The scientific and societal impact of the World Premier International Research Center Initiative

Prepared for JSPS
by Dimensions and Altmetric

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Contents

1 Executive Summary

The World Premier International Research Center Initiative (WPI) was launched in 2007 under the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) to create "globally visible" Japanese research centers focused upon basic research. Since its inception, WPI institutes have emphasized a high degree of international collaboration, innovation, and research quality, with specific aims of recruiting world-class international researchers and producing research with major societal impacts. Key to WPI institutes' collective mission are societal impact and international influence.

However, measuring societal impact for research is an ongoing challenge for research evaluators. "Real-world" impact is often intangible, making direct societal impact measurement difficult. In recent years, new bibliometric and scientometric data like altmetrics have emerged that offer proxy measures for societal impact. Though not yet direct measures for influence, these indicators allow evaluators to approximate engagement with research in the public sector in a cost-effective and scaleable manner.

This report provides an overview of the scientific and societal impacts of research produced at nine WPI institutes:

- Advanced Institute for Materials Research (AIMR)
- Earth-Life Science Institute (ELSI)
- Immunology Frontier Research Center (IFReC)
- International Center for Materials Nanoarchitectonics (MANA)
- International Institute for Carbon-Neutral Energy Research (I²CNER)
- International Institute for Integrative Sleep Medicine (IIIS)
- Institute for Integrated Cell-Material Sciences (iCeMS)
- Institute of Transformative Bio-Molecules (ITbM)
- Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU)

By tracing the scholarly influence of the WPI programme—through analysis of publication patterns, citedness, collaborations, and more—we can understand WPI's impact on science. In examining discussions of programme research online among members of the public, journalists, and other communities across social media, public policy, news media, patents, and other virtual spaces, we can understand WPI's impact on everyday citizens' lives.

The report begins by offering an overview of the data sources and analysis methods used to construct this report ("Data & Methodology").

In the pages that follow, you will learn of the WPI programme's collective societal and scholarly impact on a number of fronts, with special consideration given to the collective international influence of the programme and its societal impacts:

- **Research productivity and scientific impact**: WPI programme institutes are productive and especially impactful, having citation impact that is typically triple that of similar disciplinary research. Since 2007, WPI research has collectively been cited almost one million times.

- **International collaboration**: WPI research was highly internationally collaborative, especially with colleagues based in the United States, China, United Kingdom, Germany, and France. One in four WPI publications was the result of an international co-authorship.
- **Contributions toward UN Sustainable Development Goals**: Nearly 900 WPI programme publications advanced research in critical sustainability topics prioritized by the United Nations as Sustainable Development Goals. Areas of particular WPI programme contribution include affordable and clean energy, climate action, and good health and well being.
- **Economic impact via technology commercialization and industry collaboration**: Relationships with the private sector often lead to unintended societal benefits for research. WPI programme research fostered 230 such collaborations from 2007 onward with leading domestic and international companies like Hitachi, Samsung, and Roche. WPI programme research provided a basis for more than 4,600 patents filed by individuals and companies worldwide, supporting innovations in stem cell research, computing memory, and energy efficient lighting.
- **Global public engagement**: Nearly half of all WPI programme research has received public interest across social media, news, public policy, and other online spaces that are linked to interdisciplinary research impact, influence among health care providers, and uptake of research among policymakers. WPI programme research has had an outstanding degree of diffusion to the public and other scientists, especially in comparison to similar disciplinary research. WPI programme research has been especially influential in the United States, Japan, United Kingdom, and Germany.
- **Development of public policy**: WPI programme research has been cited in public policy issued by the World Health Organization, UK Government, US Centers for Disease Control and Prevention, and many other leading NGOs and government bodies whose recommendations shape citizens' everyday lives.

The WPI programme institutes included in this report each demonstrate a remarkable degree of societal and scientific impact through basic research. Taken as a whole, the data make a clear case for continued investment in all WPI programme institutes.

2 Data & methodology

Japan Society for the Promotion of Science (JSPS) has enlisted Digital Science companies Dimensions and Altmetric to perform a scientometric analysis that summarizes the scholarly and societal impact of each of the above WPI institutes from their date of founding onward. JSPS provided a list of 20,928 publications for analysis. 20,550 of these publications were assigned DOIs, which are unique identifiers that are crucial to searching Dimensions and Altmetric for the purposes of this analysis. 20,464 disambiguated DOIs were then analyzed.

When reporting trends for WPI programme data as a whole, we consider only unique publications with DOIs in our analysis (N=20,464). When reporting trends observed at the institute-level, we use all relevant publications with DOIs that are assigned to each institute (N=20,550), of which there is a limited degree of overlap between institutes that have co-authored the same articles (N=86).

Throughout this document, we have embedded links to publication, patent, and other records from Dimensions and Altmetric, wherever possible. To get the full benefits from this report, we recommend reading it in its digital format.

2.1 Dimensions data and analysis

Dimensions is a linked research knowledge system that makes it easy to find and analyze the most relevant research information, uncover evidence of impact, reach and engagement, and gather insights to inform future research activity.

Dimensions uses advanced text mining techniques to discover connections between documents and entities. These include links between funders and publications, links between researchers and grants, citations from clinical trials to publications, citations from policy documents to publications, as well as 1.4 billion citations between research publications.

In total, there are over 260 million records in Dimensions, with over 4 billion connections between them. Dimensions contains:

- 116 million publications, including articles, books, preprints and conference proceedings
- 8.2 million datasets
- $1.9 trillion in awarded grants
- 622,000 clinical trial records
- 134 million patents
- 577,000 public policy documents
- 1.4 billion citations

Of the 20,550 WPI institute publications assigned a DOI, 20,492 publications could be linked to a Dimensions publication ID. Publications with a Dimensions publication ID were used as the basis of some or all of the following analyses:

- **Scientific impact**: Calculating median Field Citation Ratio, per institute, based on article-level Field Citation Ratios.

- **International collaboration**: Author affiliation and location data associated with WPI programme journal articles used as the basis of country-level author counts.
- **UN Sustainable Development Goals (UN SDGs)**: Dimensions text-mining and natural language processing techniques used to determine the number of WPI programme journal articles' relevant to UN SDGs.
- **Industry collaboration**: Author affiliation data associated with WPI programme journal articles was cross-referenced with organization data from the Global Research Identifier Database <grid.ac>. Organizations labeled as a "Company" by GRID were counted towards industry collaboration rates.
- **Influence on research commercialization**: Third-party patent assignees and topics were identified using Dimensions data, based upon patent identifiers provided by Altmetric for patents that cite WPI programme journal articles.
- **Disciplinary benchmarks**: Throughout this report, Dimensions data is used to calculate the total number of publications in the top three subject areas relevant to each WPI institute. These subject areas are determined by counting how often second-level Field of Research codes[1] are automatically assigned to each institute's journal articles in Dimensions using machine learning, and then selecting the three most often assigned codes for each institute as the institute's related subject areas. For each Altmetric data source, disciplinary benchmarks are then determined by dividing the number of articles in related subject areas, published during each institute's active dates, that have been mentioned in that Altmetric data source by the total number of publications in those subject areas and timeframe reported by Dimensions.

All bibliometric data from Dimensions reflects citations and relationships recorded up to March 8, 2021.

2.2 Altmetric data and analysis

Altmetric tracks and analyzes the online activity around scholarly literature. Altmetric collates what people are saying about published research outputs in scholarly and non-scholarly forums like the mainstream media, policy documents, social networks, and blogs to provide a more robust picture of the influence and reach of research.

Collectively, these data are referred to as *altmetrics*. Since the 1990's, information scientists have referred to "invocation on the Web"[2] as a means of understanding scholarly influence. In 2010, this idea was formalized when the term "altmetrics" was coined, as a way to explain how the social Web could be leveraged to understand the broader impact of research, beyond citations alone.[3] [4] In response, Altmetric launched in 2011 with the purpose of helping publishers, institutions, funding agencies, and businesses understand the influence of the research they support.

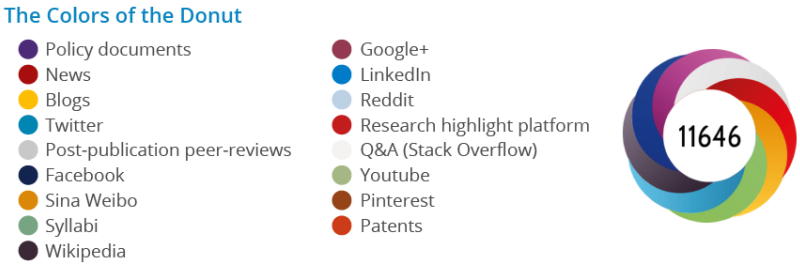
[1] The Fields of Research (FoR) classification is a component of the Australian and New Zealand Standard Research Classification (ANZSRC) system, developed in 2008. It allows all R&D activity to be categorized using a single system. The system is hierarchical, with major fields (Level 1) subdivided into minor fields (Level 2). For more information, visit Dimensions Support.

[2] Cronin, Blaise, Herbert W. Snyder, Howard Rosenbaum, Anna Martinson, and Ewa Callahan. "Invoked on the Web." Journal of the American Society for Information Science 49, no. 14 (1998): 1319–28. https://doi.org/10.1002/(SICI)1097-4571(1998)49:14<1319::AID-ASI9>3.0.CO;2-W.

[3] Priem, Jason, Dario Taraborelli, Paul Groth, and Cameron Neylon. "Alt-Metrics: A Manifesto," 2010. http://altmetrics.org/manifesto/.

[4] An overview of altmetrics and current applications can be found in the *State of Altmetrics* report: Altmetric (eds.). "The State of Altmetrics: A Tenth Anniversary Celebration." London, UK: Altmetric, October 6, 2020. https://doi.org/10.6084/m9.figshare.13010000.v2.

Altmetric has tracked over 164 million discussions around 17 million research outputs across a range of online sources including social media, policy documents, patents, and mainstream media:



In Altmetric Details Pages linked to throughout this report, you will see the Altmetric Attention Score and Altmetric Badge (also called the "Altmetric donut"; illustrated above, right). The Altmetric Attention Score provides an indicator of the amount of attention an individual research output has received. It is a weighted count derived by an automated algorithm to help analyze and filter Altmetric data.

The Altmetric Badge is a visual aid that can help you understand the diversity of attention that research has received across the sources that Altmetric tracks; each color in the Badge corresponds to an Altmetric data source summarized in the example above.

Of the 20,464 unique WPI programme publications assigned a DOI, 11,740 are included in Altmetric Explorer, which indexes only those publications mentioned online in a source that Altmetric tracks. Altmetric data was used as the basis of some or all of the following analyses:

- **Influence on research commercialization**: Altmetric uses text-mining to identify patents that cite WPI programme journal articles. Patent citation rates are then determined by dividing the number of WPI programme articles cited once or more in patents by all WPI programme articles with a unique DOI.
- **Disciplinary benchmarks**: Using Dimensions publication data as a starting point, disciplinary engagement rate benchmarks are determined by dividing the number of each subject area's publications that have at least one mention in an Altmetric data source by the total number of publications for that subject area reported by Dimensions. These disciplinary mentioned publication rates for specific Altmeric data sources are then presented alongside the rate of mentioned WPI programme publications in order to contextualize WPI programme engagement rates.
- **Global public engagement**: WPI programme journal articles that received at least one mention in any Altmetric data source were counted towards each institute's "public engagement" rate (i.e. the percentage of publications that received attention in an Altmetric data source). The total number of articles mentioned once or more was divided by the total number of unique WPI programme publications with a DOI to determine the overall global public engagement rate. WPI programme research receiving exceptional public engagement was identified as those publications whose Altmetric Attention Scores were in the 99th percentile. Attention Score percentiles are calculated for all research with an Attention Score that is published in the same journal and within six weeks before and after WPI programme research. For comparison sets with fewer than 100 articles, the article with the highest Altmetric Attention Score is automatically assigned to the 99th percentile.
- **Engagement rates for Twitter, Facebook, media, and policy**: Rates are reported as percentages, calculated by counting the number of WPI programme publications mentioned once or more in each

source, and dividing that number by the total number of unique WPI programme publications with a DOI (20,464). Source-specific data collection considerations (e.g. source curation rules) are reported in each respective section.

- **Country-level mention rates for Twitter, Facebook, media, and policy**: Country-level mention rates are determined by counting mentions of WPI programme research that originate from users or organizations located in each country; this number is divided by the total number of mentions of WPI research overall. Locations are determined differently depending upon the data source; these considerations are reported in each respective analysis section.

This report reflects the Altmetric attention recorded up to March 30, 2021 for all data except for Altmetric Attention Score percentiles, which were retrieved May 17, 2021. The differences in data retrieval dates may create a small degree of inconsistency between Altmetric Attention Scores recorded in institute-level analyses and Scores and their percentiles reported for WPI overall. However, these discrepancies are small enough that they do not affect the high-level interpretations offered in this report.

As you read this report, it is important to bear in mind that the interpretations of WPI programme performance are shaped by the nature of data available for analysis in Altmetric and Dimensions. Neither platform indexes the entirety of the Web. Furthermore, the reliance upon DOIs to retrieve and analyze data means that not all reported WPI research engagement and impact is represented in this report.

3 Scientific impact

3.1 Publishing productivity

Globally, research productivity (as measured by the number of annual published works) has nearly doubled in the last decade, from 2.8 million articles, proceedings, and preprints in 2010 to just under 6 million in 2020. The rate of growth has been linear throughout this period. One of the main drivers for growth has been the rise in Chinese research output, which has nearly tripled over the same time period, increasing to almost 900,000 in 2020.

During the period covered by this report, Japanese research was largely dominated by medicine, with engineering consistently in second place according to the Fields of Research classification system used by Dimensions[5]. Research into the physical, chemical and materials sciences is very strong from Japanese institutions, with publications typically being cited at a substantially higher rate than the global mean, as measured by the Field Citation Ratio (FCR) metric. More information about FCRs for WPI programme research can be found in the next section.

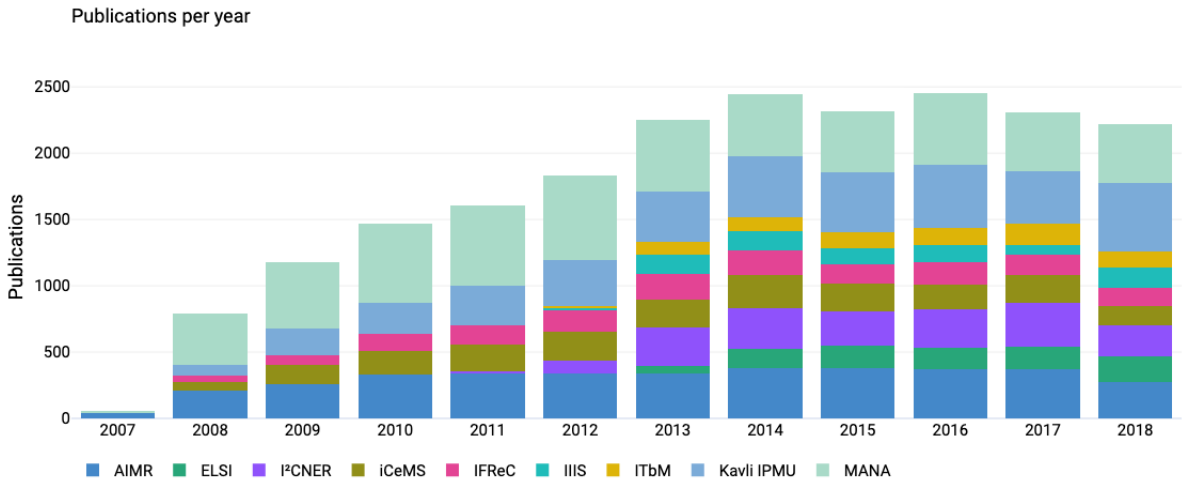


Figure 1: Publication count by institute, 2007 to 2018 (WPI)

The WPI research institutes examined in this report are strongly orientated towards innovative excellence and international collaboration, and were productive quickly following launch, publishing steadily through 2018 (Figure 1).[6]

MANA was the most productive institute in terms of total number of publications.

[5] Fields of Research classifications are automatically assigned to publications within Dimensions using machine learning. The Fields of Research (FOR) classification is a component of the Australian and New Zealand Standard Research Classification (ANZSRC) system, developed in 2008. It allows all R&D activity to be categorized using a single system. The system is hierarchical, with major fields (Level 1) subdivided into minor fields (Level 2). For more information, visit Dimensions Support.

[6] A JSPS-provided publication list included 7 publications published in 2019. To avoid outliers that do not represent the true research productivity of the studied institutes in 2019, we have excluded these data from this visualization.

3.2 Scientific impact

To understand the relative citation impact of each institute, the Field Citation Ratio metric is used. The Field Citation Ratio (FCR) is a citation-based measure of scientific influence of one or more articles. It is calculated by dividing the number of citations a paper has received by the average number received by documents published in the same year and in the same Fields of Research (FoR) categories.

The FCR is calculated for all publications in Dimensions which are at least 2 years old and were published in 2000 or later. Values are centered around 1.0 so that a publication with an FCR of 1.0 has received exactly the same number of citations as the average, while a paper with an FCR of 2.0 has received twice as many citations as the average for related Fields of Research categories.

Here, we provide the median FCR for each institute and calculate the overall median FCR for all WPI institute publications that can be found in Dimensions (N=20,492).

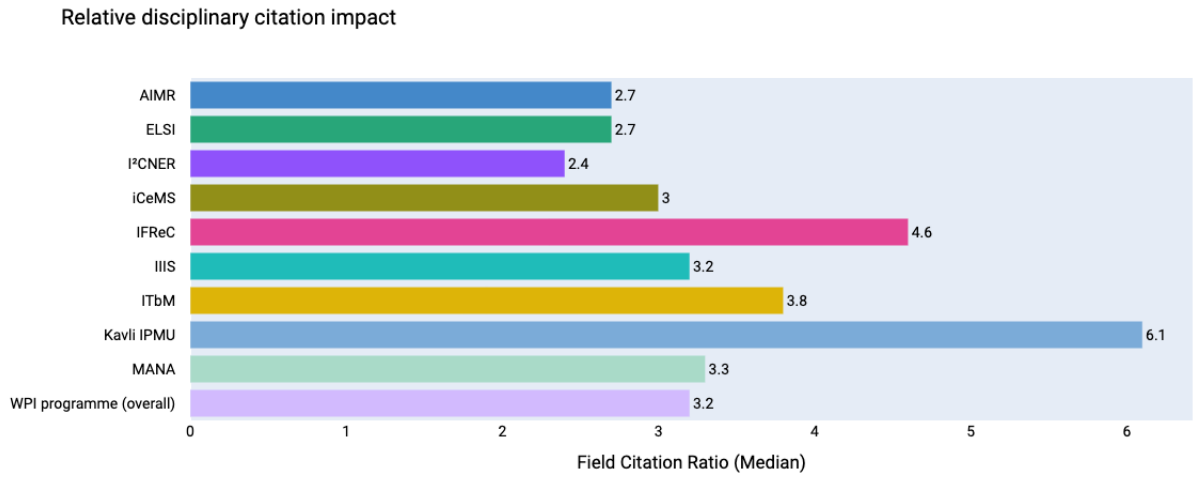


Figure 2: Median Field Citation Ratios for WPI institutes (Dimensions). Field Citation Ratios demonstrate citation impact relative to other research in a discipline.

All WPI programme publications were highly cited compared to other research published in similar fields, with median FCR ranging from 2.4 to 6.1 (Figure 2). Kavli IPMU shows the highest relative citation impact of all institutes. High FCRs indicate that each institutes' publications were cited at higher rates than the typical publication in the same discipline during each institute's active years.[7] [8]

To present, WPI institutes' publications have collectively been cited 937,955 times.

[7] FCRs use second-level Fields of Research categories in their calculation, which provide a more relevant comparison document set than broad, high-level categorization present in the first-level FoR categories. For more information, visit the Dimensions support portal.

[8] Articles assigned more than one FoR category receive a specially-calculated FCR. For these documents, we calculate an FCR value for each FoR code and then calculate the geometric mean of all values, resulting in a single FCR value for the document.

3.3 International collaboration

International collaboration is typically measured through analyzing scientific co-authorship patterns.[9] Universities benefit from international collaboration in terms of increased citation impact,[10] and increased collaboration reportedly may also be an effect of an increased need for resource-intensive research infrastructures which are typically shared across universities and sometimes even nations.[11]

Data from Dimensions shows that WPI institute researchers fostered global collaborations, spanning 92 countries and territories on six continents. Collaborations with researchers in the United States of America (3,536 co-authors) and China (2,128 co-authors) were especially productive. Within Europe, co-authorships with researchers based in the United Kingdom (1,205), Germany (1,196), and France (815) predominated.

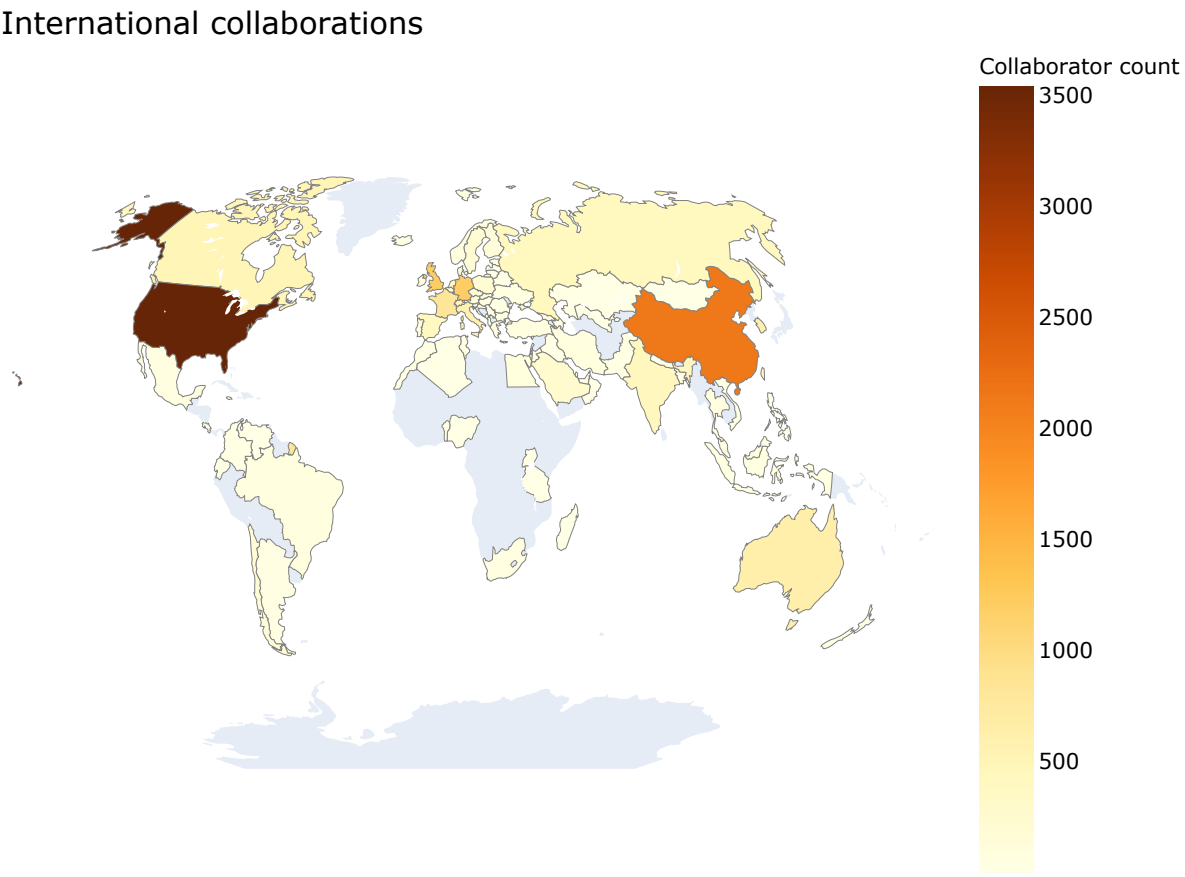


Figure 3: International collaborations for WPI research, as measured by number of co-authorships (Dimensions)

[9] Katz, J. Sylvan, and Ben R. Martin. "What Is Research Collaboration?" Research Policy 26, no. 1 (March 1, 1997): 1–18. https://doi.org/10.1016/S0048-7333(96)00917-1.

[10] Khor, K.A., and L.-G. Yu. "Influence of International Co-Authorship on the Research Citation Impact of Young Universities." Scientometrics 107, no. 3 (June 1, 2016): 1095–1110. https://doi.org/10.1007/s11192-016-1905-6.

[11] Besselaar, Peter van den, Sven Hemlin, and Inge van der Weijden. "Collaboration and Competition in Research." Higher Education Policy 25, no. 3 (September 1, 2012): 263–66. https://doi.org/10.1057/hep.2012.16.

Kavli IPMU led in terms of the number of international co-authorships; this is to be expected given collaboration norms in the institute's related fields of astronomy and physics.[12]

All studied WPI institutes collaborated with international partners at rates exceeding the global and domestic baselines.[13] On average, one in four WPI programme publications were co-authored with international collaborators.

4 Societal impact

A key goal of the WPI programme is to build globally visible research centers that demonstrate a high degree of societal and scientific impact through the development of high quality research. This section highlights the WPI programme's societal influence through several mechanisms: analyzing published research relevant to societal "grand challenges", economic impacts of programme research and its impact upon public policy, and the promotion of scientific literacy through global social media engagement and news coverage stemming from programme research.

4.1 Research contributing towards UN Sustainable Development Goals

The UN Sustainable Development Goals are overarching societal goals, developed by the United Nations, that tackle the climate crisis and environmental degradation hand-in-hand with economic and gender inequality and other societal challenges.[14] Research related to Sustainable Development Goals (SDGs) has grown since 2015, with researchers in Europe and the Americas producing the most research by volume.[15] Most growth has been in the social sciences, followed by medicine and environmental sciences.

894 WPI programme publications were associated with at least one UN Sustainable Development Goal (SDG) in Dimensions. The SDGs most often addressed in WPI research can be found in Table 1. [16] For an overview of all SDGs addressed in WPI research, see Table 8 (Appendix).

WPI programme research contributed most to research in the areas of Affordable and Clean Energy, Climate Action, and Good Health and Well Being.

MANA published the most research addressing UN Sustainable Development Goals (accounting for over one-third of all WPI-institute research addressing UN SDGs or 370 works total).

[12] Thelwall, Mike. "Large Publishing Consortia Produce Higher Citation Impact Research but Coauthor Contributions Are Hard to Evaluate." Quantitative Science Studies 1, no. 1 (February 1, 2020): 290–302. https://doi.org/10.1162/qss_a_00003

[13] For institute-level descriptions of international collaboration rates, please refer to the International Collaboration section of the Appendix.

[14] For more information, visit the UN Sustainable Development Goals website.

[15] Sweileh, Waleed M. "Bibliometric Analysis of Scientific Publications on 'Sustainable Development Goals' with Emphasis on 'Good Health and Well-Being' Goal (2015–2019)." Globalization and Health 16, no. 1 (July 28, 2020): 68. https://doi.org/10.1186/s12992-020-00602-2.

[16] During the studied time frame, Kavli IPMU did not publish any research categorized as relevant to UN SDGs according to the Dimensions machine learning-based classification system. As such, they are excluded from this analysis.

Table 1: Publications related to select UN Sustainable Development Goals, by institute (Dimensions)

Institute	Affordable and Clean Energy	Clean Water and Sanitation	Climate Action	Good Health and Well Being	Sustainable Cities and Communities
AIMR	130	-	5	-	-
ELSI	19	1	20	1	2
I²CNER	159	2	57	1	-
iCeMS	37	1	9	2	2
IFReC	1	-	-	61	-
IIIS	7	-	-	10	-
ITbM	10	-	-	1	1
MANA	346	3	17	1	1
WPI programme (total)	709	7	108	77	6

4.2 Industry collaboration

Collaboration with researchers in the private sector can have important innovation benefits, chief of which is "knowledge spillover". Knowledge spillover is the sharing of ideas between individuals that lead to unintended benefits like advances in technology and stimulation of economic growth. Researchers suggest that spillovers resulting from university-industry collaborations can have an important effect upon regional innovation.[17] International university-industry collaboration has been linked to higher levels of innovation.[18] Though innovation is not core to WPI's mission, it is included in this report because the data provide useful insight into the overall impact of basic research conducted at WPI centers. In analyzing citation patterns to research from patents, we can understand the potential effects of WPI research upon said innovation and growth.

WPI programme research fostered 230 industry collaborations between 2007 and 2019, resulting in 645 co-authored publications with global leaders in the private sector. The mean WPI programme industry collaboration rate was 3.3% (Figure 4).[19] Note that Kavli IPMU reports a relatively low industry collaboration rate, which is expected of research published by an institute focusing upon fundamental astronomy and physics research.

The most productive domestic industry partnerships in terms of number of papers published were with Hitachi (36 co-authored publications), NEC (32), JEOL (21), Denso (20), and Toyota Motor Corporation (18). A list of top

[17] Ponds, Roderik, Frank van Oort, and Koen Frenken. "Innovation, Spillovers and University–Industry Collaboration: An Extended Knowledge Production Function Approach." Journal of Economic Geography 10, no. 2 (March 1, 2010): 231–55. https://doi.org/10.1093/jeg/lbp036.

[18] Monjon, Stéphanie, and Patrick Waelbroeck. "Assessing Spillovers from Universities to Firms: Evidence from French Firm-Level Data." International Journal of Industrial Organization, The economics of intellectual property at universities, 21, no. 9 (November 1, 2003): 1255–70. https://doi.org/10.1016/S0167-7187(03)00082-1.

[19] Industry collaboration rates were estimated by analyzing co-author affiliations associated with each institute's publications. Affiliated organizations were disambiguated using the Global Researcher Identifier Database (GRID). GRID is a free and openly available global database of over 90,000 research-related organisations. GRID was created and is maintained by Digital Science. Learn more on the GRID.ac website.

domestic industry collaborators can be found in Table 18 (Appendix).

Internationally, the most productive partnerships were with Samsung (14 co-authored publications), an internationally-renowned South Korean electronics conglomerate; Roche (6 publications), the US division of a leading Swiss healthcare company; Veeco (4 publications), a US-based micro-electronic device manufacturing company; Air Liquide (3 publications), a French multinational industrial gas and service company; and Nestlé (3 publications), a Swiss multinational food and beverage manufacturing company. A list of top international industry collaborators can be found in Table 19 (Appendix).

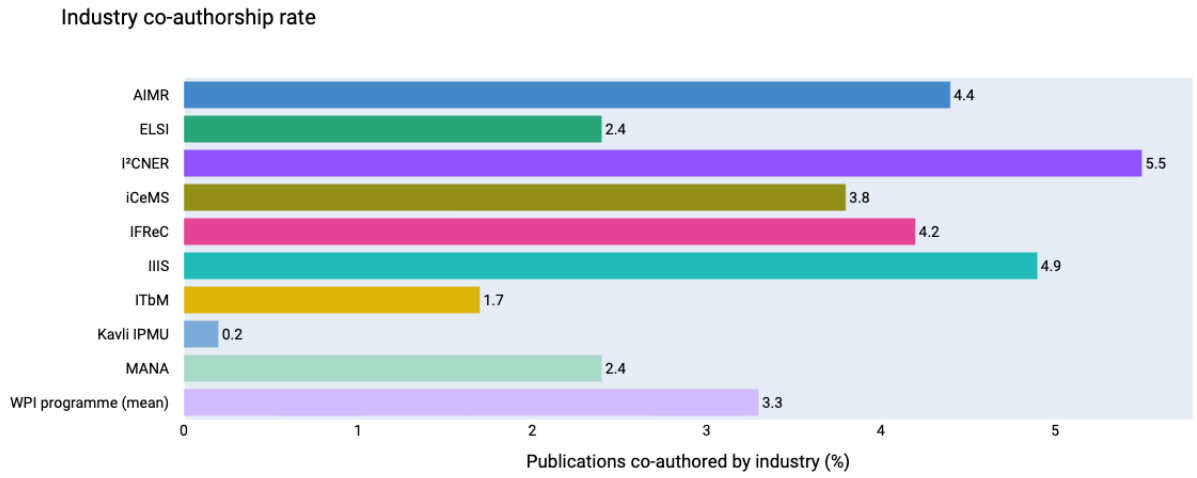


Figure 4: Industry co-authorship rate by institute, 2007 to 2019. On average, 3.3% of WPI programme publications indexed in Dimensions were co-authored with industry organizations.

4.3 Influence on research commercialization

Another important way to understand the impact of research upon technology commercialization is through studying how often patents cite scholarly works. Basic research is often the basis for breakthroughs in technological innovation[20] and regional economic growth.[21]

1,473 out of 20,464 total WPI programme publications (7.15%) were collectively cited 6,346 times in 4,631 global patents.[22] Note that Kavli IPMU reports a relatively low rate of its research being cited by patents, which is expected of research published by an institute focusing upon fundamental astronomy and physics research.

[20] Stephan, Annegret, Laura Diaz Anadon, and Volker H. Hoffmann. "How Has External Knowledge Contributed to Lithium-Ion Batteries for the Energy Transition?" IScience 24, no. 1 (January 22, 2021). https://doi.org/10.1016/j.isci.2020.101995.

[21] Rodríguez-Pose, Andrés, and Riccardo Crescenzi. "Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe." Regional Studies 42, no. 1 (February 1, 2008): 51–67. https://doi.org/10.1080/00343400701654186.

[22] Altmetric tracks citations to research from patents filed in ten jurisdictions, from 1994 onward. These jurisdictions include Australia, Canada, European Patent Office, France, Germany, Hong Kong, India, Russian Federation, United Kingdom, United States, and the World Intellectual Property Organization. As of March 2021, Altmetric has tracked 12.6 million citations from 2 million individual patents. Altmetric associates patents with research using links to publications and free text references.

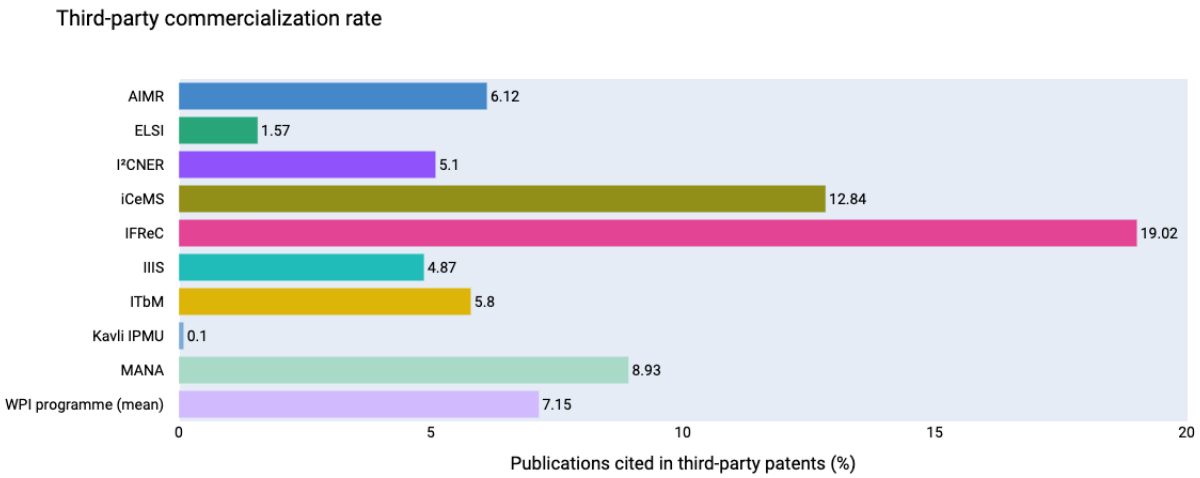


Figure 5: Rate of patent citations to research by institute, 2007 to 2019. On average, 7.15% of WPI programme institute publications were cited in patents. (Altmetric)

IFReC was the WPI institute whose research was cited most often in patents. 295 IFReC publications were cited in patents, meaning nearly one in five IFReC articles went on to support research commercialization.

Among the articles most cited in patents, many had to do with innovations in stem cell research ("Induction of Pluripotent Stem Cells from Adult Human Fibroblasts by Defined Factors", cited in 636 patents), computing memory ("Nanoionics-based resistive switching memories", cited in 107 patents), and energy efficient lighting like light-emitting diodes ("Highly efficient organic light-emitting diodes from delayed fluorescence", cited in 69 patents).

Organizations which cited WPI programme research the most included leading universities (Kyoto University, 150 patents filed; Harvard College, 98 patents filed; University of California, 61 patents filed) and companies (Moderna Therapeutics, 103 patents filed; Crossbar Inc, 74 patents filed). A list of top patent assignees whose work cites WPI research most often can be found in Table 20 (Appendix).

Takeaways

- In general, research from the WPI institutes is considerably more impactful on the creation of intellectual property, as measured by patent citations, than is expected for the relevant subject areas.
- Areas of excellence include Materials Engineering; Physical Chemistry; Biochemistry and Cell Biology; Immunology; and Macromolecular and Materials Chemistry.
- Innovative and fundamental research from institutes such as Kavli IPMU is not expected to be expressed in patent citation behavior.
- AIMR, ELSI, iCeMS, IFReC, ITbM, and MANA have exceptional rates of influence on research commercialization.

Table 2: Patent coverage, by institute (Altmetric). Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject areas) (%)
AIMR	6.1%	222	Materials Engineering; Physical Chemistry (incl. Structural); Other Physical Sciences	4.3%
ELSI	1.6%	14	Astronomical and Space Sciences; Geology; Geochemistry	0.3%
I^2CNER	5.1%	93	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	3.8%
iCeMS	12.8%	259	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	6.4%
IFReC	19%	295	Clinical Sciences; Biochemistry and Cell Biology; Immunology	3.8%
IIIS	4.9%	38	Clinical Sciences; Biochemistry and Cell Biology; Neurosciences	0.6%
ITbM	5.8%	44	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Organic Chemistry	3.9%
Kavli IPMU	<0.1%	4	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	0.7%
MANA	8.9%	504	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	4.4%

4.4 Global public engagement

Altmetric data is comprised of 17 diverse sources that together can approximate the extent of engagement with research online. By analyzing the extent of research diffusion—specifically, the proportion of total articles published that are shared, recommended, and discussed online—organizations can estimate readership for their research[23], quantify the impact of research and researchers[24], and monitor the influence of the research they fund.[25] Japanese research typically receives more engagement than other research in South Korea, Taiwan, Singapore, and China.[26]

With this in mind, consider the diffusion of WPI programme research: 9,709 WPI programme publications (47.4% of 20,464 publications total) were discussed 90,086 times online.[27]

The average rate of engagement for WPI institutes was 54% (Figure 6). All studied WPI programme research received public engagement at rates far exceeding expected engagement rates for publications in similar disciplines and time frames. In some instances, institute publications were discussed at double and triple the rate of similar research (Table 3).

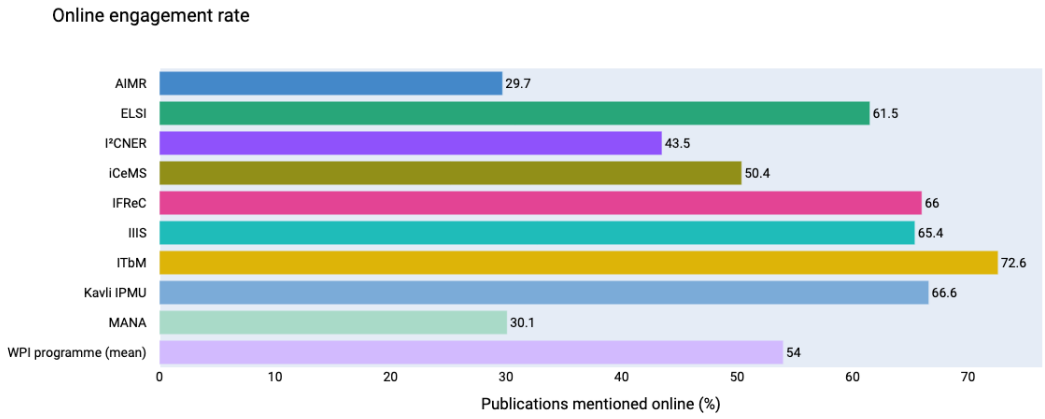


Figure 6: Rate of online engagement with WPI programme research (Altmetric)

[23] Haustein, Stefanie, and Tobias Siebenlist. "Applying Social Bookmarking Data to Evaluate Journal Usage." Journal of Informetrics 5, no. 3 (May 2011): 446-457. https://doi.org/10.1016/j.joi.2011.04.002

[24] Davis, B, I Hulpus, M Taylor, and C Hayes. "Challenges and Opportunities for Detecting and Measuring Diffusion of Scientific Impact across Heterogeneous Altmetric Sources." In Altmetrics.Org/altmetrics15. Amsterdam: Altmetrics.org, 2015. http://altmetrics.org/wp-content/uploads/2015/09/altmetrics15_paper_21.pdf.

[25] Dinsmore, Adam, Liz Allen, and Kevin Dolby. "Alternative Perspectives on Impact: The Potential of ALMs and Altmetrics to Inform Funders about Research Impact." PLOS Biology 12, no. 11 (November 25, 2014): e1002003. https://doi.org/10.1371/journal.pbio.1002003.

[26] Park, Hyejin, and Han Woo Park. "Research Evaluation of Asian Countries Using Altmetrics: Comparing South Korea, Japan, Taiwan, Singapore, and China." Scientometrics 117, no. 2 (November 1, 2018): 771–88. https://doi.org/10.1007/s11192-018-2884-6.

[27] Altmetric has tracked discussions of more than 17 million research outputs across a range of online sources including social media, policy documents, patents, and mainstream media. For a complete list of Altmetric sources, visit the Altmetric website.

Table 3: Rate of research engagement, by institute (Altmetric). Publications are counted towards overall rate if they have been mentioned once or more in an Altmetric data source. Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject areas) (%)
AIMR	29.7%	1,077	Materials Engineering, Physical Chemistry (incl. Structural), Other Physical Sciences	15.1%
ELSI	61.5%	549	Astronomical and Space Sciences, Geology, Geochemistry	35.2%
I²CNER	38.9%	710	Materials Engineering, Physical Chemistry (incl. Structural), Macromolecular and Materials Chemistry	17.5%
iCeMS	50.4%	1,016	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	27.2%
IFReC	66%	1,024	Clinical Sciences, Biochemistry and Cell Biology, Immunology	30.1%
IIIS	65.4%	510	Clinical Sciences, Biochemistry and Cell Biology, Neurosciences	36.7%
ITbM	72.6%	551	Physical Chemistry (incl. Structural), Biochemistry and Cell Biology, Organic Chemistry	34%
Kavli IPMU	66.6%	2,552	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	22.8%
MANA	30.1%	1,698	Materials Engineering, Physical Chemistry (incl. Structural), Macromolecular and Materials Chemistry	16.2%

210 WPI programme publications in total (1%) ranked within the 99th percentile for engagement by the Altmetric Attention Score (Table 21, Appendix)[28] [29], illustrating the extent to which WPI programme research that is highly discussed. In other words, 210 WPI programme publications were in the top 1% of similar articles by Altmetric Attention Score.

At the institute level, the number of articles that appeared within the 99th percentile by Altmetric Attention Score were: AIMR, 22 (0.6% of all institute articles); ELSI, 20 (2.3%); I²CNER, 12 (0.7%); iCeMS, 22 (1.1%); IFReC, 23 (1.5%); IIIS, 14 (2.0%); ITbM, 21 (2.8%); Kavli IPMU, 50 (1.3%); and MANA, 26 (0.5%). Figure 7 summarizes the number of WPI programme articles overall that appear in each percentile.

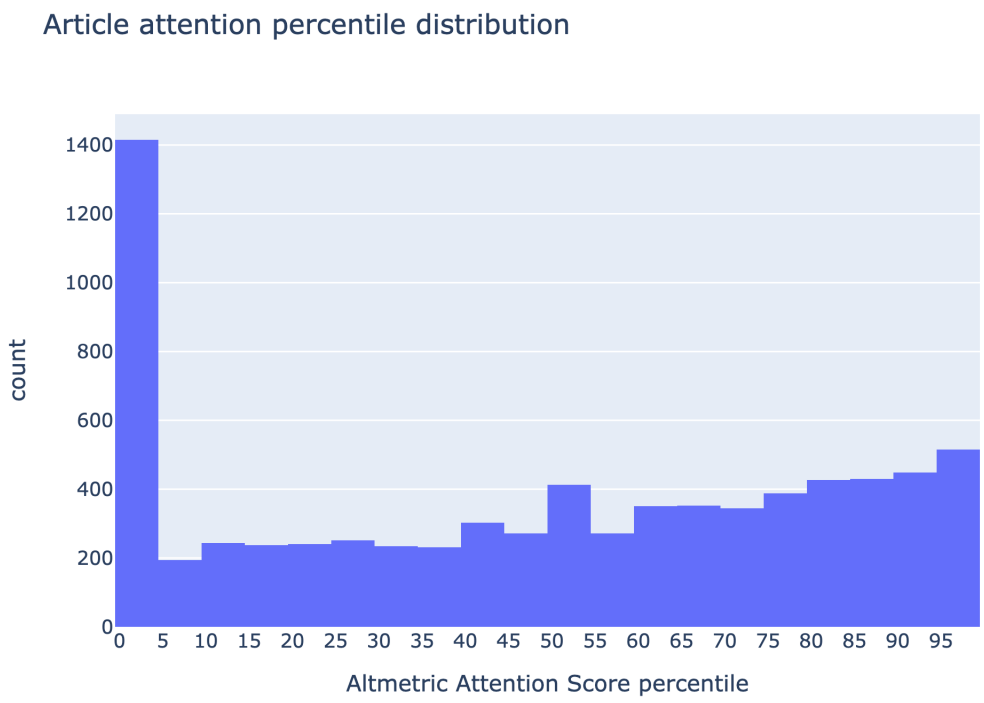


Figure 7: Article Altmetric Attention Score percentile distribution for papers with scores of 1 or more. Distribution shown in increments of 5% (Altmetric).

[28] The Altmetric Attention Score provides an indicator of the amount of attention an individual research output has received. It is a weighted count derived by an automated algorithm to help analyze and filter Altmetric data. It is not an indicator for quality nor impact; it should be interpreted with this in mind.

[29] Similar articles and their percentiles are determined by calculating percentiles for Altmetric Attention Scores for all articles published in the same journal and within six weeks before and after WPI programme research. Percentile data was retrieved from Altmetric on May 17, 2021. Note that articles with an Altmetric Attention Score but whose journals have not been indexed in Altmetric Explorer are not counted towards percentiles. The total number of WPI programme articles assigned to a percentile was N=7,560. The distribution of WPI programme articles' Altmetric Attention Scores into percentiles can be found in Figure 7.

Takeaways

- One out of every two WPI programme articles was shared online. Overall, a higher proportion of WPI programme research is shared online than expected, meaning a high proportion of WPI programme research receives public interest in comparison with similar disciplinary research.
- WPI programme articles appear in the top 1% of most discussed articles (relative to similar research) at expected rates.

4.5 Public engagement: Twitter

The diffusion and discussion of research on social media is known to be a key signal for the kinds of societal impact and influence that standard research indicators like citations cannot effectively measure.[30] [31] Twitter is the most popular social media platform for sharing research.[32] There are known differences in the tweeting patterns for research in different disciplines, with researchers retweeting content more often in biochemistry, participating in conversations more often in astrophysics, and tweeting links more often in cheminformatics.[33] Tweets accumulate quickly after research is published, making them a valuable source of data for the influence and diffusion of recently published works.[34]

WPI programme research has been discussed on Twitter in 64,292 conversations by 30,420 unique tweeters in 171 countries to date (Figure 8). 7,985 institute publications (39% of 20,464 publications total) were discussed on the platform.

Institute research was shared most often in the United States of America (15.1% of all mentions), Japan (9.6%), and the United Kingdom (6.3%). In all instances, institute research was shared domestically at rates far exceeding that of similar research.

WPI-supported research has received a tremendous amount of diffusion from Twitter users like *Nature* (@nature, 34 mentions to 2.2 million followers), *Science* (@ScienceMagazine, 41 mentions to 2.1 million followers), and Professor Brian Cox (@ProfBrianCox, 1 mention to 3 million followers).

[30] Konkiel, Stacy. "Altmetrics: Diversifying the Understanding of Influential Scholarship." Palgrave Communications 2 (August 2016): 16057. https://doi.org/10.1057/palcomms.2016.57.

[31] Thelwall, Mike, Stefanie Haustein, Vincent Larivière, and Cassidy R Sugimoto. "Do Altmetrics Work? Twitter and Ten Other Social Web." PLOS ONE 8, no. 5 (2013): e64841. http://dx.doi.org/10.1371/journal.pone.0064841.

[32] Costas, Rodrigo, Zohreh Zahedi, and Paul Wouters. "The Thematic Orientation of Publications Mentioned on Social Media." Aslib Journal of Information Management 67, no. 3 (2015): 260–288. https://doi.org/10.1108/AJIM-12-2014-0173

[33] Holmberg, Kim, and Mike Thelwall. "Disciplinary Differences in Twitter Scholarly Communication." Scientometrics 101, no. 2 (November 1, 2014): 1027–42. https://doi.org/10.1007/s11192-014-1229-3.

[34] Fang, Zhichao, and Rodrigo Costas. "Studying the Accumulation Velocity of Altmetric Data Tracked by Altmetric.Com." Scientometrics 123, no. 2 (May 1, 2020): 1077–1101. https://doi.org/10.1007/s11192-020-03405-9.

Takeaways

- WPI institutions' research is shared on Twitter at much higher rates than average.
- Typically, the coverage of articles by WPI institutes on Twitter is twice that of the global rate.
- ELSI, IFReC, IIIS, ITbM, and Kavli IPMU receive particularly high rates of attention when taking into account their subject areas.
- WPI institutions' research is shared on Twitter by an international set of communicators.
- The USA and the UK are particularly important in terms of propagating WPI research to a global audience.

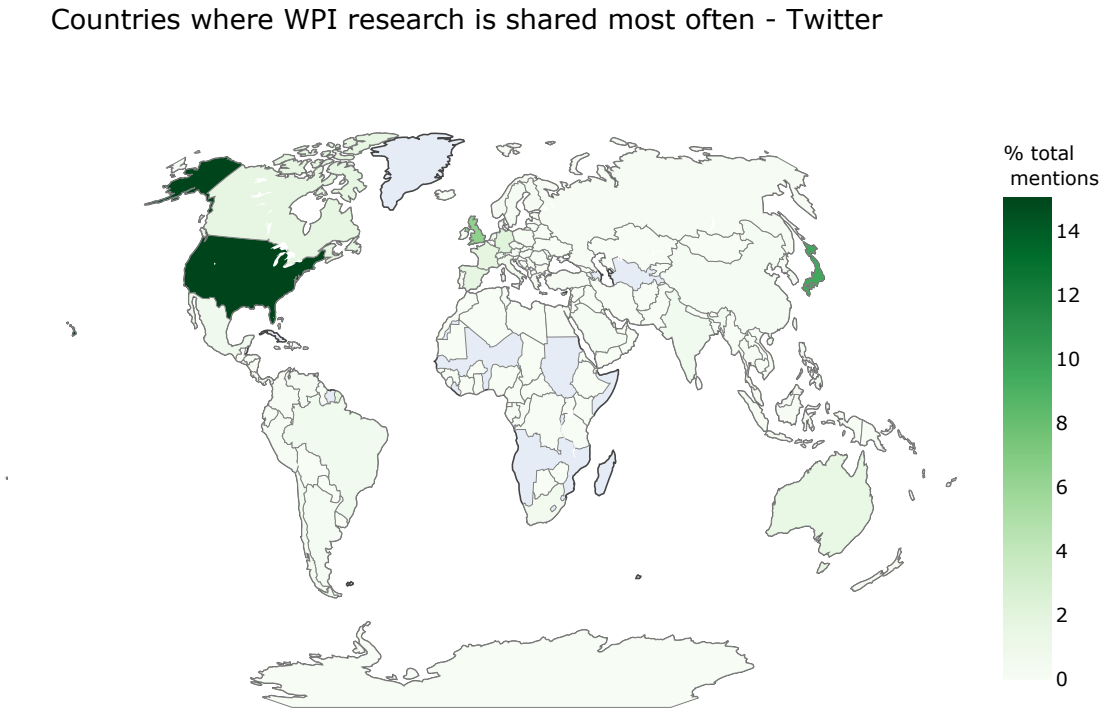


Figure 8: Global diffusion of WPI programme research on Twitter (Altmetric)

Table 4: Twitter coverage, by institute (Altmetric). Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject areas) (%)
AIMR	23.1%	836	Materials Engineering; Physical Chemistry (incl. Structural); Other Physical Sciences	9.3%
ELSI	57.1%	510	Astronomical and Space Sciences; Geology; Geochemistry	28.8%
I^2CNER	38.9%	710	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	12.4%
iCeMS	40.4%	815	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	19.4%
IFReC	51.3%	795	Clinical Sciences; Biochemistry and Cell Biology; Immunology	24.9%
IIIS	61.5%	480	Clinical Sciences; Biochemistry and Cell Biology; Neurosciences	34.4%
ITbM	66.3%	503	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	29%
Kavli IPMU	60.1%	2,305	Physical Sciences; Mathematical Sciences; Astronomical and Space Sciences; Atomic, Molecular, Nuclear, Particle and Plasma Physics	24.8%
MANA	19.2%	1,084	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	10.2%

4.6 Public engagement: Facebook

Facebook is one of the world's leading social media networks and is used in a variety of contexts, including to share research.[35] Around 5% of research indexed in Web of Science has been shared on a Facebook Page that Altmetric tracks,[36] meaning that Facebook attention for research is relatively rare in the sciences. Up to half of all clinicians[37] and nearly 40% of scientists and engineers[38] use Facebook, with smaller numbers using the site in a professional context. Given the speed with which they accumulate, Facebook mentions to research (like tweets) can be used to understand the influence of recently published research.[39]

WPI programme research has been discussed on Facebook in 3,749 conversations by 1,344 unique, public Facebook Pages in 55 countries to date (Figure 9).[40] 1,926 institute publications (9.4% of 20,464 total) were discussed on the platform—a rate nearly double that of research overall.[41]

Institute research was shared most often in the United States of America (10.1% of all mentions), Japan (5.1%), and the United Kingdom (2%). In all instances, institute research was shared at rates far exceeding that of disciplinary research published in similar timeframes (Table 5).

Facebook Pages that shared WPI-supported research the most included the IFIC AHEP research group (170 mentions) and a now-defunct Open Access topic page (120 mentions).

[35] Enkhbayar, Asura, Stefanie Haustein, Germana Barata, and Juan Pablo Alperin. "How Much Research Shared on Facebook Happens Outside of Public Pages and Groups? A Comparison of Public and Private Online Activity around PLOS ONE Papers." Quantitative Science Studies 1, no. 2 (May 4, 2020): 749–70. https://doi.org/10.1162/qss_a_00044.

[36] Haustein, Stefanie, Rodrigo Costas, and Vincent Larivière. "Characterizing Social Media Metrics of Scholarly Papers: The Effect of Document Properties and Collaboration Patterns." PLOS ONE 10, no. 3 (March 17, 2015): e0120495. https://doi.org/10.1371/journal.pone.0120495.

[37] Muhlen, Marcio von, and Lucila Ohno-Machado. "Reviewing Social Media Use by Clinicians." Journal of the American Medical Informatics Association 19, no. 5 (September 1, 2012): 777–81. https://doi.org/10.1136/amiajnl-2012-000990.

[38] Van Noorden, Richard. "Online Collaboration: Scientists and the Social Network." Nature News 512, no. 7513 (August 14, 2014): 126. https://doi.org/10.1038/512126a.

[39] Fang, Zhichao, and Rodrigo Costas. "Studying the Accumulation Velocity of Altmetric Data Tracked by Altmetric.Com." Scientometrics 123, no. 2 (May 1, 2020): 1077–1101. https://doi.org/10.1007/s11192-020-03405-9.

[40] Since 2011, Altmetric has tracked discussions of research in the mainstream media across the world's leading news outlets. As of March 2021, Altmetric monitors 297,811 public Facebook Pages for discussions of research, and to date has found 5,629,679 Facebook posts on these Pages across 190 countries. For more information on how Altmetric tracks discussions of research on Facebook, visit the Altmetric website.

[41] Haustein, Stefanie, Rodrigo Costas, and Vincent Larivière. "Characterizing Social Media Metrics of Scholarly Papers: The Effect of Document Properties and Collaboration Patterns." PLOS ONE 10, no. 3 (March 17, 2015): e0120495. https://doi.org/10.1371/journal.pone.0120495.

Takeaways

- WPI's institutes have received global public engagement on Facebook, especially throughout the Americas, Europe, and Asia-Pacific region, and in the scientific press.
- Though Facebook discussions of research are not a direct measure of societal impact, researchers have linked Facebook posts to research use by clinicians and practicing scientists and engineers, indicating societal uptake for said research.
- Overall, WPI programme research has received greater than expected rates of Facebook engagement.
- Thus, WPI institutes are fulfilling their goal of societal impact at least in part by receiving global public engagement with their research in public Facebook Pages.

Figure 9: Global diffusion of WPI programme research on Facebook (Altmetric)

Table 5: Facebook coverage, by institute (Altmetric). Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject areas) (%)
AIMR	4.9%	179	Materials Engineering; Physical Chemistry (incl. Structural); Other Physical Sciences	1.5%
ELSI	15.2%	136	Astronomical and Space Sciences; Geology; Geochemistry	6.5%
I^2CNER	4.9%	89	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	2%
iCeMS	10.5%	212	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	3.6%
IFReC	13.2%	205	Clinical Sciences; Biochemistry and Cell Biology; Immunology	6.9%
IIIS	20%	156	Clinical Sciences; Biochemistry and Cell Biology; Neurosciences	9.7%
ITbM	25.8%	196	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Organic Chemistry	4.8%
Kavli IPMU	14.6%	560	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	4.7%
MANA	3.4%	193	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	1.4%

4.7 Global media engagement

Mainstream media coverage for research is commonly understood to be a proxy for public engagement with science. Policymakers and politicians rely upon the media to understand research, which often has a downstream effect upon the development of public policy.[42] [43] Media coverage of science, especially public health topics, is linked to increased scientific literacy among the general public.[44]

With this in mind, it is remarkable to note that WPI-supported research has been referenced in 9,357 news stories published by 1,020 unique news outlets in 61 countries (Figure 10).[45] 1,249 WPI programme publications (6.1% of 20,464 publications total) were discussed on the platform. In all instances, each WPI institute's research was discussed in the mainstream media at rates meeting or exceeding that of similar research (Table 6).

1,168 of these news articles were published in high-profile outlets[46] that celebrated WPI-supported discoveries. Coverage included articles in National Geographic ("These are the top 20 scientific discoveries of the decade", 2019), Forbes ("Astronomically Rare 'Double Lens' Yields Best Single System Measurement Of Cosmic Expansion", 2019), and The New York Times ("Getting a Handle on Cosmic Dust Caused by Supernovas", 2011).

Institute research was shared most often in news outlets in the United States of America (52.2% of all mentions), United Kingdom (18.9%), and Germany (5.9%). Table 22 (Appendix) highlights the global news outlets that shared WPI programme research most often.

[42] Haynes, Abby S., Gemma E. Derrick, Sally Redman, Wayne D. Hall, James A. Gillespie, Simon Chapman, and Heidi Sturk. "Identifying Trustworthy Experts: How Do Policymakers Find and Assess Public Health Researchers Worth Consulting or Collaborating With?" Edited by David W. Dowdy. PLoS ONE 7, no. 3 (March 2012): e32665. https://doi.org/10.1371/journal.pone.0032665.

[43] Tieberghien, Julie. "The Role of the Media in the Science-Policy Nexus. Some Critical Reflections Based on an Analysis of the Belgian Drug Policy Debate (1996-2003)." The International Journal on Drug Policy 25, no. 2 (2014): 276–281. https://doi.org/10.1016/j.drugpo.2013.05.014.

[44] Austin, Erica Weintraub, Bruce W Austin, Jessica Fitts Willoughby, Ofer Amram, and Shawn Domgaard. "How Media Literacy and Science Media Literacy Predicted the Adoption of Protective Behaviors Amidst the COVID-19 Pandemic." Journal of Health Communication, 2021, 1–14. https://doi.org/10.1080/10810730.2021.1899345.

[45] Since 2011, Altmetric has tracked discussions of research in the mainstream media across the world's leading news outlets. As of March 2021, Altmetric scans 5,512 news outlets for discussions of research, and to date has found 8,460,342 news stories by 4,571 unique news outlets in 157 countries. Altmetric tracks discussions in mainstream media articles by looking for links or keywords like journal name, author name, and publication date, which are then matched against known journal article metadata. A caveat to using Altmetric data to understand global media coverage is that Altmetric's curated list of media outlets relies heavily on outlets in the United States and Europe, with lesser coverage of media outlets in the rest of the world. For more information on how Altmetric tracks discussions of research in news outlets, visit the Altmetric website.

[46] High-profile news outlets are defined as outlets that are categorized as a Tier 1 outlet by Altmetric data provider Moreover. Moreover uses a proprietary set of criteria to assign tiers to the news outlets it indexes; these tiers are generally understood to correlate to readership and reach.

Takeaways

- Though mainstream media coverage is not a direct measure of societal impact, researchers have linked media coverage of research to public scientific literacy and influence upon public policy.
- Overall, WPI programme research has received greater than expected rates of mainstream media coverage.
- Thus, WPI institutes are fulfilling their goal of societal impact at least in part through public and international engagement with their research in the mainstream media.
- WPI's institutes have received global public engagement, especially throughout the Americas, Europe, and Asia-Pacific region, and in the scientific press.
- Roughly half of all WPI programme publications have been covered in at least one high profile news outlet. Due to coverage in high profile news outlets, WPI programme research has a high potential for influence upon public policy, given the extent to which policymakers rely on the mainstream media to understand research.
- Leveraging WPI's strong international collaborations could result in broader coverage, for example supporting non-English speaking researchers to translate press releases and lay abstracts into their own language.

Table 6: News coverage, by institute (Altmetric). Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject area) (%)
AIMR	3.5%	128	Materials Engineering; Physical Chemistry (incl. Structural); Other Physical Sciences	1.0%
ELSI	15.6%	139	Astronomical and Space Sciences; Geology; Geochemistry	4.1%
I^2CNER	3.3%	61	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	1.4%
iCeMS	6.9%	140	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	2.1%
IFReC	9.2%	107	Clinical Sciences; Biochemistry and Cell Biology; Immunology	3.0%
IIIS	12.3%	96	Clinical Sciences; Biochemistry and Cell Biology; Neurosciences	4.4%
ITbM	14.1%	107	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Organic Chemistry	2.8%
Kavli IPMU	6.2%	239	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	2.5%
MANA	3.6%	206	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	1.1%

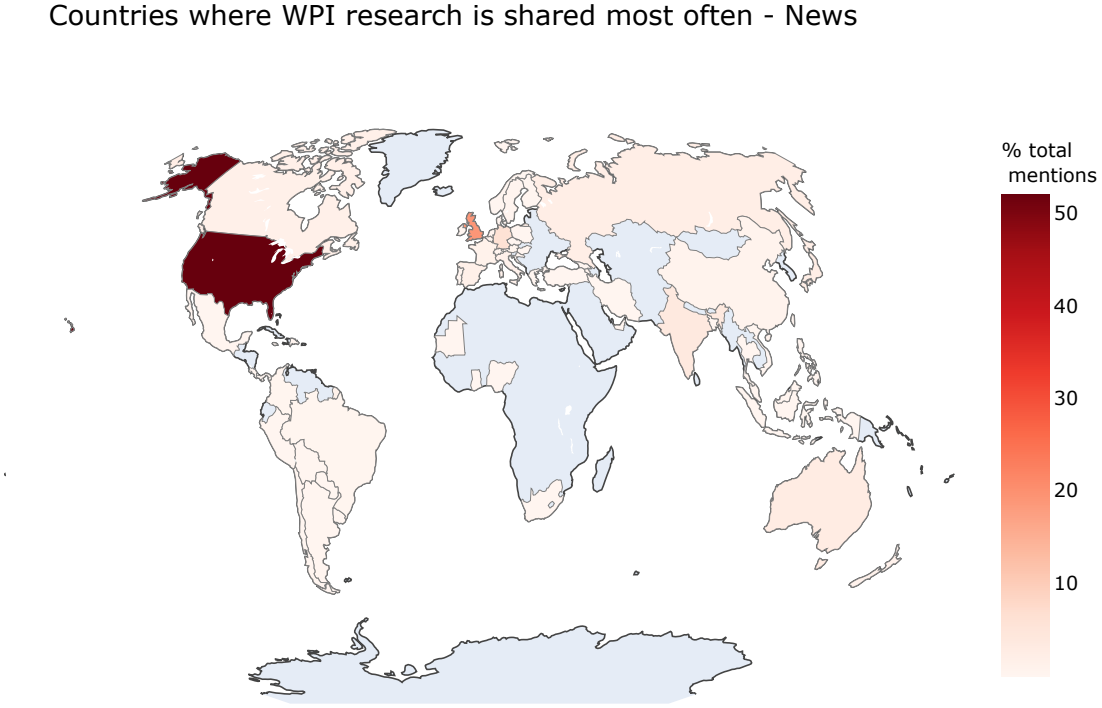


Figure 10: Global diffusion of WPI programme research in the mainstream media (Altmetric)

4.8 Policy impact

Citations to research in public policy documents have been suggested as an important measure of the societal impact of research.[47] Citations to basic research in public policy often form the basis for the application of research in citizens' everyday lives, from the healthcare they receive to government responses to climate change to environmental remediation from toxic pollution.

Policy impact is one of the slowest forms of impact to appear, with the half-life of policy citations being roughly two years.[48] Researchers estimate that on average 0.5% of journal articles are cited in public policy[49], with likelihood increasing to 1.5% for "applied" fields like climate change research.[50]

WPI-supported research has been referenced in 93 policy documents published by 19 unique policy sources[51] in 8 countries (Figure 11). 66 WPI programme publications (0.3% of total) were cited in policy documents. Given that the bulk of WPI publications analyzed were relatively recent and given the focus of the WPI programme upon fundamental research, this rate of policy citedness is expected (even in comparison with the norms described above).

Policy implementation for WPI-supported research included citations in policy from the World Health Organization ("Genomic sequencing of SARS-CoV-2: a guide to implementation for maximum impact on public health, 8 January 2021", 2021), PBL Netherlands Environmental Assessment Agency ("Towards an urban preview: Modelling future urban growth with 2UP", 2018), the World Meteorological Organization ("Global Warming of 1.5°C", 2018), and the US National Academies of Sciences, Engineering and Medicine ("Human Genome Editing: Science, Ethics and Governance", 2017).

Institute research was shared most often in the United States of America (32.3% of all mentions), Switzerland (17.2%), and the Netherlands (16.1%). Table 23 (Appendix) highlights the global policy makers that cited WPI programme research.

Please note that the low rates of policy citation imply a high degree of variability. Caution should be taken in interpretation. For example, IIIS's rate of 0.6% (5 publications with policy citations) cannot be assumed to be a statistically significant under-performance against a global average of 1.2% (which would translate into only 10 publications being expected to receive policy citations).

[47] Haunschild, Robin, and Lutz Bornmann. "How Many Scientific Papers Are Mentioned in Policy-Related Documents? An Empirical Investigation Using Web of Science and Altmetric Data." Scientometrics 110, no. 3 (March 2017): 1209–16. https://doi.org/10.1007/s11192-016-2237-2.

[48] Fang, Zhichao, and Rodrigo Costas. "Studying the Accumulation Velocity of Altmetric Data Tracked by Altmetric.Com." Scientometrics 123, no. 2 (May 1, 2020): 1077–1101. https://doi.org/10.1007/s11192-020-03405-9.

[49] Haunschild, Robin, and Lutz Bornmann. "How Many Scientific Papers Are Mentioned in Policy-Related Documents? An Empirical Investigation Using Web of Science and Altmetric Data." Scientometrics 110, no. 3 (March 2017): 1209–16. https://doi.org/10.1007/s11192-016-2237-2.

[50] Bornmann, Lutz, Robin Haunschild, and Werner Marx. "Policy Documents as Sources for Measuring Societal Impact: How Often Is Climate Change Research Mentioned in Policy-Related Documents?" Scientometrics 109, no. 3 (December 1, 2016): 1477–95. https://doi.org/10.1007/s11192-016-2115-y.

[51] Altmetric tracks citations to research in public policy documents from over 250 global government bodies, NGOs, and nonprofits, including Japanese policymaker, The Japan Institute of International Affairs. Altmetric uses text mining to find references to research outputs in policy documents. To date, Altmetric has tracked more than 2.5 million references to research in public policy documents.

Takeaways

- ELSI research appears to have a much higher rate of influence, as measured by policy citations, than expected for its subject areas.
- However, rates of policy citation are traditionally low for fields such as Engineering, Chemistry and Physics.
- Consequently, WPI institutions' research - largely focused in these areas - is not expected to find its societal impact via policy documents.
- Where WPI's research is in fields that are more frequently impactful in policy documents (for example iCeMS and IFReC), it receives expected rates of citation.

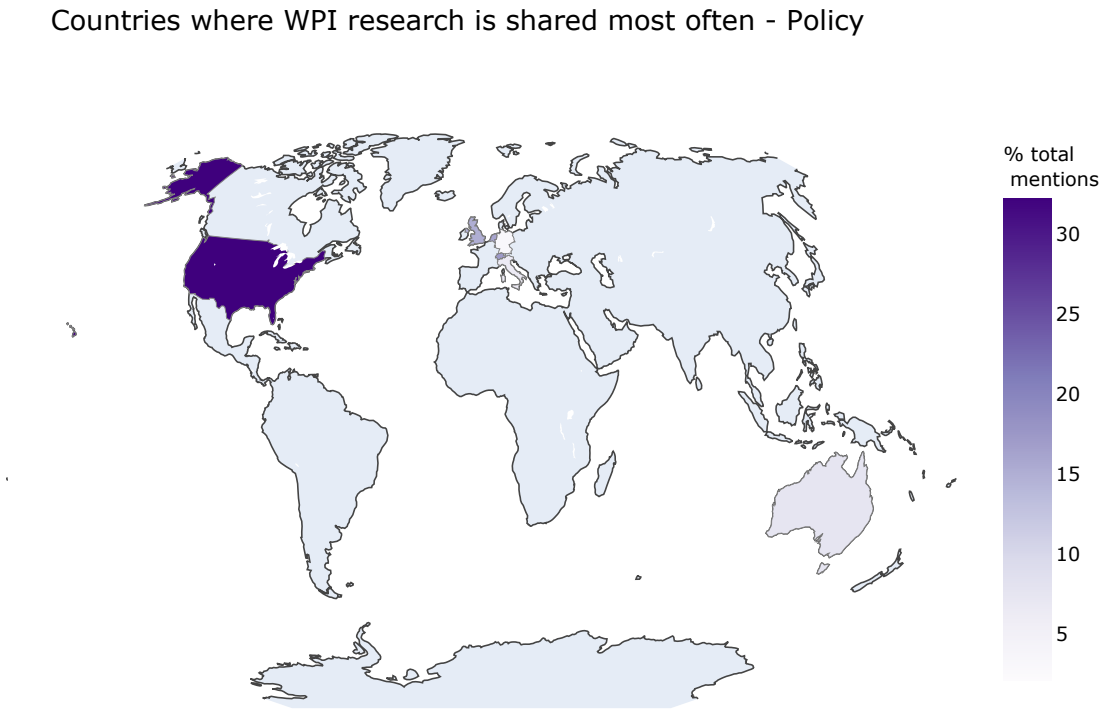


Figure 11: Global diffusion of WPI programme research cited in public policy documents (Altmetric). See Table 23 in the Appendix for a full list of policy bodies citing WPI programme research.

Table 7: Policy coverage, by institute (Altmetric). Subject area coverage is calculated relative to the years during which each institute actively published.

Institute	Articles mentioned (%)	Articles mentioned	Subject areas	Articles mentioned (subject areas) (%)
AIMR	<0.1%	2	Materials Engineering; Physical Chemistry (incl. Structural); Other Physical Sciences	<0.1%
ELSI	2.1%	19	Astronomical and Space Sciences; Geology; Geochemistry	0.7%
I^2CNER	<0.1%	2	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	<0.1%
iCeMS	0.6%	12	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Macromolecular and Materials Chemistry	0.3%
IFReC	1.5%	23	Clinical Sciences; Biochemistry and Cell Biology; Immunology	1.6%
IIIS	0.6%	5	Clinical Sciences; Biochemistry and Cell Biology; Neurosciences	1.2%
ITbM	0	0	Physical Chemistry (incl. Structural); Biochemistry and Cell Biology; Organic Chemistry	<0.1%
Kavli IPMU	0	0	Atomic, Molecular, Nuclear, Particle and Plasma Physics; Astronomical and Space Sciences; Quantum Physics	<0.1%
MANA	0.05%	3	Materials Engineering; Physical Chemistry (incl. Structural); Macromolecular and Materials Chemistry	0.1%

5 Summary

WPI-supported research published by nine key research institutes (AIMR, ELSI, I²CNER, iCeMS, IFReC, IIIS, ITbM, Kavli IPMU, and MANA) has had wide-ranging scientific and societal impact. Relative to other research published in similar disciplines, each institute has had an outsize influence on their respective fields and public engagement with basic science.

Overall, WPI institutes are highly productive and internationally collaborative organizations that are well-cited, compared to national and global trends.

WPI programme research has shown important societal influence. It underpins technology commercialization in renewable energy, disease treatment and diagnostics, and other important areas that have a direct bearing on human health and quality of life. Crucially, WPI-supported research has made important contributions to furthering UN Sustainable Development Goals, particularly in the area of affordable and clean energy development.

Institute research has had an indelible impact upon scientific literacy for the general public. WPI-supported research has been highly discussed on social media, at greater rates than similar disciplinary research. One out of every two publications originating from a WPI programme has been shared online. Moreover, WPI-supported research has been featured over 1,000 times in high profile media outlets worldwide, and covered in more than 9,000 news articles total.

WPI-supported research has had an important influence upon public policy, particularly in Europe and the United States. WPI research has been cited in public policy addressing topics like climate change preparedness, public health crises like COVID-19, and the bioethics of human genome editing—topics that will govern the future of humanity.

In conclusion, such impacts demonstrate each institute's commitment to embodying the values and goals of the overall WPI programme, their public outreach success, and the high degree of prestige afforded by their research on the international stage.

6 Appendix

Table 8: Publications related to all UN Sustainable Development Goals, by institute (Dimensions)

Institute	Affordable and Clean Energy	Clean Water and Sanitation	Climate Action	Decent Work and Economic Growth	Good Health and Well Being	Life Below Water	Life on Land	Peace, Justice and Strong Institutions	Quality Education	Reduced Inequalities	Responsible Consumption and Production	Sustainable Cities and Communities	Zero Hunger
AIMR	130	-	5	-	-	-	-	-	1	1	-	-	-
ELSI	19	1	20	-	1	2	-	1	-	-	-	2	3
I²CNER	159	2	57	-	1	1	-	-	-	-	1	-	-
iCeMS	37	1	9	1	2	-	1	-	1	-	-	2	-
IFReC	1	-	-	-	61	1	-	-	-	-	-	-	-
IIIS	7	-	-	1	10	-	-	-	-	-	-	-	1
ITbM	10	-	-	-	1	-	-	-	-	-	-	1	-
MANA	346	3	17	-	1	-	-	-	1	-	1	1	-
WPI programme (total)	709	7	108	2	77	4	1	1	3	1	2	6	4

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	268	148	55.22%	19.22%	10.81%
2017	365	182	49.86%	17.33%	10.52%
2016	346	187	54.05%	19.37%	10.55%
2015	376	198	52.66%	17.64%	10.11%
2014	380	186	48.95%	17.80%	9.64%
2013	340	147	43.24%	16.49%	9.13%
2012	333	127	38.14%	15.88%	8.95%
2011	334	120	35.93%	14.45%	8.27%
2010	330	83	25.15%	13.16%	8.39%
2009	258	54	20.93%	13.81%	8.04%
2008	206	33	16.02%	13.54%	7.79%
2007	37	5	13.51%	13.45%	7.05%

Table 9: Annual international collaboration rates for AIMR publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	185	87	47.03%	19.22%	10.81%
2017	163	72	44.17%	17.33%	10.52%
2016	151	65	43.05%	19.37%	10.55%
2015	164	71	43.29%	17.64%	10.11%
2014	140	58	41.43%	17.80%	9.64%
2013	53	24	45.28%	16.49%	9.13%
2012	1	0	0.00%	15.88%	8.95%

Table 10: Annual international collaboration rates for ELSI publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	230	106	46.09%	19.22%	10.81%
2017	314	137	43.63%	17.33%	10.52%
2016	281	106	37.72%	19.37%	10.55%
2015	254	96	37.80%	17.64%	10.11%
2014	293	93	31.74%	17.80%	9.64%
2013	272	74	27.21%	16.49%	9.13%
2012	94	25	26.60%	15.88%	8.95%
2011	21	4	19.05%	14.45%	8.27%

Table 11: Annual international collaboration rates for I²CNER publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	139	56	40.29%	19.22%	10.81%
2017	207	88	42.51%	17.33%	10.52%
2016	179	62	34.64%	19.37%	10.55%
2015	203	70	34.48%	17.64%	10.11%
2014	235	60	25.53%	17.80%	9.64%
2013	199	53	26.63%	16.49%	9.13%
2012	200	54	27.00%	15.88%	8.95%
2011	192	56	29.17%	14.45%	8.27%
2010	167	23	13.77%	13.16%	8.39%
2009	133	25	18.80%	13.81%	8.04%
2008	62	7	11.29%	13.54%	7.79%
2007	2	1	50.00%	13.45%	7.05%

Table 12: Annual international collaboration rates for iCeMS publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	134	48	35.82%	19.22%	10.81%
2017	157	62	39.49%	17.33%	10.52%
2016	166	52	31.33%	19.37%	10.55%
2015	148	50	33.78%	17.64%	10.11%
2014	183	79	43.17%	17.80%	9.64%
2013	192	62	32.29%	16.49%	9.13%
2012	165	66	40.00%	15.88%	8.95%
2011	149	60	40.27%	14.45%	8.27%
2010	121	44	36.36%	13.16%	8.39%
2009	76	28	36.84%	13.81%	8.04%
2008	50	14	28.00%	13.54%	7.79%

Table 13: Annual international collaboration rates for IFReC publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	142	48	33.80%	19.22%	10.81%
2017	69	22	31.88%	17.33%	10.52%
2016	120	32	26.67%	19.37%	10.55%
2015	115	38	33.04%	17.64%	10.11%
2014	131	49	37.40%	17.80%	9.64%
2013	120	28	23.33%	16.49%	9.13%
2012	15	2	13.33%	15.88%	8.95%

Table 14: Annual international collaboration rates for IIIS publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2019	6	4	66.67%	20.49%	10.94%
2018	124	47	37.90%	19.22%	10.81%
2017	157	62	39.49%	17.33%	10.52%
2016	134	50	37.31%	19.37%	10.55%
2015	124	42	33.87%	17.64%	10.11%
2014	105	34	32.38%	17.80%	9.64%
2013	97	27	27.84%	16.49%	9.13%
2012	9	2	22.22%	15.88%	8.95%

Table 15: Annual international collaboration rates for ITbM publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2018	518	281	54.25%	19.22%	10.81%
2017	393	161	40.97%	17.33%	10.52%
2016	461	187	40.56%	19.37%	10.55%
2015	444	235	52.93%	17.64%	10.11%
2014	450	264	58.67%	17.80%	9.64%
2013	378	252	66.67%	16.49%	9.13%
2012	338	216	63.91%	15.88%	8.95%
2011	287	165	57.49%	14.45%	8.27%
2010	235	153	65.11%	13.16%	8.39%
2009	195	106	54.36%	13.81%	8.04%
2008	66	21	31.82%	13.54%	7.79%
2007	2	0	0.00%	13.45%	7.05%

Table 16: Annual international collaboration rates for Kavli IPMU publications (Dimensions)

Year	Institute Publications	Institute Publications w/ International Collaborators	Institute International Collaboration Rate	Japan International Collaboration Rate	Global International Collaboration Rate
2019	1	0	0.00%	20.49%	10.94%
2018	444	294	66.22%	19.22%	10.81%
2017	433	240	55.43%	17.33%	10.52%
2016	533	266	49.91%	19.37%	10.55%
2015	459	245	53.38%	17.64%	10.11%
2014	472	199	42.16%	17.80%	9.64%
2013	539	253	46.94%	16.49%	9.13%
2012	636	260	40.88%	15.88%	8.95%
2011	602	186	30.90%	14.45%	8.27%
2010	589	153	25.98%	13.16%	8.39%
2009	501	121	24.15%	13.81%	8.04%
2008	381	87	22.83%	13.54%	7.79%
2007	17	5	29.41%	13.45%	7.05%

Table 17: Annual international collaboration rates for MANA publications (Dimensions)

Table 18: Top domestic industry collaborators, by co-authored publication count (Dimensions)

Organization	Co-authored publications
Hitachi (Japan)	36
NEC (Japan)	32
JEOL (Japan)	21
Denso (Japan)	20
Toyota Motor Corporation (Japan)	18
Toyota Central Research and Development Laboratories (Japan)	15
JFE Holdings (Japan)	13
NTT (Japan)	13
Fujifilm (Japan)	12
Nissan Chemical Corporation (Japan)	10
Konica Minolta (Japan)	10
Mitsubishi Chemical Holdings (Japan)	9
Panasonic (Japan)	9
Nippon Steel & Sumitomo Metal (Japan)	9
Japan Aviation Electronics Industry (Japan)	8
Tokyo Gas (Japan)	7
Olympus (Japan)	7
Kao Corporation (Japan)	7
Kuraray (Japan)	7
JXTG Holdings (Japan)	7

Table 19: Top international industry collaborators, by co-authored publication count (Dimensions)

Organization	Co-authored publications
Samsung (South Korea)	14
Roche (United States)	6
Veeco (United States)	4
Nestlé (Switzerland)	3
Air Liquide (France)	3
Swiss Center for Electronics and Microtechnology (Switzerland)	2
Amgen (United States)	2
Colgate-Palmolive (United States)	2
Hewlett-Packard (United States)	2
Adnet Systems (United States)	2
AstraZeneca (Sweden)	2
Biocompatibles (United Kingdom)	2
Biogen (United States)	2
Bayer (Germany)	2
Radiation Monitoring Devices (United States)	2
Aecom (United States)	2
GlobalFoundries (Singapore)	2

Table 20: Top patent assignees whose patents cite WPI research (Dimensions)

Assignee	Citing patents
Kyoto University	150
Moderna Therapeutics Inc	103
Harvard College	84
Crossbar Inc	74
University of California	61
University of Tokyo National University Corporation	36
Samsung Electronics Co Ltd	35
Osaka University National University Corporation	33
Janssen Biotech Inc	32
Viacyte Inc	32
Fujifilm Cellular Dynamics Inc	32
Massachusetts Institute of Technology	31
University of Michigan	31
National Institute for Materials Science	29
Commissariat a l'Énergie Atomique et aux Energies Alternatives	27
Capacitor Sciences Inc	26
Dana Farber Cancer Institute Inc	21
University of Texas System	21
INST NAT SANTE RECH MED	20
Scripps Research Institute	20
CENTRE NAT RECH SCIENT	19
Japan Science and Technology Agency	19
Memorial Sloan Kettering Cancer Center	18

Table 21: Top 99th percentile articles, by Altmetric Attention Score (Top 5 articles for each institute)

Institute	Title	Publication year	Altmetric Attention Score
AIMR	Formation And Characterization Of Hydrogen Boride Sheets Derived From Mgb2 ...	2017	410
AIMR	Atomically Well-Ordered Structure At Solid Electrolyte And Electrode Interf...	2018	170
AIMR	Bottom-Up Graphene-Nanoribbon Fabrication Reveals Chiral Edges And Enantios...	2014	99
AIMR	Cooperation Between Holey Graphene And Nimo Alloy For Hydrogen Evolution In...	2018	79
AIMR	Nematicity Of Correlated Systems Driven By Anisotropic Chemical Phase Separ...	2018	76
ELSI	Accretion Of Phobos And Deimos In An Extended Debris Disc Stirred By Transi...	2016	782
ELSI	The Abiotic Chemistry Of Thiolated Acetate Derivatives And The Origin Of Li...	2016	330
ELSI	Ring Formation Around Giant Planets By Tidal Disruption Of A Single Passing...	2017	262
ELSI	Exoplanet Biosignatures: Observational Prospects...	2018	133
ELSI	Conducting Miller-Urey Experiments...	2014	113
I²CNER	A Sublimation Heat Engine...	2015	180
I²CNER	Characterization Of Immiscible Fluid Displacement Processes With Various Ca...	2016	54
I²CNER	Ultra-High Aspect Ratio Inp Junctionless Finfets By A Novel Wet Etching Met...	2016	42
I²CNER	Effect Of Charged Group Spacer Length On Hydration State In Zwitterionic Po...	2017	41
I²CNER	A Fusion Of Biomimetic Fuel And Solar Cells Based On Hydrogenase, Photosyst...	2017	31
iCeMS	Integrated Heart/Cancer On A Chip To Reproduce The Side Effects Of Anti-Can...	2017	94
iCeMS	A Synthetic Dna-Binding Inhibitor Of Sox2 Guides Human Induced Pluripotent ...	2017	78
iCeMS	Self-Assembly Of Metal-Organic Polyhedra Into Supramolecular Polymers With ...	2018	69
iCeMS	Assessment Of Established Techniques To Determine Developmental And Maligna...	2018	36
iCeMS	Endodermal Differentiation Of Human Pluripotent Stem Cells To Insulin-Produ...	2014	26
IFReC	Klb Is Associated With Alcohol Drinking, And Its Gene Product Beta-Klotho I...	2016	747
IFReC	Deep Whole-Genome Sequencing Reveals Recent Selection Signatures Linked To ...	2018	690
IFReC	Immunodominant Sars Coronavirus Epitopes In Humans Elicited Both Enhancing ...	2016	302
IFReC	Innate And Adaptive Immune Responses To Viral Infection And Vaccination...	2011	224
IFReC	Molecular Mechanisms Of Cell Death: Recommendations Of The Nomenclature Com...	2018	135
IIIS	Regulation Of Rem And Non-Rem Sleep By Periaqueductal Gabaergic Neurons...	2018	950
IIIS	Bmal1 Function In Skeletal Muscle Regulates Sleep...	2017	510
IIIS	Muscarinic Acetylcholine Receptors Chrm1 And Chrm3 Are Essential For Rem Sl...	2018	502

Continued on next page

Table 21: Top 99th percentile articles, by Altmetric Attention Score (Top 5 articles for each institute)

Institute	Title	Publication year	Altmetric Attention Score
IIIS	Olfactory Receptor Responding To Gut Microbiota-Derived Signals Plays A Rol...	2013	496
IIIS	Epigenetic Regulation Of The Nuclear-Coded Gcat And Shmt2 Genes Confers Hum...	2015	207
ITbM	The Highest-Ranking Rooster Has Priority To Announce The Break Of Dawn...	2015	210
ITbM	Electrically Activated Conductivity And White Light Emission Of A Hydrocarb...	2017	141
ITbM	Construction Of Covalent Organic Nanotubes By Light-Induced Cross-Linking O...	2016	126
ITbM	A Water-Soluble Warped Nanographene: Synthesis And Applications For Photoin...	2018	100
ITbM	Eta(6)-Cycloparaphenylene Transition Metal Complexes: Synthesis, Structure,...	2015	99
Kavli IPMU	Extreme Magnification Of An Individual Star At Redshift 1.5 By A Galaxy-Clu...	2018	1796
Kavli IPMU	Multi-Messenger Observations Of A Binary Neutron Star Merger...	2017	1521
Kavli IPMU	Two Peculiar Fast Transients In A Strongly Lensed Host Galaxy...	2018	1301
Kavli IPMU	First Identification Of Direct Collapse Black Hole Candidates In The Early ...	2016	1032
Kavli IPMU	On The Metallicity And Origin Of The Smith High-Velocity Cloud...	2016	440
MANA	Tuning Of The Optical, Electronic, And Magnetic Properties Of Boron Nitride...	2017	431
MANA	Mesoporous Semimetallic Conductors: Structural And Electronic Properties Of...	2017	410
MANA	Ultratrace Detection Of Toxic Chemicals: Triggered Disassembly Of Supramole...	2016	213
MANA	Fabrication Of Zeolite-Polymer Composite Nanofibers For Removal Of Uremic T...	2014	78
MANA	Titanium Nitride Nanoparticles As Plasmonic Solar Heat Transducers...	2016	49

Table 22: News coverage (Global) - Top 20 sources (Altmetric)

	News outlet	Country	Mentions
	Phys.org	GB	541
	EurekAlert!	US	437
	Nanowerk	US	275
	Science Daily	US	259
	Health Medicinet	US	189
	AlphaGalileo	GB	155
	Science Newsline	JP	149
	MedicalXpress	GB	127
	Space Daily	US	112
	Yahoo! News	US	93
	The Medical News	AU	93
	Technology.org	US	91
	Sci-News	US	89
	Innovations Report	DE	86
	Asian Scientist	SG	85
	Sky Nightly	US	84
	ChemistryViews	DE	77
	Newswise	US	75
	Bioportfolio	GB	68
	MSN	US	67

Table 23: Policy bodies citing WPI research (Altmetric)

Organization	Country	Citations
National Academies Press	US	20
World Health Organization	CH	13
Analysis & Policy Observatory (APO)	AU	7
UK Government (GOV.UK)	GB	6
European Food Safety Authority	IT	6
Centers for Disease Control and Prevention (CDC)	US	6
Rijksinstituut voor Volksgezondheid en Milieu	NL	5
rijksoverheid.nl	NL	5
National Institute for Health and Care Excellence	GB	5
overheid.nl	NL	4
World Meteorological Organization (WMO)	CH	3
UK Parliament Briefing notes	GB	3
World Bank	US	2
Office of Technology Assessment at the German Bundestag (TAB)	DE	2
The Publications Office of the European Union	LU	2
RAND Corporation	US	1
PBL Netherlands Environmental Assessment Agency	NL	1
National Academy of Medicine	US	1
The Association of the Scientific Medical Societies in Germany	DE	1