CWTS BIBLIOMETRIC REPORT

Meaningful metrics

Bibliometric study of PSI (2009-2020/2021)

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Universiteit Leiden

Bibliometric study of PSI (2009–2020/2021)

Report for the ETH Board

Nicolas Leclaire
Häldeliweg 15
8092 Zurich, Switzerland
E-mail nicolas.leclaire@ethrat.ch
Webpage https://www.ethrat.ch/en

CWTS

Ed Noyons, Clara Calero, Rodrigo Costas, Jeroen van Honk

CWTS B.V.
P.O. Box 905
2300 AX Leiden, The Netherlands
Tel +31 71 527 5806
E-mail info@cwts.nl
Webpage http://www.cwtsbv.nl/

General parameters of the bibliometric report

Parameters

Database	:	Web of Science (Articles, Reviews and Proceedings papers in the SCIE, SSCI, AHCI, and CPCI)
Version	:	2152 (CWTS)
Classification system	:	Publication-level classification system (about 4000 fields, referred to as research areas)
Publication window	:	2009–2020
Citation window	:	Maximum 4 years (and until 2021)
Counting Method	:	Fractional counting at the level of organisation for citation impact measurement
Self-citations	:	Excluded
Top indicators	:	Top 10%

Contents

List of indicators

Avg Reads Average number of reads per DOI. A *read* is defined by saving a publication in a Mendeley user account.

IntCov Internal coverage. Estimated Web of Science coverage of a set of publications. A description of the calculation is provided in Annex C.1.

IntDisc Measure of *interdisciplinary* research, defined by the proportion of references in a publication assigned to other fields. Fields are defined by journal categories. In addition, the cognitive distance of fields to each other is also considered (more info at Section 2.2 (p. 16) and Annex D).

MCS Mean citation score. The average number of citations received by a publication (TCS/P[full]).

MNCS The mean normalised citation score. This represents average citation score per publication, normalised by research area and publication year. Research areas are defined by a detailed publication classification system of CWTS, consisting of about 4000 areas. The average MNCS in the entire database is 1. Scores higher than 1 reflect a citation-based impact that is higher than the world average.

MNJS The mean normalised journal score. This represents the normalised average citation impact of journals. The MNJS is an average score for all publications in the same journals in which an institution published. The normalisation is based on the same principles as the MNCS. The average MNJS in the entire database is 1. Scores higher than 1 reflect a journal citation impact that is higher than the world average.

P[full] The number of publications, full counting. Each publication is counted in full (i.e. as 1).

P[fract] The number of publications, fractionally counted. The fraction is determined based on the number of co-authoring organisations.

P[OA] Number of publications, full counting, in Open Access(OA). In addition, we provide the number for the different kinds of OA: Gold, Hybrid, and Green. A publication is tagged by one type only. Gold and Hybrid overrule Green. Information is based on Unpaywall data (July 2021).

PP[OA] The proportion of publications in Gold, Hybrid or Green OA, while publications without a DOI are discarded (OA unknown).

PP[collab] Proportion of publications, full counting, involving collaboration (at least two institutions co-authoring).

PP[int collab] Proportion of publications, full counting, involving international collaboration (co-authorship of organisations from more than one country).

PP[industry] Proportion of publications, full counting, involving industry (co-authorship with companies).

PP[uncited] Proportion of publications, full counting, that are not cited.

PP[self cits] The average number of author-self citations per publication. A self-citation is defined as any of the authors of a cited publication is the same as any of the authors of the citing publication.

P[top10%] The number of publications, counted in full belonging to the top 10% of their research area. The area is determined on the basis of a detailed publication classification system of CWTS, consisting of about 4000 areas (See Annex B).

PP[top10%] The proportion of publications (P[fract]) belonging to the top 10% most cited of their area and in the same year. The areas are determined using a detailed publication-level classification system , consisting of about 4000 areas. The PP[top10%] in the entire database is 10%. A score above 10% represents impact that is higher than the world average.

PA[F inst] Share of female authors of an institution within a publication.

PA[F pubs] Share of female authors within a publication (institution plus co-authors).

A[M inst] Number of male authors of an institution.

A[FM inst] Number of authors of an institution for which we could define gender male or female.

RPA[F] Proportion of female authors compared to the total of authors for which gender (male or female) was defined (more info at Section 2.2).

TCS The total citation score. This represents the total number of citations accumulated within the citation window, excluding author self-citations.

For more details about the normalised citation indicators, please refer to Waltman et al. (2012). More information about the mentioned publication-level classification is in Annex B.

Definitions, abbreviations and acronyms

CWTS Centre for Science and Technology Studies, Leiden University

A&HCI Arts & Humanities Science Citation Index

SCIE Science Citation Index Expanded

SSCI Social Science Citation Index

CPCI Conference Proceedings Citation Index

DOI Digital Object Identifier (a permanent ID for publications)

JSC Journal Subject Category

OA Open Access

Research area A set of publications on a certain topic, identified by the Leiden Algorithm (Annex B)

Subject A set of publications in journals belonging to a (subject) category

WoS Web of Science

1 Introduction

The ETH Domain consists of two Federal Institutes of Technology, ETH Zurich and EPFL, and four research institutes PSI, WSL, Empa and Eawag. Together, they play a vital role in the Swiss science system for education, research and transfer of knowledge and technology.

The ETH Board commissions an intermediate evaluation every four years. The most recent one took place in 2019. The bibliometric study was executed in 2018. The evaluation is a moment for the Swiss Federal Council, the ETH Board, as well as staff and management of ETH Domain to find out where ETH Domain stands vis-a-vis the ambitions and measures formulated in the strategic planning document. Moreover, the intermediate evaluation should lead to recommendations relating to these ambitions and measures.

Bibliometric studies can provide evidence related to ambitions and measures as part of a self-assessment report. Although we consider that meeting the standards of objectivity for determining the impact of scientific research is important, we believe that decision-making towards the goal of evaluating the quality of institute's research ought to be multi-dimensional rather than overwhelmingly quantitative. Bibliometric measures provide objective evidence about production, collaboration and impact but only for the research that has been published in (international) journals and proceedings. Therefore, we strongly recommend that quantitative evaluations are complemented with qualitative information (for example the mission and the research goals of a department) and expert assessments.

This report includes the bibliometric analysis of the scientific output of PSI, covering the period 2009-2020, including citations up to 2021. The studies are based on a quantitative analysis of scientific publications in journals and proceedings processed for the Web of Science (WoS) versions of the Science Citation Index and associated citation indices: the Science Citation Index (SCI), the Social Science Citation Index (SSCI), the Arts & Humanities Citation Index (A&HCI) and the Conference Proceedings Citation Index (CPCI).

Although most of the methodology is similar to the study performed four years ago for PSI, the results may sometimes differ substantially, due to the fact that in the current report conference proceedings papers are included and fully integrated, but that depends on the role conferences play for an institution if this is actually the case. Moreover, new indicators were introduced: RPA[F], IntDisc, P[OA], PP[OA], and Avg Reads.

We introduce each result in brief, while more detailed information about data and method is provided in Section 2.1 and Annex C) of this report.

In Section 3 the results of our analysis and interpretations are reported. These results are discussed in 5 parts:

1. Section 3.1: Overall output and impact
2. Section 3.2: Research focus in context
3. Section 3.3: Collaboration and partners
4. Section 3.4: Research accessibility
5. Section 3.5: Impact and knowledge use.

In the annexes, we provide more detailed scores for some indicators, more detailed information about specific approaches, as well as information about CWTS infrastructural elements involved in the analyses.

2 Data collection and methodology

2.1 Data collection

PSI provided CWTS with a list of publications from its own repository. CWTS used these data to match the publication records with the records in its database (matched results). Simultaneously, CWTS collected PSI's publication data from its database using the author affiliations in publications. Both data sets were compared to each other.

After PSI and CWTS compared, checked and corrected these two sets, the final dataset was prepared for the bibliometric analysis.

Additionally, for the Mendeley readership analysis PSI provided CWTS with any DOI registered in its repository.

2.2 Summary of method

In this section, we discuss the methods underlying the bibliometric analysis developed. We discuss the basic principles of our indicators and the context in which they can (or should not) be used. Additional and more detailed information about methods and data can be found in the annexes.

2.2.1 Indicators

In bibliometric analyses regarding research performance, we usually discern two types of indicators: size-dependent and size-independent, taking into account the different size of institutions under investigation. Larger institutions, for instance, will be involved in more publications than smaller ones. Subsequently, this will affect the absolute number of top 10% publications, as well as all other size-dependent indicators. In Figure 1 we visualise the correlation between the two indicators for the 6 ETH institutions.

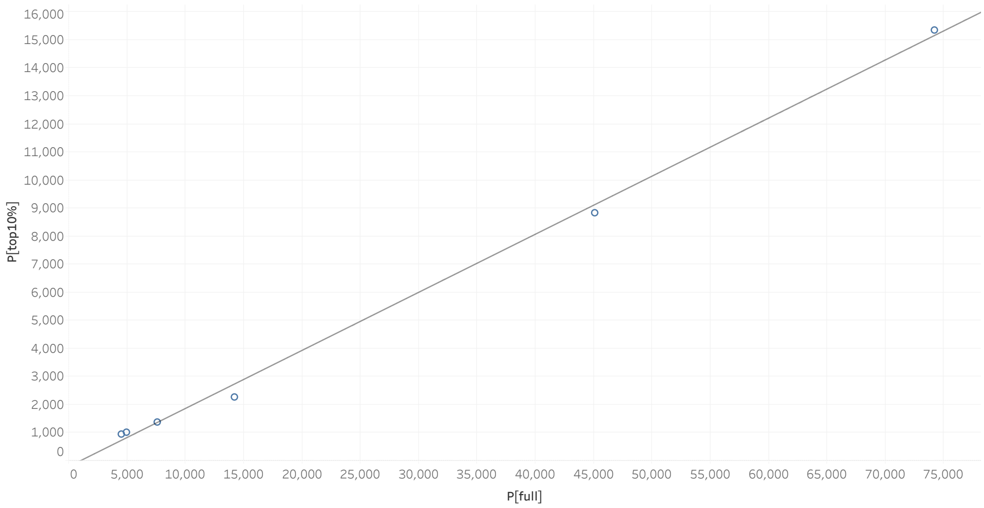

Figure 1: P[full]vs.P[top10%]for 6 ETH institutions

Proportion indicators (e.g., PP[collab], PP[int collab], PP[industry], PP[OA], PP[top10%]) and average indicators (MNCS, MNJS) are size-independent, while others used in this study (e.g., P[full], P[fract], TCS) are size-dependent. In the report we will primarily discuss the results using the size-independent indicators to account for the size differences of the organisations. Moreover, the results for size-independent indicators can, in most cases, be related to the world average.

Output indicators

Size-dependent

The total number of publications in which researchers from an institution were involved (**P[full]**) is the basic output measure. In addition, we provide the indicator **P[fract]** which assesses an institution's contribution to the output P[full]. Each individual publication is divided by the number of organisations co-authoring, regardless of the number of organisations involved. If authors have two affiliations and mention both, both affiliations are counted as fractions. P[fract] is the sum of these fractions of publications in which an institution was involved.

Size-independent

Proportion indicators characterise sets of publications regardless of the number and are therefore size-independent. They are often used to characterise output. For instance, **PP[collab]** indicates the proportion of output with at least two different organisations involved. **PP[int collab]** indicates the proportion of output involving international collaboration. In this report, a publication is tagged as an international collaboration if at least one of the co-authoring organisations is based outside of Switzerland. Furthermore, two other proportion indicators are used: **PP[industry]**, representing the proportion of P[full] co-authored with a company and **PP[OA]**, the proportion of P[full] published in Open Access (OA).

For OA publications, we discern different types: OA Gold, OA Hybrid and OA Green. The definition of the types used in this report are:

- Gold: The publisher makes all articles and related content available for free immediately on the journal's website.
- Hybrid: Publication freely available under an open license in a paid-access journal.
- Green: Published in toll-access journals, self-archived by authors (in repositories or researchers' websites), independently from publication by a publisher.

OA publications are counted only as one type at the same time. If a paper is both Green and Gold, it is counted as Gold. Bronze OA publications are free to read only on the publisher page without a license. As such, they were disregarded as OA. These were identified as *Closed Access* publications.

Impact indicators

Size-dependent

The scientific impact of an institution's output is measured by citations. We provide the total number of citations received (**TCS**) in the period of maximum 4 years after publication, up to 2021. For more recent years the citation window is shorter than 4 years. We exclude author self-citations. Another size-dependent indicator of impact is P[top10%], i.e. the absolute number of publications belonging to the top 10% most cited publications (in their area and from the same year).

It should be noted that all citation-based indicators (including TCS) are calculated using a limited and fixed time-window. The total amount of citations for early publications may therefore be higher than processed for this report.

Size-independent

The **MNCS** is the indicator to measure citation impact after normalising by research area and publication year. The research area to which a publication belongs is defined by a publication-level classification (for details, see Annex B). In this classification each publication is uniquely assigned to a research area. Areas are defined by their citation environment (cited and citing publications). This classification is more fine-grained and is considered more accurate than a journal classification (Ruiz-Castillo and Waltman, 2015). In a journal classification all publications from one journal are in the same class. Similar journals are in the same class and journals may belong to more than one class. We use this journal classification to characterise an institution's output in its research profiles but not to normalise impact. The journal classification is less fine-grained and as such easier to relate to the main subjects addressed.

In addition, we provide the proportion of publications in the top 10% most cited publications (within their research area, i.e. class, and in the same year, **PP[top10%]**).

This indicator correlates strongly with the MNCS but is not sensitive to outliers. The MNCS can sometimes be biased by one paper being cited many times. The PP[top10%] is not influenced by this one paper, as it is 'just' one of the top 10% or not. An MNCS that is relatively much higher than the PP[top10%] points to a highly skewed distribution of impact across publications. In other words, a few publications receive a huge number of citations, compared to the other publications.

Finally, we also use an indicator measuring the impact of journals, the Mean Normalised Journal Score (**MNJS**). This indicator assesses the impact in term of citations of the journals (aggregated), in which the institution has published, using the same normalisation as we use for measuring the impact (MNCS). As such, the MNJS does not measure the (average) impact of an institution's publications, but rather the impact of the journals in which its researchers publish.

2.2.2 Additional indicators

In this study we introduce indicators that relate to the context of the published research. We will discuss them in brief in the next subsections.

Worldwide growth of research fields

An indicator to position an institution's research activities in the context of what happens at a larger scale is the [**Field growth**]. We use the science landscape (see Annex B) to reflect what happens worldwide, by calculating a growth indicator for each area (the [**Area Growth**]).

The [Field growth] relates the output of an institution to these area growth values ([Area Growth]) as follows. First, we calculate for each of the 4000 research areas in the science landscape, the share output of the most recent two years (2019-2020) as compared to the total in 2009-2020 (the period under study). This share of output in the most recent years is normalised by a reference value, which is the result of the number of recent years (2) and the number of years of the total period considered (12): 0.17. Areas in which the share of output in the recent years is higher than 0.17, have a [Area Growth] above 1, a positive growth.

Any value above 1 means a positive growth, while values below 1 indicate a negative growth. In Figure 2, we plotted the [Area Growth] in the landscape of all science, by color-coding. Green areas show a positive growth (>1) in the most recent two years, while red areas show a negative growth (<1). The size of a circle proportionally reflects the number of ETH Domain publications published in 2009-2020 worldwide, ranging from 1 up to 1,400.

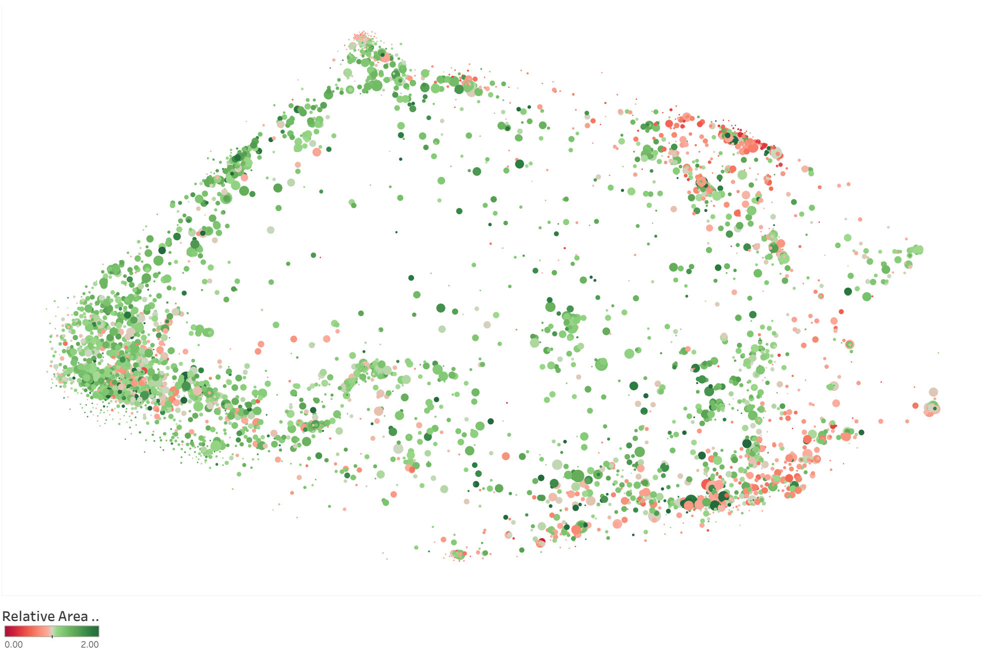

Figure 2: Landscape of all science, color-coded by [Area Growth]

[Field growth]

We use the [Area Growth] to characterise the fields in which PSI researchers are active. Thus we contribute to the answer to the question: is PSI's research positioned in fields with an increasing interest worldwide or not?

The [Field growth] is the average of [Area Growth] values of the areas in which an institution's publications can be found. Consider the output of an institution X, with 100 publications. These 100 publications may be in 20 different areas. Depending on the [Area Growth] values of these areas, these 100 publications relate to 20 different [Area Growth] scores. The average [Area Growth] values of the 100 publications, then indicates the estimated growth of fields in which X is active: the [Field growth] of institution X.

Interdisciplinary research

We introduce a measure related to the interdisciplinary character of the published research. Being more or less interdisciplinary is defined by the knowledge base (the prior art that is being cited) of the published research. The content of cited publications is defined by the journal subject categories.

If a publication cites research from one (and most likely its own) subject category only, it is defined as mono-disciplinary (measure close to 0). If a publication cites research from different subjects, we consider it as interdisciplinary. If the subjects are cognitively at a long distance from each other, the measure of interdisciplinarity is even higher, with a maximum of 1.

The cognitive distance between subject categories is determined by the density of the citation traffic between them. If a publication (A) cites output in subject X and Y, while X and Y are remote from each other (little citation traffic between them), it is considered more interdisciplinary than publication B, which cites publications from Y and Z, which are cognitively closely related (i.e., in subject categories frequently citing each other).

For each publication we calculate an interdisciplinary value and for sets of publications we then calculate their average (**IntDisc**), which is a value between 0 and 1, where 0 indicates mono-disciplinary and 1 means maximum interdisciplinarity.

In summary, interdisciplinarity is:

1. Defined by cited references in a publication;
2. On the basis of the variety of journal categories of cited publications;
3. Considering cognitive distance between these categories;
4. While this distance between categories is based on mutual citation traffic.

The above leads to the definition of interdisciplinarity we use in this report:

> The interdisciplinarity indicator (IntDisc) relates to the diversity of research supporting the current research.

In order to be able to interpret the IntDisc measure in a broader context, we calculated a reference value (**Ref Intdisc**), which is the IntDisc for the journal category at large in 2020. In this way interdisciplinarity can be assessed within each journal subject category by relating it to the world average. We integrated both scores (IntDisc and Ref Intdisc) in profiles, where interdisciplinarity is included. More info can be found in Annex D.

Share of female authors

We also introduce an indicator related to gender diversity of research staff. We calculated the probability of an author name to be male or female, by looking at the first name. If first names (or nicknames) point to a gender within a specific country, the gender is set using the following four-step procedure (also described at CWTS Leiden Ranking):

1. Author disambiguation. Using an author disambiguation algorithm developed by CWTS (Caron and van Eck, 2014), authorships are linked to authors. If there is sufficient evidence to assume that different publications have been authored by the same individual, the algorithm links the corresponding authorships to the same author.

2. Author-country linking. Each author is linked to one or more countries. If the country of the author's first publication is the same as the country occurring most often in the author's publications, the author is linked to this country. Otherwise, the author is linked to all countries occurring in his or her publications.

3. Retrieval of gender statistics. For each author, gender statistics are collected from three sources: Gender API, Genderize.io , and Gender Guesser. Gender statistics are obtained based on the first name of an author and the countries to which the author is linked.

4. Gender assignment. For each author, a gender (male or female) is assigned if Gender API is able to determine the gender with a reported accuracy of at least 90%. If Gender API does not recognize the first name of an author, Gender Guesser and Genderize.io are used. If none of these sources are able to determine the gender of an author with sufficient accuracy, the gender is considered unknown. For authors from Russia and a number of other countries, the last name is also used to determine the gender of the author. Using the above procedure, the gender can be determined for about 70% of all authorships of major universities. For the remaining authorships, the gender is unknown.

For each publication, we counted the *number* of female authors at the level of the institution (A[F **inst**]) as well as at the level of the entire publication (A[F **pubs**]). In addition we counted those for male authors. We disregarded authors for which the gender cannot be defined or is ambiguous. The total amount of authors which we defined female or male is indicated by A[FM **inst**] and A[FM **pubs**].

Hence, for each publication in which PSI authors were involved, there is a share of female PSI authors (PA[F **inst**]), and a share of female authors for the publication at large (PA[F **pubs**]). The latter is used as a benchmark for the former. RPA[F] indicates the PSI share, normalised by the share of the benchmark. A value higher than 1 for an institution X, indicates a higher proportion of female authors at X than for its community at large (X plus co-authoring partners).

2.2.3 Profiles

In the report we use two types of profiles:

1. A research profile in which we look at performance of an institution on the level of journal categories; and

2. A collaboration profile in which we look at performance of an institute of three collaboration types of publications.

In a research profile, we breakdown the PSI output into Journal Subject Categories (JSC) to add content to the general statistics. It gives a general impression of all the broad subjects in which PSI is involved. We include categories that cover at least 1% of the total output (P[full]).

For collaboration profiles, we classify all publications by their author affiliation information. The different types of collaboration are: (1) Single institution, in which only the institution under study is involved, (2) National collaboration for publications with co-authors from at least two different institutions from the same country, and (3) International collaboration for publications co-authored by institutions from at least two countries.

Output

By breaking down the output over categories, we provide a broad overview of activities and focus, by subject. In each profile we include both P[full] and P[fract], i.e. the number of publications in which an institution was involved (P[full]) and the number of publications normalised by the number of institutions involved as co-author (P[fract]). Moreover, if a publication is in a journal that belongs to two categories, it is assigned 0.5 to each category. In addition, we include an estimated growth factor for each subject [Field growth]. This growth factor is calculated on the basis of developments of research areas (see Section 2.2.2). A [Field growth] above 1 means a growth of output worldwide in the most recent two years.

By breaking down an institution's output over collaboration types, we provide insight into the publication strategy, as well as the integration of an institution into the national or international research community. Large shares of international collaboration output (P[full] and P[fract]) point to a strong international network.

Impact

In both types of profiles, the impact of individual publications is measured in the same way as for the entire institution (PP[top10%], MNCS and MNJS) and broken down over subjects and collaboration types. In the research profile, we rank subject categories on the basis of P[full] (using full counting). In this way we depict an institution's main focus by the number of publications in which its researchers are involved, while the impact is measured by the proportion to which it contributes, hence consistent with the overall impact measurement.

Research profiles in other contexts

We also used the breakdown over subject categories to provide more detailed information on the context in which research is executed and published. The main indicators we provide by subject are:

- RPA[F]: the share of Female authors relative to a benchmark
- P[OA], PP[OA]: the number and share of publications in OA
- IntDisc: the measure to which research is interdisciplinary
- PP[collab]: the proportion of output involving collaboration
- PP[int collab]: the proportion of output involving international collaboration

3 Results

3.1 Overall output and impact

Main findings

> The overall output of PSI amounts up to 14,191 publications, with the overall number of publications increasing over time. PSI exhibits an overall high citation impact, with field-normalised impact above the international reference values (with an overall MNCS value of 1.34 and a PP[top10%] of 14%). PSI's publications are predominantly performed in collaboration (90%), with a predominant role of international collaboration (76%), and about 9% involving collaboration with industry. The scientific production of PSI is mostly published Open Access (63%), showing an increasing pattern over time towards more openness. PSI contributes substantially to research areas of all the 5 main disciplines of the science landscape, although with a stronger focus on topics related to Physical Sciences & Engineering.

3.1.1 Overall performance

In Table 1 the overall bibliometric statistics for PSI are presented. Overall PSI has produced a total of 14,191 publications, with almost 13,000 journal papers and about 1,200 proceeding papers. The overall internal coverage (IntCov) is 0.84, meaning that about 84% of PSI cited references are themselves also covered in the Web of Science database, implying that the topics researched by PSI can be considered as being well covered by the database chosen (i.e. Web of Science) for this bibliometric study.

PSI publications have received a total of 150,506 citations (excluding self-citations – which roughly represent 33% of all citations). The vast majority of citations are concentrated around journal papers, with a mean citation impact (MCS) of 11.50. The mean overall citation impact of the proceeding papers is much lower (MCS=0.94) which can be explained by the shorter nature of proceeding papers, making them less prone to receive citations, which is also supported by the rather high percentage of uncited proceeding papers (PP[uncited]=65%).

When it comes to field-normalised citation impact, the MNCS value of PSI is rather high with a value of 1.34, meaning that PSI field-normalised impact is 34% higher than it would be expected by its international expected baseline. Proceeding papers have a particularly high normalised impact (MNCS=1.83), indicating that although this document type is not especially prone to accrue citations, PSI is still having a high citation impact in its set of proceeding papers.

When analysing the production of highly cited outputs, PSI has produced more than 2,000 top 10% highly cited publications (P[top10%]=2,069 of journal papers and P[top10%]=206 of proceeding papers), meaning that in proportion PSI has produced about 14% of its contributions with high impact (PP[top10%]=14%).

More than 60% of PSI publications have some form of Open Access (PP[OA]=63%). Proceeding papers are proportionally more often published in OA as compared to journal papers, with 77% of PSI proceeding papers with some OA version.

PSI publications are mostly performed in collaboration, with about 90% of all its outputs with some degree of institutional collaboration (PP[collab]=90%), and 76% of all PSI publications involving co-authors from more than one country (PP[int collab]=76%). In the case of collaboration with industry (indicator PP[industry]), about 9% of all PSI publications are performed in co-authorship with industrial partners. Proceeding papers, although with an overall lower presence of institutional collaboration (PP[collab]=75% in contrast with 91% of journal papers) as well as international collaboration (PP[int collab]=60% vs. 77% of journal papers), exhibit a higher presence of collaboration with industrial partners (PP[industry]=12% vs. 9% of journal papers). This may suggest a potential role of proceeding papers at PSI as conveyors of more local and industry-oriented research.

Finally, PSI's publications' level of interdisciplinarity is captured by the indicator IntDisc(0.34). Compared to the overall value of the ETH Domain (IntDisc=0.35), it can be argued that PSI has a similar degree of interdisciplinary as the domain at large. In Section 3.2 we will discuss the IntDisc values in more detail.

Most of the bibliometric results in Table 1 are provided by document type (proceedings and journals). Readership and author gender statistics are presented at the overall level only. Readership results are based on provided DOIs which were not classified by these types, while author gender could be defined in journal papers only. The results for these indicators are in their proper section (Section 3.2 and 3.5).

Overall, 16% of the PSI authors is female (4,367 vs 22,191 male, PA[F inst]: 0.16), which is 45% above the benchmark (all co-authors in the PSI output, PA[F pubs]: 0.11). The share of female author for the ETH Domain is higher at 20%. The average number of reads (Avg Reads) is 3.55, while the Avg Reads for ETH Domain is 5.09.

Table 1: Overall bibliometric performance statistics PSI

Indicator	Journals	Proceedings	Overall
Output			
P[full]	12,992	1,199	14,191
P[fract]	4,212	579	4,792
Int Cov	0.85	0.74	0.84
InterDisc	0.34	0.35	0.34
P OA [Gold, Hybrid, Green]	8,056	639	8,695
PP [OA]	62%	77%	63%
Collaboration			
PP[collab]	91%	75%	90%
PP[industry]	9%	12%	9%
PP[int collab]	77%	60%	76%
Citedness			
TCS	149,373	1,133	150,506
MCS	11.50	0.94	10.61
P[top10%]	2,069	206	2,275
PP[top10%]	14%	17%	14%
MNCS	1.27	1.83	1.34
MNJS	1.23	1.12	1.21
PP[self cits]	34%	26%	33%
PP[uncited]	12%	65%	16%
Author gender			
A[F inst]			4,367
A[M inst]			22,191
PA[F inst]			0.16
PA[F pubs]			0.11
RPA[F]			1.45
Readership			
N reads			22,378
N pubs read			6,311
Avg Reads			3.55

The landscape in Figure 3 is a two-dimensional representation of all science (covered by WoS) with an overlay of the output by PSI researchers in the different research areas. In Annex B we provide a more detailed description of the landscape and the way it is created. The size of a circle reflects the relative number of publications in which PSI researchers were involved. The colors in the landscape point to 5 main disciplines we use to support the interpretation of the landscape.

Figure 3 captures an overall topical distribution of PSI. As can be seen PSI has contributed to research areas of all the 5 main disciplines of the classification system, although it presents a strong concentration of publications in areas of Physical Sciences & Engineering, while still having a visible publication activity in the areas of Life & Earth Sciences, and a much more sparse publication activity in the other disciplines. Via this link you can open a web-based version of the landscape in your browser. By opening the menu on the left, you can change the perspective to any of the six ETH institutions.

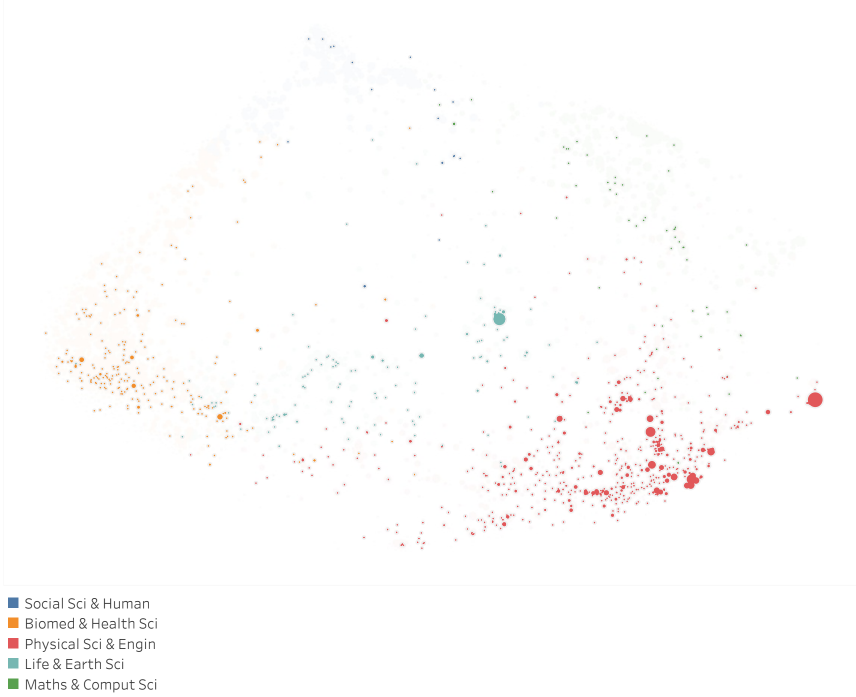

Figure 3: Distribution of PSI's output across landscape of science (interactive version via this link)

3.1.2 Trends

Table 2 below presents the trend analysis of PSI by overlapping four-year period of the indicators previously considered. Figure 4 captures the trend evolution of the Journal papers of PSI, while Figure 5 captures the trend of proceeding papers.

In general a sustained increasing trend in the number of journal papers is observable in Figure 4. Proceeding papers also exhibit an increasing trend up to the period 2014-2017, with a rather pronounced decrease from that period onward (Figure 5).

In addition to the number of publications, PSI also exhibits patterns of increase in indicators such as IntCov, suggesting an increasing focus on research covered in Web of Science. The growth in the indicator IntDisc indicates an increase in the interdisciplinarity of the research of the institute. The proportion of OA publications

(PP[OA]) has also increased from 51% in the period 2009-2012 to about 74% in the most recent period 2017-2020.

The overall impact of the institute as measured by the TCS indicator shows a mostly increasing trend from the initial period 2009-2012 up to the period 2015-2018. There is a decline in the overall TCS impact of PSI in the more recent periods (2016-2019 and 2017-2020). This decline could be partly attributed to the time lag in the indexing of publications and citations in Web of Science.

The share of female authors at PSI (RPA[F]) increases steadily from around 22% up to 72% above the benchmark over time. Readership is not included in the trend analyses due to missing proper publication year information in DOIs.

Table 2: Trends of PSI's bibliometric performance

Indicator	2009-2012	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017	2015-2018	2016-2019	2017-2020
P[full]	3,929	4,116	4,533	4,712	5,006	5,235	5,228	5,310	5,256
P[fract]	1,545	1,574	1,707	1,705	1,730	1,713	1,617	1,578	1,516
Int Cov	0.83	0.83	0.84	0.85	0.85	0.85	0.85	0.85	0.85
InterDisc	0.32	0.32	0.33	0.34	0.34	0.35	0.35	0.36	0.36
P [OA]	1,938	2,130	2,405	2,660	2,952	3,271	3,466	3,666	3,805
PP [OA]	51%	54%	55%	59%	61%	65%	68%	71%	74%
PP[collab]	85%	86%	86%	88%	90%	91%	93%	93%	94%
PP[industry]	9%	9%	8%	8%	9%	9%	9%	9%	9%
PP[int collab]	71%	71%	71%	73%	74%	76%	79%	80%	80%
TCS	48,228	52,323	53,866	59,210	55,860	58,720	60,485	55,120	46,418
MCS	12.27	12.71	11.88	12.57	11.16	11.22	11.57	10.38	8.83
P[top10%]	661	682	738	795	840	872	847	807	775
PP[top10%]	15%	14%	14%	14%	15%	15%	15%	14%	13%
MNCS	1.42	1.41	1.33	1.38	1.37	1.36	1.36	1.27	1.22
MNJS	1.22	1.20	1.18	1.20	1.22	1.23	1.24	1.21	1.20
PP[self cits]	32%	32%	33%	33%	34%	34%	34%	34%	34%
PP[uncited]	17%	16%	16%	16%	15%	14%	13%	13%	17%
RPA[F]	1.22	1.30	1.38	1.41	1.40	1.43	1.55	1.65	1.72

In terms of field-normalised impact (i.e., PP[top10%] and MNCS; see Figures 6 and 7), PSI presents a sustained high impact over the whole period. For example the MNCS value has been above 1.20 for journal papers, and above 1.40 for proceeding papers. Similarly, PSI has sustained a production of over 12% of highly cited journal and proceeding papers in each of the periods.

There is however a slight decrease in field-normalised citation impact of journal papers in the most recent periods observable for journal papers. A similar trend as for journal papers is also observed for proceeding papers (see Figure 6), with a more pronounced decrease in the overall field-normalised impact of PSI in the most recent years. It is only in the most recent periods (2015-2018 to 2017-2020) that such impact exhibits a decline.

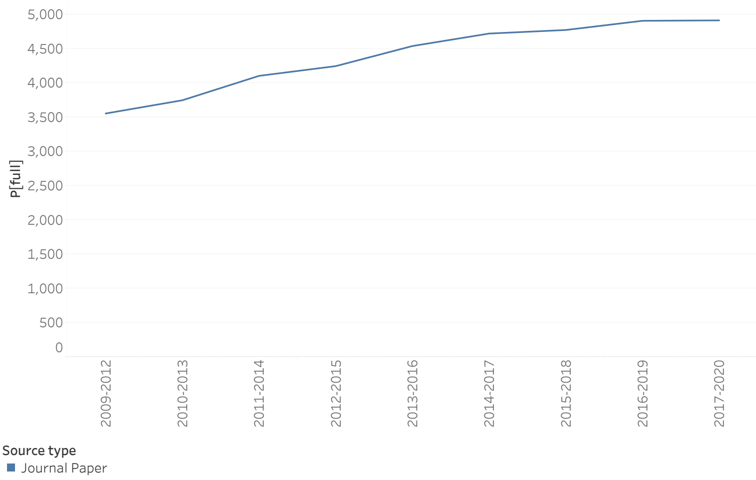

Figure 4: PSI's journal output trend (P[full]) by overlapping 4-years' period

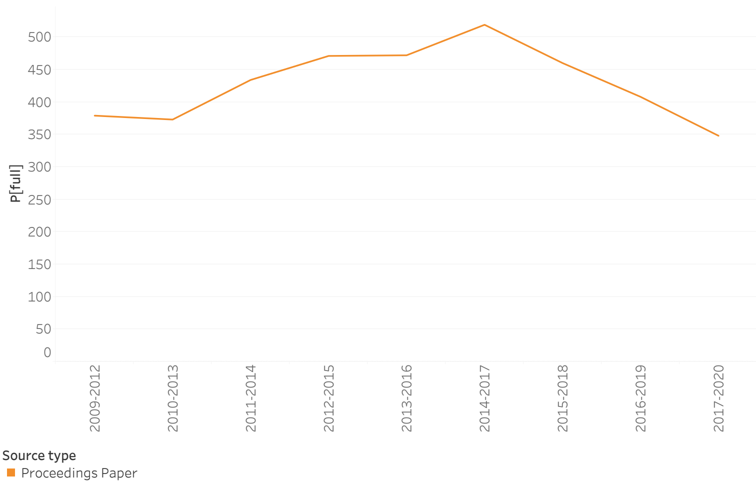

Figure 5: PSI's proceedings output trend (P[full]) by overlapping 4-years' period

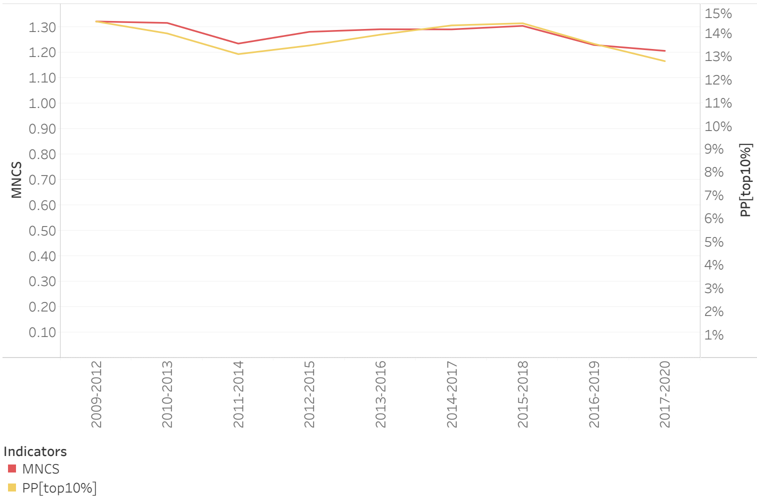

Figure 6: PSI's journal impact trend (MNCS and PP[top10%]) by overlapping 4-years' period

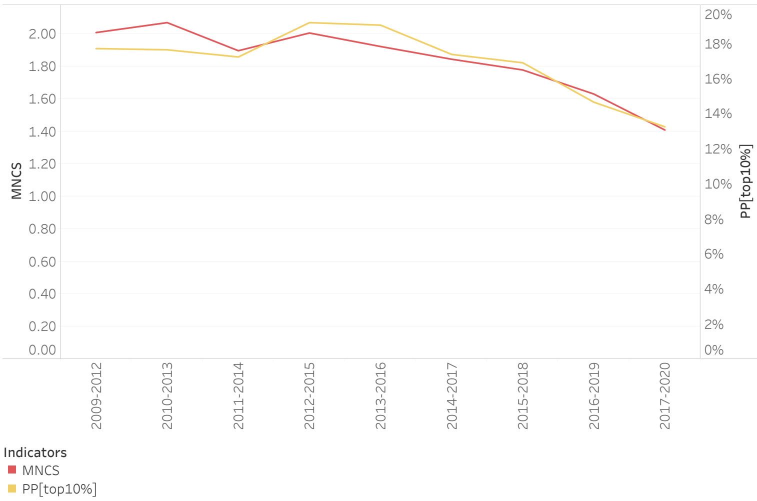

Figure 7: PSI's proceedings impact trend (MNCS and PP[top10%]) by overlapping 4-years' period

3.2 Research focus in context

Main findings

> The most important categories for PSI in terms of the output are *Physics, Applied*; *Materials Science, Multidisciplinary*; *Physics, Particles & Fields*; *Physics, Multidisciplinary*; *Physics, Condensed Matter*; *Chemistry, Physical*; *Nuclear Science & Technology* and *Multidisciplinary Sciences*. The impact of PSI's publications in these categories is high or around average. Research in these subjects remained stable or have experienced a growth during the last two years. Furthermore, in these main categories the share of female authors is around the benchmark.

3.2.1 Research profile

In this section we break down the output of PSI into Journal Subject Categories (JSC) to add context to the general statistics. We call this a research profile. It gives a general impression of broad subjects in which PSI's researchers are involved. The list of categories in the profile is limited to those that represent at least 1% of PSI's total output.

In each profile we include both P[full] and P[fract], i.e. the number of publications in which PSI was involved (P[full]) and the number of publications normalised by the number of organisations involved. Note that in such profiles, if a publication is in a journal that belongs to two subject categories, it is assigned half (0.5) to each category. The profile (Figure 8) also shows MNCS, MNJS (second column) and PP[top10%] (third column) per category, to measure impact.

It is important to keep in mind that the indicators displayed in the research profiles are distributed into journal subject categories (since these are well know and recognized discipline categories), while their normalisation has been performed based on the CWTS field categorisation (as these are more fine-tuned, see Annex B).

In addition, we include a growth indicator in Figure 8 for each category: [Field growth] (second column). This value indicates the estimated growth worldwide of a subject category. A [Field growth] above 1 means a positive growth of output worldwide in the most recent two years.

Figure 8 shows that the main Subject Categories in terms of share of the total output are: *Physics, Applied*; *Materials Science, Multidisciplinary*; *Physics, Particles & Fields*; *Physics, Multidisciplinary*; *Physics, Condensed Matter*; *Chemistry, Physical*; *Nuclear Science & Technology*, and *Multidisciplinary Sciences*. These Subject Categories have at least 5% of PSI's total output. Additionally, *Physics, Multidisciplinary* and *Multidisciplinary Sciences* perform as the Subject Categories with the highest impact in the overall profile.

In the remaining subject categories, we see a particularly strong performance on impact for *Optics*.

Finally, the field growth indicator shows that most of the fields present in Figure 8 remained stable or have experienced a certain growth during the last two years, especially *Electrochemistry* and *Energy & Fuels*. Subjects with a negative growth worldwide are *Physics, Particles & Fields* and *Astronomy & Astrophysics*.

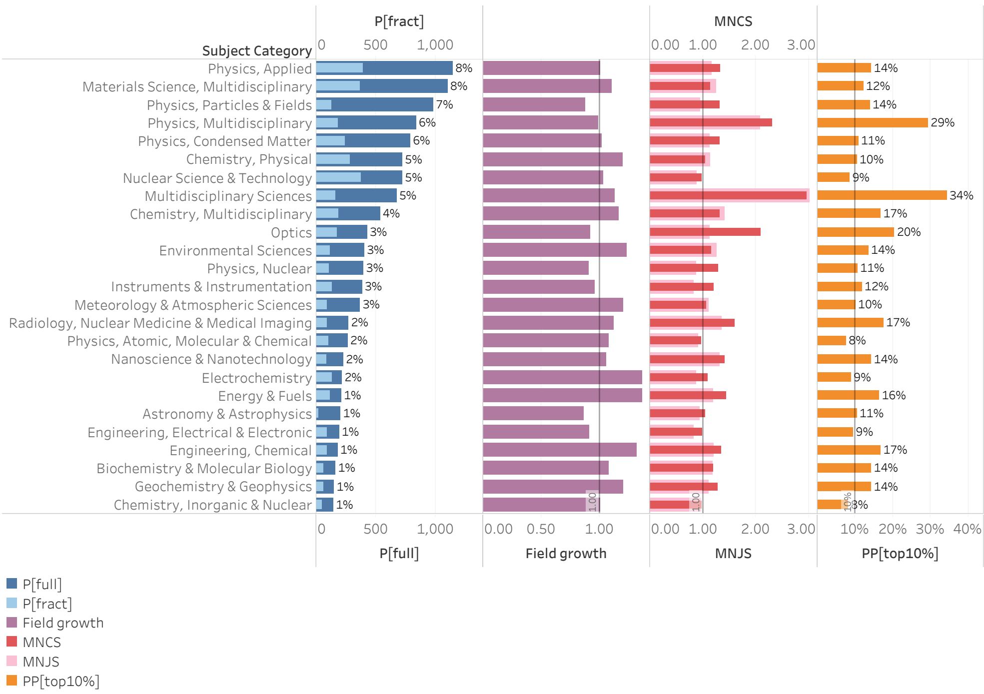

Figure 8: PSI's research profile (output, impact across subject categories)

3.2.2 Female author contribution across subjects

In Figure 9, we present the same Journal Subject Categories as in Figure 8 and added information related to author gender diversity (RPA[F], third column). PSI's authors are tagged as male or female using the first name or nickname as it appears on the publication. PA[F inst] indicates PSI's share of female authors identified for publications (second column). Subsequently, this share is compared with the share of female authors in the publication at large (including all co-authors, PA[F pubs]). The ratio of female authors within PSI and the share within the publication at large is RPA[F] and visualised in the third column with 1 as a point of reference. A value above 1 means a higher share of PSI female authors than for all institutions in the same set of publications. For instance, if a publication has 10 authors, of which 3 are female, the PA[F pubs] (reference value) is 0.33. If PSI is represented by 4 authors, 2 of which are female, the PA[F inst] is 0.5. The RPA[F] would then be

0.5/0.33: 1.52.

A more detailed description of the approach is in Section 2.2. Underlying statistics for PSI as large can be found in Annex A.

Focusing on the indicator RPA[F], Figure 9 shows that for a substantial amount of subjects the share of PSI's female authors is slightly lower than or around the benchmark. There are also a few subjects with a much higher share of PSI female authors (at least 30% higher) compared with the benchmark: *Physics, Nuclear*; *Physics, Particles & Fields*; *Astronomy & Astrophysics*,and *Instruments & Instrumentation*. On the other side, subjects with a lower share of PSI females authors (25% lower) are *Engineering, Chemical* and *Physics, Atomic, Molecular & Chemical*.

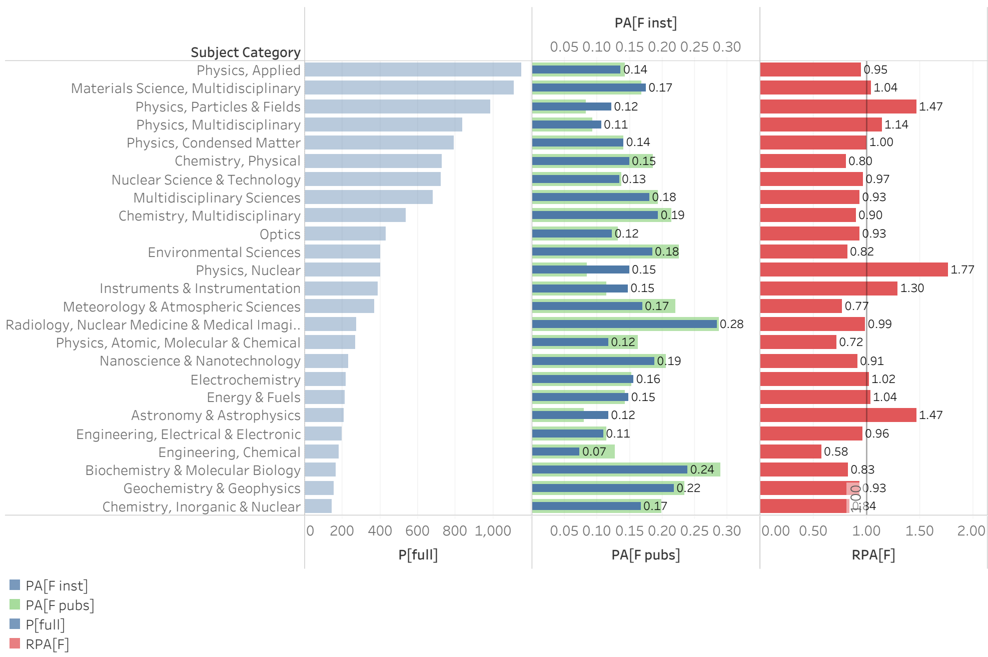

Figure 9: PSI's share of female authors across subject categories

3.2.3 Interdisciplinarity

Figure 10 represents interdisciplinarity of PSI's research output. It uses the same subject categories as in Figure 8 and relies on the publications' references (i.e. other publications cited by the publication of interest). For a more detailed explanation of our definition of interdisciplinary research, see Section 2.2 and Annex D. If a publication cites publications from different subject categories, it is more interdisciplinary than if it cites publications from the same category. In addition, we use a cognitive distance measure to value the diversity of fields being cited. If a paper cites publications from fields that are not closely related (e.g., medical sciences and mathematics) it is more interdisciplinary than if it cites publications from different medical fields. The benchmark we introduce for this indicator is the IntDisc for a subject category at large in 2020.

As Table 1 showed in Section 3.1 the overall value of IntDisc=0.34 for PSI indicates a relatively low degree of interdisciplinarity, since PSI research tends to rely on a small set of cognitively nearby disciplines. From a comparative point of view, the degree of interdisciplinarity of PSI is around the average value of ETH Domain (IntDisc=0.35), therefore not specially high or low within the context of the organization.

At the level of subject categories, Figure 10 shows broad values of interdisciplinarity. There are subjects with much lower degree of interdisciplinarity compared to the overall PSI (e.g. *Physics, Condensed Matter*;*Materials Science, Multidisciplinary*; *Physics, Applied*and *Electrochemistry*) and subjects with much higher degree of interdisciplinarity compared to the overall PSI (e.g. *Geochemistry & Geophysics*; *Environmental Sciences*; *Meteorology & Atmospheric Sciences*and *Instruments & Instrumentation*).

Figure 10 also shows the overall value of IntDisc per subject categories (grey color). This value is used as the benchmark for the interdisciplinarity values for PSI (green color). *Geochemistry & Geophysics*; *Chemistry, Inorganic & Nuclear*; *Astronomy & Astrophysics*; *Meteorology & Atmospheric Sciences*and *Physics, Particles & Fields* are the ones with the highest interdisciplinarity values compared to the benchmark, but it is important to highlight that the first two have a lowest output. On the other side, main fields in terms of output like *Physics, Applied*; *Materials Science, Multidisciplinary*; *Physics, Multidisciplinary* and *Physics, Condensed Matter*, show lower interdisciplinarity values compared to the benchmark.

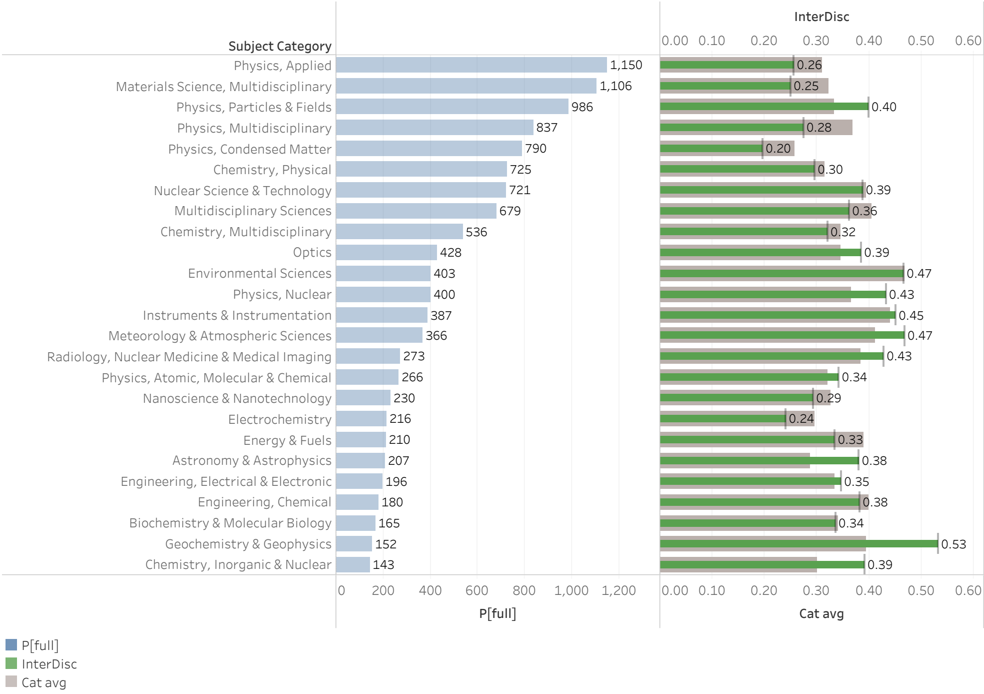

Figure 10: PSI's interdisciplinarity across subject categories

3.3 Collaboration and partners

Main findings

> For PSI, we see an increase in the proportion of publications with both collaboration and international collaboration, while industry collaboration remains stable. International collaboration takes up the largest share of PSI's publications, though the difference is less pronounced when looking at P[fract]. There is little distinction on impact between collaboration types. Of the ETH institutions, PSI collaborates most with ETH Zurich, yet has the highest impact when collaborating with Empa, and the lowest comparative impact when not collaborating with any other ETH institutions. On a country level, PSI collaborates most with German institutions.

3.3.1 Collaboration profile

This section includes a trend analysis for the collaboration indicators as well as a collaboration profile.

The trend analysis in Table 3 breaks PSI's output and collaboration indicators down over time, using overlapping four-year publication windows.

In the collaboration profile in Figure 11, we break down PSI's output and impact by collaboration type, distinguishing between 'no collaboration' (single author or all authors affiliated with PSI), national collaboration (all authors having a Swiss affiliation from different institutions) and international collaboration.

Table 3: PSI's trend collaboration statistics

Indicator	2009–2012	2010–2013	2011–2014	2012–2015	2013–2016	2014–2017	2015–2018	2016–2019	2017–2020
P[full]	3,929	4,116	4,533	4,712	5,006	5,235	5,228	5,310	5,256
PP[collab]	85%	86%	86%	88%	90%	91%	93%	93%	94%
PP[int collab]	71%	71%	71%	73%	74%	76%	79%	80%	80%
PP[industry]	9%	9%	8%	8%	9%	9%	9%	9%	9%

In Table 3, what is immediately notable is that PP[collab] slowly grows over time, with the most recent window having the highest proportion (94%). The same is true for PP[int collab], growing steadily from 71% to 80%. Meanwhile, industry collaboration (PP[industry]) is very stable at 9%, with just one window having a (slight) aberration from that number.

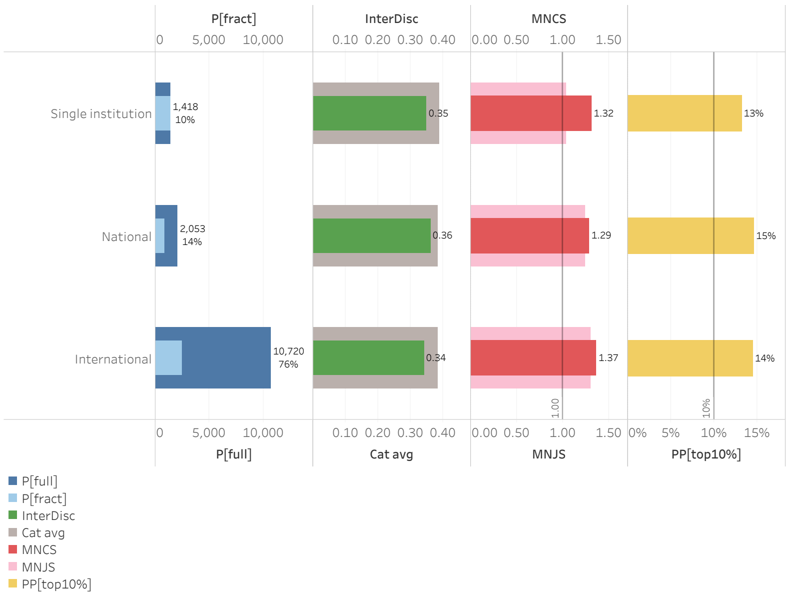

Figure 11: Collaboration profile (output, impact) of PSI

The first column of Figure 11 shows the publication output per collaboration type. While it looks very skewed when it comes to full-counting output, with international collaboration taking the lion's share, it is worth noting that the differences are smaller when considering fractional counting. International remains the largest share, but closer to the other two and national collaboration has a lower fractional counting output than single institution paper.

Unsurprisingly, given PSI's overall impact, impact indicators for all collaboration types are above world average. The differences between collaboration types are small. Perhaps the most notable aberration is the MNJS for single institution publications, which sits only just above world average at 1.04, while the MNJS of national and international collaboration sits at 1.25 and 1.30 respectively.

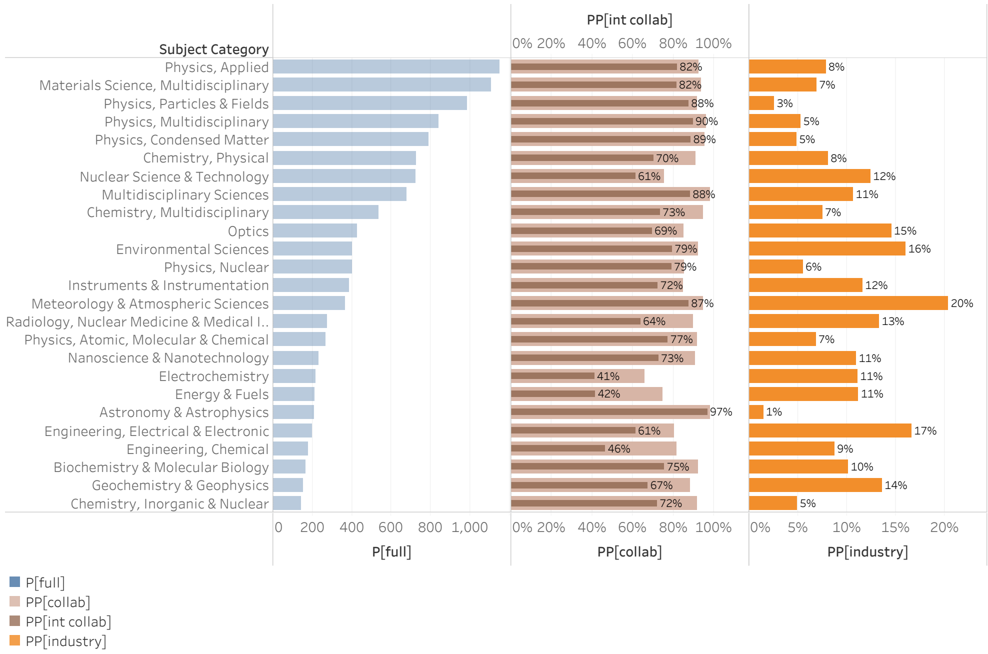

Figure 12: PSI's output and collaboration types across subject categories

In Figure 12, the collaboration indicators PP[collab], PP[int collab] and PP[industry] are calculated by Web of Science subject category for PSI publications.

What is notable for the first two columns is that physics fields perform high on both output and impact. Out of the subject categories having a higher output, *Nuclear Science & Technology*has a noticeably lower proportion of both PP[collab] (76%) as well as PP[int collab] (61%). Inversely, *Nuclear Science & Technology* performs high on PP[industry]. Lower down the list, *Meteorology & Atmospheric Sciences* has a 20% PP[industry], meaning one in five of their publications is done in collaboration with an industry partner. Finally, the profile of *Astronomy & Astrophysics* stands out for having both the highest levels of PP[collab] and PP[int collab] (almost 100%) as well as the lowest level for PP[industry] (almost zero).

3.3.2 Collaboration within the ETH Domain

Table 4 shows PSI's output and impact (highlighted column), as well as the number of co-publications and impact of PSI with other ETH institutions.

Table 4: Co-authorship and impact within the ETH Domain

Indicator	ETH Zurich	EPFL	PSI	WSL	Empa	Eawag
P[full]	4,294	1,279	14,191	125	512	27
MNCS	1.54	1.45	1.34	1.47	1.64	1.50

We can see that in terms of output, collaboration is far and away the most frequent with ETH Zurich while being virtually non-existent with Eawag. Impact, as measured by MNCS, is highest for Empa and also high for ETH Zurich. Notably, MNCS is higher for all collaborations within the ETH Domain than it is for publications featuring only PSI. Ultimately, this is not surprising given that for overall publication impact, PSI has the lowest MNCS of institutions.

3.3.3 Collaboration outside the ETH Domain

This section seeks to delve deeper into PSI's collaboration partners outside of the ETH Domain, categorising them first by country and then by institution. Tables 5 and 6 highlight the top collaborators in terms of output. For the results at country level, we used full counting. The output numbers reflect the number and share of output in which countries were involved. For the analysis of co-authoring institutions (Table 6), we used fractional counting. The output numbers indicate the contribution of partnership compared to the total.

The map in Figure 13 highlights countries with more intensive collaboration, with the darkness or intensity of the red indicating the relative level of co-authorship.

In this section we exclude collaborations within the ETH Domain. However, if a publication involves a ETH Domain member and also an external member, it is included.

Country-level

Table 5: Top 12 countries co-authoring with PSI researchers, excluding ETH Domain internal co-authorship. P[full] and % to PSI's total

Country	Co-pubs	% to total
Germany	4,392	31%
Switzerland	3,623	26%
United States	3,435	24%
France	3,160	22%
United Kingdom	2,787	20%
Italy	2,167	15%
China	1,809	13%
Spain	1,689	12%
Russian Federation	1,677	12%
Poland	1,554	11%
Belgium	1,553	11%
Austria	1,484	10%

In Table 5, we can see that most collaboration is done with Germany, followed by Switzerland (here represented by non-ETH Domain collaborating institutions), the United States, France and the UK.

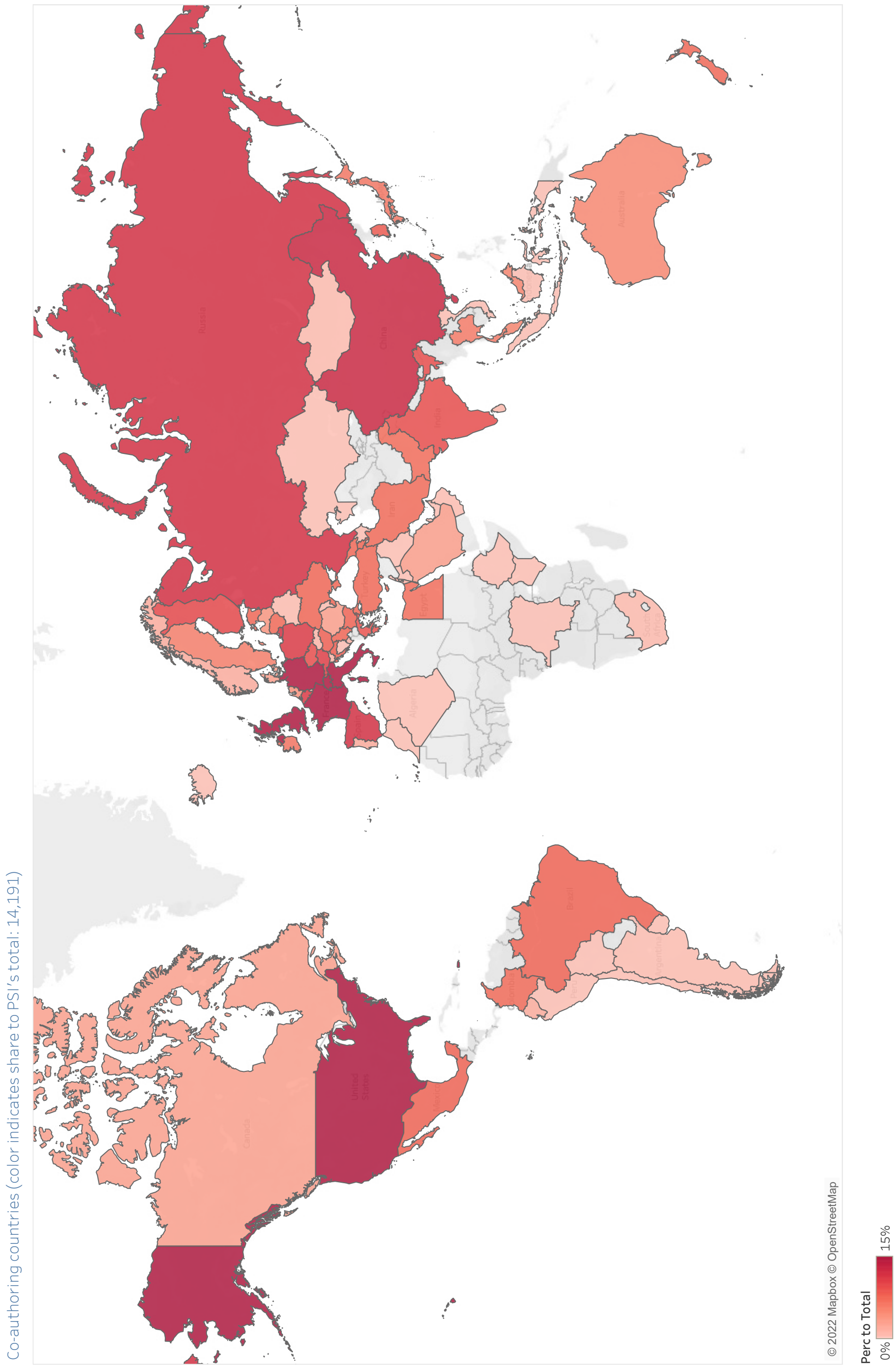

Figure 13: Map of countries co-authoring with PSI

Institutions

Table 6: Top 20 collaborating institutions of PSI, excluding ETH Domain internal co-authorship (fractional output and impact)

Inst	Country	Co-pubs	MNCS
University of Zurich	CH	177	1.65
University of Bern	CH	166	1.25
Max Planck Society for the Advancement of Science	DE	135	2.09
Istituto Nazionale di Fisica Nucleare	IT	128	1.20
Chinese Academy of Sciences	CN	123	1.92
Karlsruhe Institute of Technology	DE	94	1.59
Centre National de la Recherche Scientifique	FR	85	1.65
University of Basel	CH	82	1.59
Technical University of Munich	DE	70	1.67
Bhabha Atomic Research Center	IN	65	0.74
Deutsches Elektronen-Synchrotron	DE	65	1.83
Russian Academy of Science	RU	61	1.49
University of Geneva	CH	56	1.30
Helmholtz Centre Berlin for Materials & Energy	DE	55	1.53
Forschungszentrum Jülich	DE	55	1.49
University of Helsinki	FI	53	1.85
CERN European Organization for Nuclear Research	CH	52	1.62
University of Fribourg	CH	48	1.53
Technische Universität Dresden	DE	44	1.66
Johannes Gutenberg University Mainz	DE	43	1.71

Table 6 shows two Swiss institutions, the Universities of Zurich and Bern, as top collaborating institutions. The most frequent collaborating institution outside of Switzerland is the Max Planck Society for the Advancement of Science, which also performs best on impact (as measured by MNCS: 2.09). Other high-impact collaborators include the Chinese Academy of Sciences (MNCS: 1.92), Deutsches Elektronen-Synchrotron (MNCS: 1.83) and the University of Helsinki (MNCS: 1.85).

3.4 Research accessibility

Main findings

> PSI's research is published increasingly in Open Access. Especially, the number (and share) of Gold OA publications grows steadily during the period 2009 up to 2020. Also the number of top 10% most cited publications of Gold OA publications increases significantly between 2011 and 2018. The number of Closed Access top 10% publications drops dramatically in the most recent years. The impact of OA publications is structurally higher than the impact of Closed Access publications. Moreover, the impact of the latter decreases in the most recent years.

3.4.1 OA publishing and impact

In this section we discuss the accessibility of PSI's research output. For publications with a DOI we could define whether it was published Open Access (OA) or not based on Unpaywall data (version July 2021). Therefore, the below statistics only include publications for which we could define OA or not. In addition, we could also determine the type of OA (Gold, Hybrid or Green). The trend analyses allow us to monitor the evolution of PSI regarding OA publishing.

Using OA information we assess the overall accessibility of PSI's OA output as well as its citation-based impact, by benchmarking it to non-OA output.

Table 7: PSI's Open Access (OA) performance statistics by type, excluding publications for which no OA info available

Indicator	OA Gold	OA Hybrid	OA Green	Closed Access	Total
P[full]	2,756	1,831	4,108	5,062	13,757
P[top10%]	500	364	726	649	2,238
PP[top10%]	17%	20%	15%	12%	14%
PP[int collab]	82%	88%	81%	65%	76%

In Table 7, we provide an overview of main performance statistics for three types of OA (Gold, Hybrid and Green) together with their overall performance. P[full] reflects the total number of publications, P[top10%] the number belonging to the top 10% most cited (within its year and field). PP[top10%] assesses the impact of each type, while PP[int collab] reflects the share of output involving international collaboration.

Looking at the entire period (2009-2020), we see a preference for Green OA publications (P[full]), while the impact is the highest for Hybrid OA publications

(PP[top10%]). For this type of output involving international collaboration is the highest (PP[int collab]: 88%). Both PP[top10%] and PP[int collab] substantially are higher for all types of OA publications, compared to Closed output.

Table 8: PSI's performance statistics trend, Closed vs. Open Access publications

	Indicator	2009–2012	2010–2013	2011–2014	2012–2015	2013–2016	2014–2017	2015–2018	2016–2019	2017–2020
Closed	P[full]	1,844	1,847	1,960	1,876	1,868	1,773	1,608	1,518	1,350
	P[top10%]	259	259	264	253	253	236	197	165	137
	PP[top10%]	13%	13%	12%	12%	12%	13%	12%	10%	10%
	PP[int collab]	62%	61%	62%	63%	64%	66%	67%	67%	69%
Open	P[full]	1,938	2,130	2,405	2,660	2,952	3,271	3,466	3,666	3,805
	P[top10%]	381	408	461	529	575	625	643	639	634
	PP[top10%]	18%	17%	16%	17%	17%	17%	17%	16%	15%
	PP[int collab]	81%	81%	80%	81%	82%	83%	85%	85%	85%

In Table 8, we provide trend results for the same indicators as in Table 7, comparing OA publications with non-OA (Closed Access) publications. These results only include publications for which OA information was available (included in Unpaywall, have a DOI). In Figures 14 and 15, P[full] and P[top10%] are depicted by OA type.

The results in Table 8, show the steady increase of OA publications, together with the top 10% output. Normalised by the total number of output per year, we see a high impact (PP[top10%]) for OA publications. The impact of Closed Access publications decreased somewhat to world average (PP[top10%]: 10%) in the most recent years.

From the international perspective, we see that OA publishing is increasingly done with foreign partners, while Closed access publications remain at a lower level involving international collaboration (PP[int collab]).

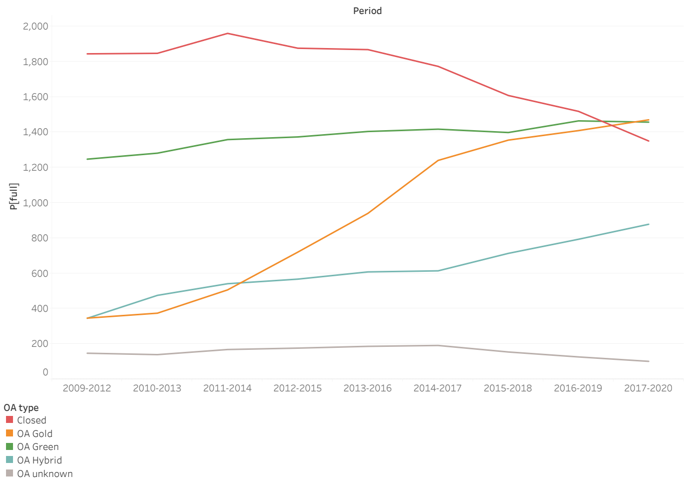

Figure 14: PSI's output trend by Open Access (OA) type

In Table 2, we already showed the increase of the number and proportion of PSI's OA publications. In Figure 14, this is shown in more detail for the different types of OA. In particular Gold OA publications increased over the years and is now the preferred type over Hybrid and Green. This means that most publications are now published in OA journals. In parallel the number of P[top10%] publications increased over time for all there OA types and particularly for Gold OA publications until 2017.

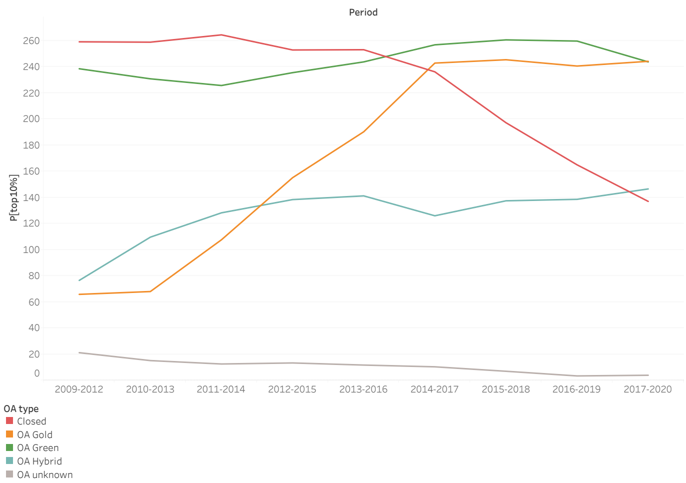

Figure 15: PSI's trend of top 10% publications by Open Access (OA) type

These results show PSI's shift towards open science, particularly since 2015. The increase of P[top10%] for OA publications shows that this shift did not lead to less citation-based impact. In fact, the OA publications involve more international partners and have and remain to have a significantly higher impact.

3.4.2 OA publishing and impact by subject

In this section we present PSI's performance statistics by journal subject category. In Figure 16, we visualise the share of OA publications, related to the overall output (for which access information was available). The bars in the second column of the diagram represent the ratio of the sum of OA publications to the sum of all publications. The light blue bar in the profile in the first column represents the total number of publications. The list of subject categories is limited to those that cover at least 1% of the total output of PSI.

In Figure 17, the second column visualises the impact of both Closed and Open access publications by PP[top10%] by subject.

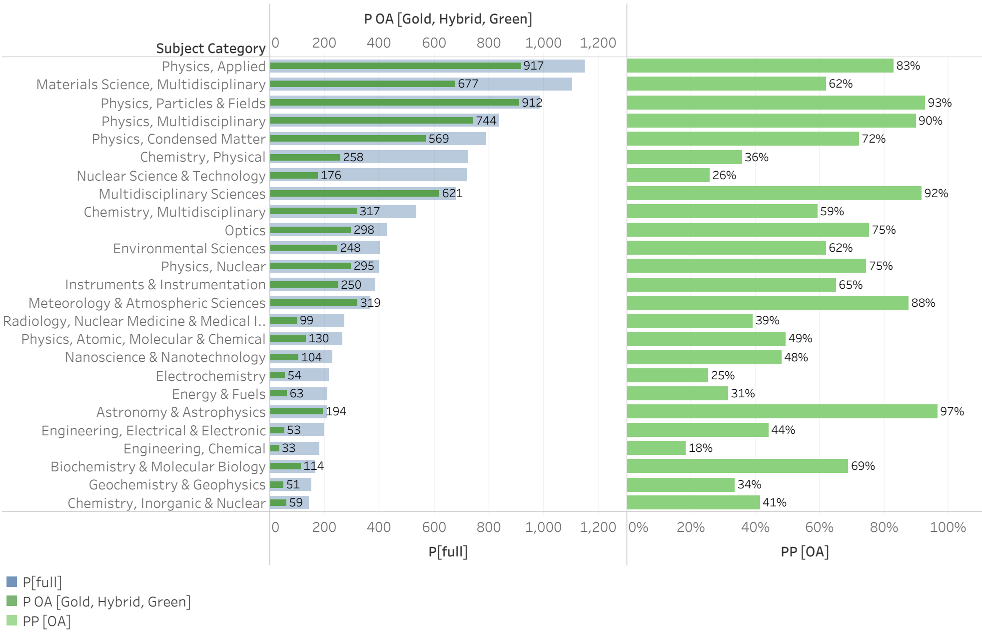

Figure 16: PSI's output and share of OA publications across subject categories

In the above profile, the share of OA publications (PP[OA]) differs substantially from one subject to the other. There are a few categories in which the percentage is really high ($> 90\%$), such as *Physics, Particles & Fields*; *Physics, Multidisciplinary* and *Astronomy & Astrophysics*. Besides these the share of OA publications is high in *Multidisciplinary Sciences*. At the other end, we find *Nuclear Science & Technology*; *Electrochemistry* and *Engineering, Chemical* with less than 30% OA publications.

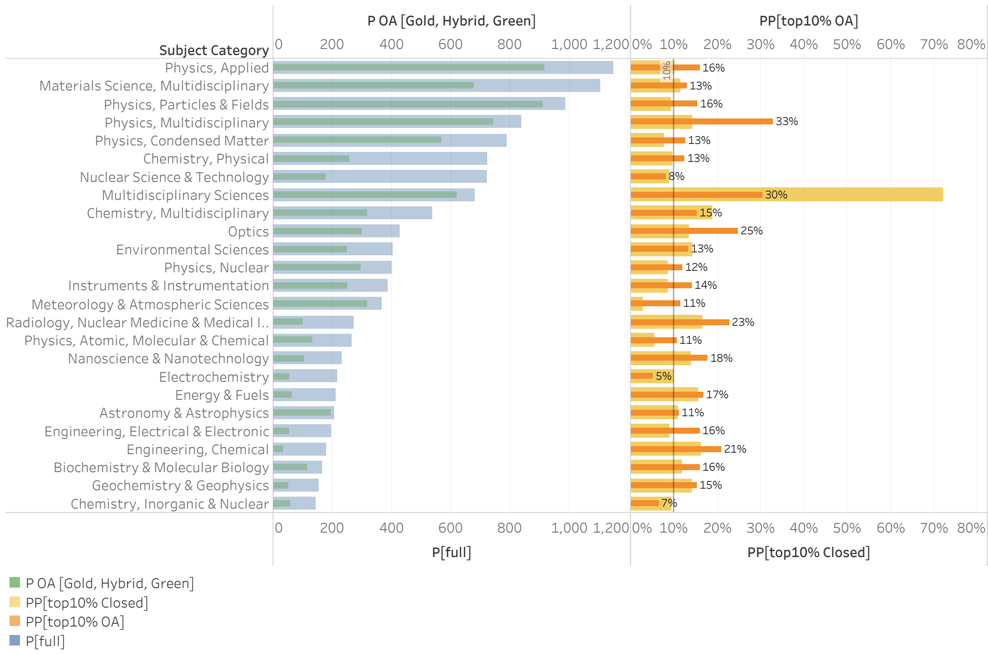

Figure 17: PSI's impact distribution (PP[top10%]) of Open and Closed output across subject categories

Figure 17 visualises that in almost all subjects where PSI is active, the impact (PP[top10%]) for OA publications is higher than for Closed Access publications. The usual exception is *Multidisciplinary Sciences*, where the impact of the few *Nature* and *Science* publications contribute to a high value for Closed publications.

3.5 Impact and knowledge use

Main findings

> PSI's research is read and cited from all over the world. The citation-based impact is primarily determined by institutions located in Asia, Europe, and the United States. The readership analysis also shows significant impact of PSI's research in countries that are not well represented in WoS (e.g., Brazil and Mexico).

In this section, we discuss the actors (countries, institutions) that define the impact and use of PSI's research. We estimate the impact and use by analysing (1) the publications citing PSI's publications and (2) the country of people reading its publications.

The analysis of publications citing PSI's output shows the most prominent countries and institutions. Thus we provide an overview of the geographical distribution of PSI's impact and more specifically the institutions that use PSI's research.

The readers are analysed using Mendeley data, in which a 'read' is defined by a person (i.e., Mendeley user) saving a publication. The results should be interpreted with that disclaimer in mind. The user information includes the country of origin (if available). In this report, we will present the countries and compare these to the ones citing PSI's output. Including readership in this study does not show a broader (e.g., societal) impact of PSI research but merely catches the (potential) scientific impact beyond the WoS data.

3.5.1 Impact and knowledge use at country level

The citation-based impact is defined by publications citing PSI's output. In these citing publications, we use the affiliations of authors to measure their contribution to the impact of PSI's research. Table 9 shows the 20 most prominent countries citing PSI's research output. In the table we include the number of PSI publications being cited, the number of citations they receive and the average number of citations per publication. The top 20 is defined by the number of citations received (N cits). This list is obviously dominated by countries with many publications in WoS, and we cannot deny their significant role in determining the citation-based impact. By considering the top countries and subsequently looking at the average number of citations given, we normalise to some extent the results.

Table 9: PSI given citations by country (top 20 most given citations)

Country	N pubs	N cits	Avg cits
United States	7,916	31,661	4.00
China	6,861	24,508	3.57
Germany	6,602	17,773	2.69
United Kingdom	4,951	9,807	1.98
France	4,985	9,189	1.84
Japan	4,082	8,535	2.09
Switzerland	4,127	7,211	1.75
Italy	3,589	6,489	1.81
Spain	2,982	5,261	1.76
Canada	2,917	4,493	1.54
Russia	2,519	4,473	1.78
India	2,697	4,452	1.65
South Korea	2,426	4,105	1.69
Australia	2,179	3,098	1.42
Sweden	2,204	2,955	1.34
Netherlands	2,064	2,879	1.39
Poland	1,697	2,582	1.52
Belgium	1,581	2,016	1.28
Brazil	1,332	1,910	1.43
Taiwan	1,251	1,822	1.46

In Table 9, the dominance of the United States and China defining PSI's impact is demonstrated. Not only by absolute numbers of citations but also by the averages, these two countries attribute great value to PSI's research. US researchers cite on average a PSI publication 4 times and Chinese researchers over 3.5 times. Next in line are researchers from Switzerland, and other European countries, Japan, Russia, India, South Korea, Australia, Brazil, and Taiwan with between 1.28 (Belgium) and 2.09 (Japan) citations per publication on average.

In Table 10, we introduce a different perspective on the impact PSI's research has. By looking at the number of reads by Mendeley users from different countries, we get a better view on the geographical distribution beyond the perimeter of the academic debate (as defined by citations). We realise that this distribution is defined primarily by the authors citing PSI's output but we hope to broaden the view on the impact somewhat. The List in Table 10 shows the top 20 most prominent countries 'reading' PSI's publications. The list order is defined by the number of reads (second column: N reads). In the table the first column shows the number of publications being read (N pubs). The third column shows the average number per read publication (Avg Reads). We consider the countries that end up in the readership list (Table 10) but not in the citing countries list (Table 9) as the ones showing the impact beyond the WoS.

Table 10: PSI readership by country (top 20, by most reads)

Country	N pubs	N reads	Avg Reads
United States	2,612	4,910	1.88
Germany	1,512	2,212	1.46
United Kingdom	1,349	1,943	1.44
Switzerland	1,349	1,670	1.24
Japan	971	1,179	1.21
France	816	1,000	1.23
Belgium	719	763	1.06
Spain	583	687	1.18
Canada	561	651	1.16
India	527	609	1.16
Brazil	464	555	1.20
China	457	516	1.13
Italy	449	510	1.14
Netherlands	393	439	1.12
Denmark	306	383	1.25
Sweden	322	382	1.19
Mexico	354	363	1.03
Australia	234	269	1.15
Russia	251	264	1.05
Poland	173	182	1.05

From the reader perspective we see some interesting differences, comparing them to Table 9. First of all, the less prominent position of China which is an artefact of the data being used. Chinese researchers and academics do not use Mendeley to manage their literature (Fairclough and Thelwall, 2015; Zahedi and Costas, 2020). The same argument can explain the absence of South Korea and Taiwan in this list. In addition, we see a non-European country included in Table 10 that does not show up in Table 9: Mexico. Countries like Brazil and Mexico have less visibility in WoS and show a significant interest in the research published by PSI, by readership.

3.5.2 Impact by citing institution

In Table 11, we list the top 20 most prominent citing institutions of PSI's publications. This list provides more insight in the actual research actors being impacted by PSI. As the list is based on the number of citations given (N citing pubs, second column), it will be biased towards large institutions (with many publications). We normalise these large numbers by including the number of publications being cited (N cited pubs, first column), which leads to the average in the third column (Avg cits).

Table 11: PSI's top 20 most citing institutions (by number of given citations)

Institution	Country	N cited pubs	N citing pubs	Avg cits
CHINESE ACAD SCI	CN	3,266	6,680	2.05
CNRS	FR	3,652	5,961	1.63
MAX PLANCK SOCIETY	DE	2,067	3,052	1.48
PAUL SCHERRER INST	CH	1,944	2,236	1.15
RUSSIAN ACAD SCI	RU	1,399	2,164	1.55
UNIV CHINESE ACAD SCI	CN	1,417	2,112	1.49
IST NAZL FIS NUCL	IT	950	1,984	2.09
UNIV TOKYO	JP	1,243	1,919	1.54
BERKELEY NATL LAB	US	1,463	1,828	1.25
ETH ZURICH	CH	1,458	1,695	1.16
UNIV PARIS-SACLAY EPE	FR	1,173	1,647	1.40
ARGONNE NATL LAB	US	1,250	1,643	1.31
PEKING UNIV	CN	1,058	1,554	1.47
KARLSRUHE INST TECHNOL (KIT)	DE	1,304	1,542	1.18
TSING HUA UNIV	CN	1,032	1,509	1.46
UNIV CALIF BERKELEY	US	1,267	1,475	1.16
CEA FRANCE	FR	1,165	1,462	1.25
DESY HAMBURG	DE	1,058	1,426	1.35
CERN	CH	748	1,417	1.89
BROOKHAVEN NATL LAB	US	1,006	1,344	1.34

Table 11 too is dominated by the largest research institutions in the world with many WoS publications and located in the countries in Table 9, the Chinese Academy of Science and CNRS and Max Planck Society being the mega-institutions. PSI is the fourth institution contributing to its own impact, but we need to emphasise that these citations do not include author self-citations. The average citation per publication is significant lower for PSI than for most other institutions. Researchers from PSI cite more publications (N cited pubs). Finally, the Italian National institute for Nuclear Physics (IST NAZL FIS NUCL) is worth mentioning citing 2.09 times PSI's publications.

References

Emile Caron and Nees Jan van Eck. Large scale author name disambiguation using rule-based scoring and clustering. In *19th International Conference on Science and Technology Indicators*, volume 19, pages 79–86, Leiden, September 2014.

Ruth Fairclough and Mike Thelwall. National research impact indicators from Mendeley readers. *Journal of Informetrics*, 9(4):845–859, October 2015. ISSN 1751-1577. doi: 10.1016/j.joi.2015.08.003. URL https://www.sciencedirect.com/science/article/pii/S1751157715300596.

Javier Ruiz-Castillo and Ludo Waltman. Field-normalized citation impact indicators using algorithmically constructed classification systems of science. *Journal of Informetrics*, 9(1):102–117, January 2015. ISSN 17511577. doi: 10.1016/j.joi.2014.11.010. URL https://linkinghub.elsevier.com/retrieve/pii/S1751157714001126.

Ludo Waltman and Nees Jan van Eck. A new methodology for constructing a publication-level classification system of science. *Journal of the American Society for Information Science and Technology*, 63(12):2378–2392, December 2012. ISSN 15322882. doi: 10.1002/asi.22748. URL http://doi.wiley.com/10.1002/asi.22748.

Ludo Waltman, Clara Calero-Medina, Joost Kosten, Ed C. M. Noyons, Robert J. W. Tijssen, Nees Jan van Eck, Thed N. van Leeuwen, Anthony F. J. van Raan, Martijn S. Visser, and Paul Wouters. The Leiden ranking 2011/2012: Data collection, indicators, and interpretation. *Journal of the American Society for Information Science and Technology*, 63(12):2419–2432, December 2012. ISSN 1532-2890. doi: 10.1002/asi.22708. URL https://onlinelibrary.wiley.com/doi/abs/10.1002/asi.22708.

Zohreh Zahedi and Rodrigo Costas. Do Online Readerships Offer Useful Assessment Tools? Discussion Around the Practical Applications of Mendeley Readership for Scholarly Assessment. *Scholarly Assessment Reports*, 2(1):14, November 2020. ISSN 2689-5870. doi: 10.29024/sar.20. URL http://www.scholarlyassessmentreports.org/articles/10.29024/sar.20/. Number: 1 Publisher: Levy Library Press.

Annexes

A PSI's author gender statistics

Table 12: PSI: Underlying gender diversity statistics

Indicator	Value
A[F inst]	4,367
PA[F inst]	0.16
A[FM inst]	26,558
A[F pubs]	28,593
PA[F pubs]	0.11
A[FM pubs]	252,637
RPA[F]	1.45

The indicators presented in this table are described in Section 2.2, p. 17.

B Publication level classification

The CWTS citation database is a bibliometric version of Web of Science (WoS). One of the special features of this database is the publication-based classification. This classification is an alternative to the WoS journal classification, the WoS subject categories. The reason to have this publication-based classification is the problems we encounter using the journal classification for particular purposes. We discern the following as the most prominent ones.

B.1 Journal scope (including multi-disciplinary journals)

A journal classification introduces sets of journals to represents a class, in this case a subject category. This implies that journals have a similar scope. They do not need to be comparable with regard to volume (number of articles per year) but they should represent a similar specialisation. This is not the case, of course. Journals represent a very broad spectrum. There are very specialist journals (e.g., Scientometrics) and very general ones (e.g., Nature or Science but also British Medical Journal). The classification scheme can therefore not be very specialised. In WoS, a subject category Multi-disciplinary hosts the very general ones so that a bibliometric analysis of, for instance, the Social Sciences or Nanotechnology, using this classification, will not take papers in Nature into consideration.

B.2 Granularity of the WoS subject categories

The WoS journal classification scheme contains 255 elements. As such it is a stable system. In many cases however, it appears that these 255 subject categories are insufficient to be used for proper field analyses. The problem is that the granularity of the system looks somewhat arbitrary. 'Biochemistry & Molecular Biology' on the one hand and 'Ornithology' on the other, for instance, represent rather different aggregates of research. This is illustrated by the number of journals in each of them. Where the 'Biochemistry & Molecular Biology' category contains almost 500 journals, 'Ornithology' has only 27. We acknowledge that there is no perfect granularity, but we argue that in the WoS subject categories the differences are really too big. A classification based on more objective grounds does not solve this problem but is at least transparent.

B.3 Multiple assignment of journals to categories

In journal classifications from multi-disciplinary databases, journals are assigned to more than one category. Journals often have broader scopes than the categories allow. Also here there are large differences between categories. In the example we used before, 'Biochemistry & Molecular Biology,' journals are on average assigned to almost 2 categories. This means that (on average) each journal in this category is also assigned to one other category. For the more specialist category of 'Ornithology', the average is 1. This means that in this category all journals are assigned to this category only. If publications in journals with a multiple assignment would always cover the categories at stake, this should not necessarily be a problem. However, it mostly means that such journals structurally contain publications from the different categories. Therefore, publications may be assigned to two categories although they belong to just one of them.

B.4 The CWTS publication-based classification scheme

CWTS has developed an advanced alternative for the Web of Science journal classification. It counters three major issues:

1. Journal scope (including multi-disciplinary journals)
2. Granularity of the WoS subject categories
3. Multiple assignment of journals to categories

The CWTS publication-based classification is developed as described in Waltman and van Eck (2012). Since the first version there have been yearly updates of the system. The main characteristics of the classification are as follows.

Publication to publication citation clustering

Clusters of publications are created on the basis of citations from one publication to another. Tens of millions of publications have been processed. The clusters contain publications from multiple years (2000–2020). Each publication is assigned to one cluster only at each level. A cluster is considered, and in many cases validated as, representative for disciplines, research areas, fields or sub-fields. For each cluster, we can calculate growth indices pointing at changing research focus over time.

Multi-level clustering

The classification scheme has at present three different levels. The clusters are hierarchically organised. Currently we discern the following levels.

1. A top level of 25 clusters (fields)
2. A second level of around 800 clusters (sub-fields)
3. A third level of more than 4,000 clusters (research areas or micro-fields)

A common way of visualising the landscape of science by the publication clusters is a 2-dimensional map. In such a landscape (see Figure 18), we position publication clusters in relation to each other on the basis of citation traffic. The denser the traffic between two clusters, the closer they are. The two dimensions do not represent anything. The only thing that matters is the distance. Furthermore, the size of a cluster represents the relative volume (number of publications included), while the color coding adds a main clustering labeled by main disciplines.

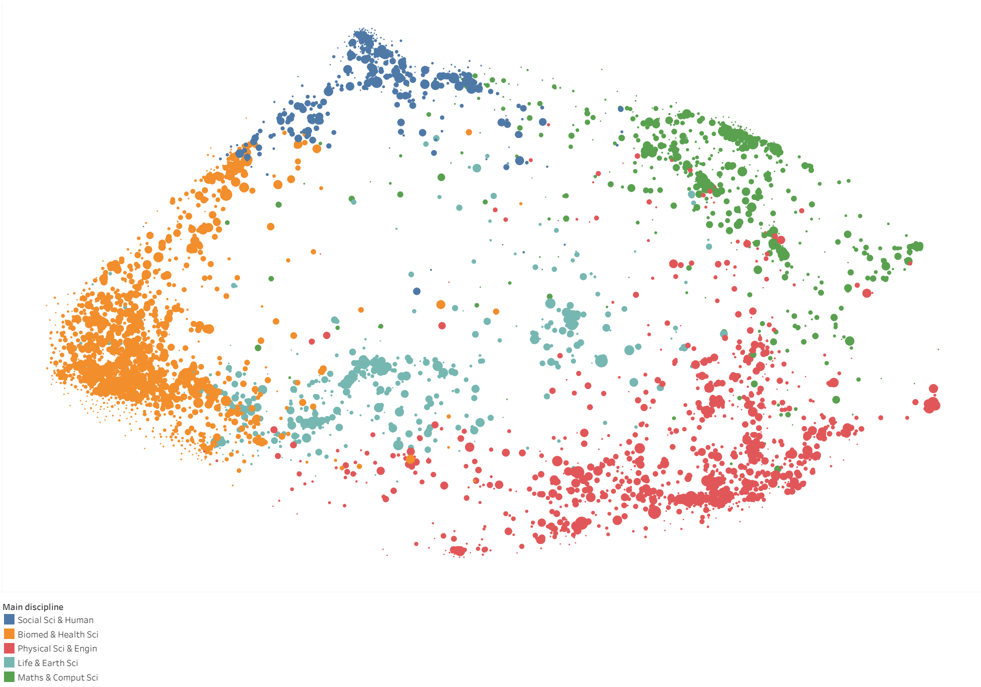

Figure 18: Landscape of all science (around 30 million WoS publications). Circles represent (over 4,000) publication clusters. Position is defined by citation traffic between clusters. Size indicates relative volume. Color reflects 5 main disciplines

C Citation data and analysis

In this annex we provide more detail about the methodology developed at CWTS and applied in this study.

C.1 Database coverage

In a bibliometric study, we base the analyses on publication data. To relate counting and measuring to standards, we depend on international bibliographic databases, such as Web of Science, Scopus, Dimensions. We realise that by using such databases, we may be missing relevant scientific outputs and achievements. In order to assess how much the database *does* cover we calculate the Internal Coverage (**IntCov**) indicator. This indicator is the ratio of cited references covered by the database, to the total number of cited references. If a publications contains 10 references, five of which are also in the database, the IntCov of this publication is 0.5. For a set of publications the IntCov is defined by the average IntCov per publication. If the IntCov of an institution's output in WoS is 0.8, we estimate the coverage of WoS for this institution at 0.8 (80%).

C.2 Database Structure

At CWTS, we calculate bibliometric indicators based on an in-house version of the Web of Science (WoS) online database, which will be referred to as the CI-system. The WoS is a bibliographic database that covers publications of about 12,000 journals and each of these journals is assigned to one or more Journal Subject Categories (JSC). Each publication in the CI-system has a document type. The most frequently occurring document types are 'articles', 'reviews', 'proceeding papers', 'corrections', 'editorial material', 'letters', 'meeting abstracts' and 'news items'. In this report, we only consider document types 'articles', 'reviews' and 'proceedings papers'. In limiting the analysis to these three types of publications, we consider that these documents reflect most of the original scientific output in a field.

The CI-system is an improved and enhanced version of the WoS database versions of the Science Citation Index (SCI), Social Science Citation Index (SSCI), and Arts & Humanities Citation Index (A&HCI). The CI-system implements a publication-based field classification which clusters publications into research areas based solely on citation relations (Waltman and van Eck, 2012) (more detail in Annex B). One important advantage of this publication-level classification system is that it allows for a taxonomy of science that is more detailed and better matches the current structure of scientific research. This not only reduces classification bias but is also essential for calculating field-normalised indicators (Ruiz-Castillo and Waltman, 2015).

Moreover, in this study we include citation data up to 2021. Please note that publications require at least one full year to receive citations in order to make robust calculations of citation impact indicators. For this reason, we will work with publications up to and including 2020, counting citations up to and including 2021. For each publication (and its benchmark publications), we consider 4 years of citations since the year of publication. For a publication from 2010, we count citations in the years 2010-2014.

C.3 Citation Window, Counting Method and Field Normalisation

Citation window

Several indicators are available for measuring the average scientific impact of the publications of a research unit, e,g. and institution. These indicators are all based on the idea of counting the number of times the publications of a unit have been cited. Citations can be counted using either a fixed-length citation window or a variable-length citation window. In the case of a fixed-length citation window, only citations received within a fixed time period (e.g. four years fixed window) are counted. The main advantage of a fixed-length citation window is that it is possible to meaningfully analyse the trend patterns of the non-normalised impact indicators, setting the same criteria for all publications included. A variable-length window, on the other hand, uses all the citations that are available in the database until a fixed point in time, which not only yields higher citation counts (depending on the window length), but also more robust impact measurements. When using a variable-length citation window, impact indicators such as the average impact (MCS) and the total impact score (TCS) may systematically present a decreasing pattern.

In this study, we use a fixed-length window of 4 year (if available) for the overall period of the analysis (2009-2020). The most recent year for receiving citations is 2021.

Self-citations

In the calculation of advanced citation impact indicators, we disregard self-citations. A citation is considered a self-citation if the cited publication and the citing publication have at least one author (i.e. last name and initials) in common. The main reason for excluding self-citations is that they often have a different purpose from ordinary citations. Specifically, self-citations may indicate how different publications of a researcher build on one another, or they may serve as a mechanism for self-promotion rather than for indicating relevant related work. Self-promotion can in turn be used to manipulate the impact of a publication in terms of the number of citations received. Excluding self-citations from the analysis effectively reduces the sensitivity of impact indicators to potential manipulation. In doing so, impact indicators can be interpreted as the impact of researchers' work on other members of the scientific community rather than on his or her own work.

Field Normalisation

There can be quite large differences in citation practices in different scientific fields. Field normalisation is about correcting for differences in citation practices between different scientific fields. The goal of field normalisation is to develop citation-based indicators that allow for valid between-field comparisons.

In this report, we will use our in-house publication-based classification system of science to define the scientific fields that are used in this normalisation process. This system has three major advantages compared to the conventional journal-based classification systems of science: Web of Science Journal Subject Categories:

- Proper granularity in terms of fields.
- Fields are defined at the level of publications citing each other, not on allocating complete journals to field(s) where inaccuracies are introduced.
- Publications from journals like Nature, Science, PLoS ONE (multidisciplinary journals) are allocated to the field they actually belong to and not to the artificial journal field 'Multidisciplinary Sciences'.

The reasons to use this publication-based classification are furthered explained in Annex B.

Counting method

Counting methods are about the way in which co-authored publications are handled. For instance, if a publication is co-authored by researchers from two countries, should the publication be counted as a full publication for each country or should it be counted as half a publication for each of them? In this study, we use both full and fractional counting. Full counting means that if a publication is co-authored by multiple organisations, that publication counts multiple times, once for every organisation, regardless of the weight of their contribution. In this report, we use mainly the full counted publications for output and fractionalised (by number of institutions involved) for impact measures.

D Interdisciplinary research

While there are different understandings of interdisciplinarity, the definition that has gained more consensus is the one provided by the US National Academy of Sciences (2005) that states:

> "Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice."
>
> *https://www.nap.edu/read/11153/chapter/4*

There are two key elements in this definition we consider as basic notions to articulate our proposal: the concept of integration and the idea of combining knowledge from two or more disciplines.

We characterise interdisciplinarity at the level of each individual publication, by analysing the disciplines cited by the publication. This approach will allow us to consider the citations to distinct disciplines by the same citing publication as a proxy of the integration of knowledge from different disciplines. For this analysis we consider the Web of Science Journal Subject Categories as disciplines. We analyse the degree or extent of integration through the concept of diversity. Diversity is based on three concepts: variety, balance and disparity. We operationalise interdisciplinarity using Rao-Stirling diversity, an indicator which captures the three inter-related concepts of diversity, and is computed as follows:

$$\Delta = \sum_{ij} p_i p_j d_{ij}$$

$$(i \neq j)$$

> Where pi is the proportion of cited references in the subject category i, pj is the proportion of cited references in the subject category j, and dij is the cognitive distance between the subject categories i and j

In this formula, disparity refers to the cognitive distance existing between two scientific disciplines (or subject categories, in our case). In order to compute the disparity measure, we will create a similarity matrix Sij for the WoS subject categories based on the of citation flows between them. This will be then transformed into a Salton's cosine similarity matrix in the citing dimension. In this transformed matrix, the Sij represents the similarity between each pair of WoS categories, thus the cognitive distance (d) between two subject categories can be computed as d = 1- Sij.

The indicators of interdisciplinarity will allow us to identify an institution's subject categories of a prepresenting the most interdisciplinary research.

We apply the state of the art in analysing interdisciplinarity using bibliometric techniques. However, current approaches to characterise interdisciplinary research from a bibliometric perspective remain contentious. Like any other methodology suggested so far to measure and characterise interdisciplinarity based on scientific publications, our approach is not free of limitations and therefore results of these analyses need to be interpreted with caution.