912	Not ranked	N/A
III	Belgium	897	Not ranked	N/A
IV	Denmark	894	Not ranked	N/A
V	Finland	876	Not ranked	N/A
VI	Norway	854	Not ranked	N/A
VII	Iceland	759	Not ranked	N/A
VIII	South Africa	749	Not ranked	N/A

Table 22. GDP growth by country over thirty-nine years (IMF)

Country	GDP per capita, USD, 1980 (current prices USD), from IMF	GDP per capita, 2019 (current prices USD), from IMF	Growth in GDP per capita, 1980 to 2019
Sample Average	*$9,972*	*$47,017*	*722%*
Australia	$10,986	$53,825	490%
Austria	$10,732	$50,023	466%
Belgium	$12,596	$45,176	359%
Canada	$11,280	$46,213	410%
China	$309	$10,099	3265%
Denmark	$13,886	$59,795	431%
Finland	$11,258	$48,869	434%
France	$13,070	$41,761	320%
Germany	$11,110	$46,564	419%
Israel	$6,075	$42,823	705%
Japan	$9,466	$40,847	431%
Korea, Rep.	$1,761	$31,431	1785%
Netherlands	$13,749	$52,368	381%
New Zealand	$7,204	$40,634	564%
Singapore	$5,005	$63,987	1278%
Sweden	$16,423	$51,242	312%
Switzerland	$18,870	$83,717	444%
Taiwan	$2,368	$24,828	1049%
UK	$10,735	$41,030	382%
US	$12,553	$65,112	519%

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