Bibliometrics as a tool for the analysis of the scientific production of a country

Table of contents

1. Brief introduction to bibliometrics **2**
1.a. "Publication" as a practice in science 2
1.b. The building of bibliographic databases 2

2. The database: Web of Science **3**

3. From data to indicators **3**
3.a. Journals and documents selected 3
3.b. Classifying journals in disciplines 4
3.c. Fractional and integer counts 4

4. Indicators presented in the leaflets **5**
4.a. Scientific production indicators 6
4.b. Visibility indicators 6
4.c. Indicators of scientific cooperation 7
4.d. Variation of the indicators over time 8

5. Conclusions **9**

6. Annex 1: Definition of the 8 scientific disciplines **10**

This document is a methodological note that accompanies the Country Leaflets produced by OST in project ESTIME. Country leaflets were produced for the following countries: Algeria, Egypt, Lebanon, Jordan, Morocco, Syria, Tunisia. All the documents are available on the ESTIME website www.estime.ird.fr

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1. *Brief introduction to bibliometrics*

1.a. "Publication" as a practice in science

Publications are written by researchers (or scientists) and published in scientific journals, thus becoming known to the research community where they belong. Writing an article in a scientific journal implies respecting some "rules": enter a peer review process, accept the evaluations of the referees, etc. An article is only published several months (even 2 years) after the results of the research are obtained. The journals are collected by database producers in order to allow the end-user to know the latest scientific results, and provide a tool that permits to quickly identify interesting articles and to retrieve the information.

Hence, publication in a scientific journal constitutes one of the main dissemination modes for new scientific knowledge. Since the production of knowledge is a cumulative process, researchers refer to previous studies and results. The value of a publication lies both in the "peer-review" process organized by the journal's editors before accepting the articles for publication, and in its dissemination, through citations made by other articles after its publication. This explains also why scientific publications are used as a major tool for evaluating the scientific activity of researchers.

Hereafter, we explain the methodology used in this project, describe the sources of publications that we use, the procedure for attributing a scientific publication to a given country or discipline, and the construction and uses of various indicators.

1.b. The building of bibliographic databases

The information that describes each scientific publication is registered in large bibliographic databases. A bibliographic database is primarily an information tool for researchers that can also be used to elaborate scientific indicators on countries, institutions, disciplines. This "bibliometric" analysis, that is the statistical analysis of bibliographic data, requires data to be processed in order to extract the relevant information on sources (journals, authors and their affiliations), descriptive texts (titles, key-words, abstracts…), scientific fields or disciplinary classification and references to other publications (cited and citing publications).
The most commonly used bibliometric indicators include: the volume of publications, the volume of citations received, and the volume of scientific relationships through co-signed articles. The potential biases of the database regarding the selection of journals to be registered and the statistical limits in data treatment affect the resulting indicators. The indicators will therefore depend a lot on the methodological choices. They must be interpreted with caution and with a good understanding of the methodology used.

2. The database: Web of Science

In order to build indicators of the scientific activity, OST uses a multidisciplinary bibliographic database called "*Web of Science*", produced by Thomson Reuters. It is considered as a reference tool for the production of indicators worldwide.

The characteristics of this database are important to understand since they have consequences on most of the international statistics on scientific publications. The database – created as a documentary source and not as a source for building indicators – is a selective survey of the best scientific journals throughout the world.
WoS covers several thousands scientific journals (about 8 000 in 2004), selected as having well known editorial management, a good scientific level, and a good international visibility level. This visibility is the result of the average number of citations received by articles published by each journal. Nevertheless this journal selection is not necessarily the more representative one for each discipline. The database has recently included more conference proceedings and electronic journals.
The most often heard criticism of the *Web of Science* is that it favours Anglo-American science. The majority of the publications registered by the WoS are in English and this proportion is growing. This is partly related to a linguistic bias of the database but mainly to the growing use of English for communication on a global scale.
The representativeness of the WoS is generally accepted in the most internationalised fields such as physics or biology. The situation is different for scientific fields with a strong national specificity, for those using other types of dissemination than scientific articles, for those more applied disciplines, and for small sized disciplinary fields.
Social sciences and humanities are excluded from the bibliometric indicators presented in the ESTIME project leaflets, because the databases produced by Thomson Reuters (Social Science Citation Index – SSCI, Arts & Humanities Citation Index – A&HCI) have an important North-American bias.

3. From data to indicators

3.a. Journals and documents selected

The journal coverage of the Web of Science changes with the changing international visibility of scientific journals. When calculating the bibliometric indicators, OST follows the principle of a “dynamic group” of journals, more representative over time than the alternative solution that would be to have a “constant group” of journals. Then, the indicators are smoothed on a three-years basis to cope with the annual changes in coverage.

In the tables of the leaflets, the last year of information is used to date the indicator, for example: 2004 is used for dating the production (date of articles) of the 2002-2004 period.
OST indicators retain five types of documents of the Web of Science: articles, review articles, letters, notes and articles from meeting proceedings. The latter often appear as a selection of conference presentations in special issues of journals. The proportion of meetings covered by the Web of Science is still relatively low.

3.b. Classifying journals in disciplines

Journals in the WoS are divided into eight large academic disciplines, assigned by Thomson Reuters based on the main subject matter of the journals. OST assigns each subject category to only one major discipline: for example immunology is assigned to "fundamental biology". Besides the eight disciplines, a ninth very heterogeneous "multidisciplinary" section includes some very prestigious journals (*Nature*, *Science*…).This section is not included in the tables but contributes to the totals for all disciplines. The classification into 8 major scientific disciplines has the advantage of a good stability for macro-indicators.

Another classification into 31 sub-disciplines is also used. Each sub-discipline is not strictly related to only one large discipline. The classification process of an article is slightly more complex since one particular subject can be assigned to more than one sub-discipline.

The journals themselves can be assigned to different categories (up to 6) by Thomson Scientific. As we will see in next section, the counting can be either fractional or integer;; with fractional counts, the articles assigned to many categories are fractioned amongst their categories, whereas with the integer counts they are integrally counted as a unit in each category to which they have been assigned.

3.c. Fractional and integer counts

The statistics by country (region or institution) are not calculated on the basis of the nationality of the authors but on the basis of the address of the signing laboratories and institutions. In other words, an article signed by an Egyptian scientist working in the UK and signing as being affiliated to the UK institution, will be counted as an article from the UK..

Scientific articles are often co-signed by many authors belonging to several laboratories and institutions. Two different options for counting these articles can be chosen, either the **fractional count** or the **integer count**.

If we want to measure the *contribution* to world science, each laboratory gets a share of the article. Each article represents 100% of all the contributions made by the signing laboratories. This principle is also applied when a scientific journal is assigned to several different subject categories. This type of count, called "**fractional count**", is additive (the sum of all signatures is always equal to the sum of articles). It is well adapted to macro-analysis. Extended to the relative impact indexes, this type of count is preferable for international visibility comparisons.

If we want to measure the "*participation*" to world science, we rely on "distinct integer" or "full integer" counts: each laboratory signing an article is credited with a unitary participation. A publication can also in the same manner be assigned many times to the different disciplinary categories of the journals. The sum of participations will thus be superior to the number of articles. Because of multiple counts, the integer count produces a sum of all laboratories (or authors) participations that is superior to the sum of publications. Despite this disadvantage, the "integer distinct count" is well adapted to micro-analysis and is easier to interpret for co-publications.

The two counts provide very different results: for example, France *participates in* 8% of the world publications (integer count) but *contributes to* 5% of world publications (fractional count).
The following table presents the disciplinary distribution of the scientific publications registered in the Web of Science, for the three year averaged data, dated 1999 and 2004, and for both types of counts.

Table 1: Disciplinary distribution of the OST publication database based on the Web of Science (1999, 2004)

	Fractional counts				Distinct integer counts			
	1999		2004		1999		2004	
Discipline	Number of publications	Disciplinary share (%)	Number of publications	Disciplinary share (%)	Number of publications	Disciplinary share (%)	Number of publications	Disciplinary share (%)
Fundamental biology	113 448	15,7	116 812	15,2	144 363	20,0	148 814	19,3
Medical research	222 535	30,9	229 672	29,9	247 212	34,3	255 695	33,2
Applied biology-ecology	50 756	7,0	51 199	6,7	65 442	9,1	64 240	8,3
Chemistry	100 497	14,0	111 893	14,5	123 066	17,1	139 159	18,1
Physics	83 398	11,6	88 762	11,5	97 641	13,6	106 489	13,8
Astro and Geo- sciences	42 253	5,9	48 940	6,4	49 772	6,9	57 427	7,5
Engineering	74 147	10,3	88 924	11,6	96 381	13,4	114 519	14,9
Mathematics	21 098	2,9	23 852	3,1	24 401	3,4	28 407	3,7
Total	720 320	100,0	769 398	100,0	720 320	100,0	769 384	100,0

Thomson Scientific data, OST computing *OST - 2007*

Important remark

In the country leaflets, the most up-to-date indicators are proposed given that OST bibliometric database is updated once a year. At the time of writing, the most recent available year for publications is the smoothed year 2004 (the mean of 2002+2003+2004). At that time, the database was partly incomplete for those articles which were published in the year 2004.
Methodologically, this choice does not impact significantly on the resulting indicators because they are calculated as a ratio between the publications of the country under study and the worldwide publications (world share, impact index (share of citations divided by share of publications …) at the macro level (for countries and/or for large disciplines). It has been shown on a historical basis, that the indicators calculated with some missing data from last year are a very good approximation of those calculated with complete database.
When dealing with smaller entities (sub-disciplines for example), the indicators for 2004 must be considered as provisional and a note is written under the table to highlight that fact.

4. *Indicators presented in the leaflets*

Careful interpretation of the indicators is needed for small entities (small countries, small disciplines), which could be statistically sensitive, the statistical fluctuations associated with these indicators being potentially important.

4.a. Scientific production indicators

Scientific production indicators, also called scientific activity indicators, are calculated for all disciplines and for each of the eight standard scientific disciplines.

4.a.i. World share of publications

The world share of publications is defined as the number of publications of a country (a region, or an institution) divided by the number of worldwide publications, expressed as a percentage (%). It is the easiest comparable production indicator.

$$\text{Country world share (\%) in discipline "i"} = \frac{\text{Number of publications in discipline "i" of a country}}{\text{Total number of worldwide publications in discipline "i"}} \times 100$$

where discipline "i" is one among the eight standard disciplines in our classification,

The higher the value of this share (between 0 and 100%), the more active the country in its world scientific production.

4.a.ii. Specialisation index

The specialisation index of a country (a region or an institution) is the ratio of its world share in one particular discipline to its world share for all disciplines.

$$\text{Specialisation index in discipline "i"} = \frac{\text{Publication world share of the country in discipline "i"}}{\text{Publication world share of the country for all disciplines}}$$

A specialisation index of 1 in discipline "i" implies that this entity has a world share for that discipline similar to its share in all disciplines combined. This is a “neutral” situation meaning there is no relative specialisation in that particular discipline. When the specialisation index is greater than 1, the country is said to be specialised in that discipline, at the expense of some other disciplines for which the index is less than 1.

4.b. Visibility indicators

The “visibility” of a country, i.e. of its overall scientific production, is approached by counting the citations that each article produced by the country receives from other articles. The citation is an implicit way of recognising the value of the work presented in the article, improving it by giving it some “visibility”. At the end of each scientific article, a list of bibliographical references is inserted, recognising and underlining the value and the use of previous works (their contribution) in the research presented in the article. By linking these references (i.e. these citations) to the articles cited, and by doing this for each list of references, and each article, it is possible to count how many citations an article has received.

This way of counting references received by an article can be considered a proxy for measuring the visibility of an article.

4.b.i. *World share of citations*

The *world share of citations* is defined as the sum of citations received by the publications of a country (a region, or an institution) divided by the total number of citations received worldwide, during a given period.

Citations are received by an article several years after its publication. In the leaflets, the "citation window" used is two years, meaning that the indicators are calculated from the number of citations received for a period of two years following publication.

$$\text{Country world share (\%) of citations in discipline "i" for year N} = \frac{\text{Number of citations received by a country in discipline "i" during years N and N+1}}{\text{Number of citations received worldwide in discipline "i" during years N and N+1}} \times 100$$

The higher the value of the world share of citations for a country (comprised between 0 and 100%) the more visible the publications of that country in the worldwide scientific production.

4.b.ii. *Relative impact index*

The relative impact index for a country (a region, or an institution) in the world is defined as the ratio of the world share of citations for that entity to its world share of publications. The citation window used for this indicator is logically the one previously used for the calculation of the world share of citations.

$$\text{Relative impact index in discipline "i"} = \frac{\text{Citation world share of a country in discipline "i"}}{\text{Publication world share of a country in discipline "i"}}$$

A relative impact index of 1 in the discipline "i" implies that the visibility of the country's publications is equal to the average visibility of worldwide publications in that discipline. When the relative impact index is greater than 1, the country's visibility is better than the world average. When the relative impact index is less than 1 the country's visibility hasn't reached world average visibility in discipline "i".

4.c. Indicators of scientific cooperation

The use of addresses in the signatures of co-authored scientific articles allows the OST to produce indicators that underline links between laboratories (and hence at another level, between countries). A scientific article can be co-signed by two or more institutions (or laboratories). Counting these common signatures makes it possible to analyse the links at a national or international scale. Two laboratories in two different countries co-signing the

same article can be considered as a measure of the internationalisation of the research activity, and of the international collaborations of the co-signing laboratories.

The co-publication indicators (those based on co-authored publications) are calculated in the leaflets on an integer count, which is more intuitive to understand regarding the notion of collaboration. In this way co-authorships in an article means the existence of a “link” between the co-signing authors, independently of the other possible co-signing authors of the same article.

4.c.i. Level of internationalisation

The share of international co-publications of a country, used to estimate its level of internationalisation, is defined as the total number of international co-publications of that country divided by its total number of publications.

$$\text{Share of international co-publications (\%) in discipline "i"} = \frac{\text{Total number of international co-publications of the country in discipline "i"}}{\text{Total number of publications of the country in discipline "i"}} \times 100$$

The higher the share of international co-publications for a country (comprised between 0 and 100%) the more the country cooperates internationally.

4.c.ii. International partnerships between countries

The share of co-publications of a country A, with country B is defined as the number of co-publications between these two countries divided by the total number of international co-publications of country A. This indicator is expressed in percent, and in the leaflet the ten first scientific partners of country A are presented.

$$\text{Share of co-publicationsof country A with country B (\%)} = \frac{\text{Number of co-publications of country A with country B}}{\text{Total number of international co-publications of country A}} \times 100$$

The higher the share of co-publications of country A with country B (comprised between 0 and 100%), the more the country B can be considered as a scientific partner of country A.

4.d. Variation of the indicators over time

In several tables the growth of indicators between two years is presented. The value of the indicator for the year under study is compared with its value in 1999 or in 1993 (the reference years) in the ESTIME project. The evolution is the percentage increase (with the sign "+" if the value the last year is higher than in the reference years) or decrease (the sign "-" if the value is less than in the reference years) with respect to the indicator’s value for the reference year.

Over the long run, the value of an indicator provides useful information on the position of a country in the world research and development scene.

5. Conclusions

Within the ESTIME project, OST has defined a coherent and original set of indicators, elaborated on the basis of the Web of Science, which has been computationally re-modelled for that purpose by OST. The goal of these indicators is to characterise and monitor the scientific production of the different countries (or a set of countries or regions). Based on a simple counting of publications, this set of indicators (world share, specialisation index, impact index, internationalisation ratio, etc…) allows not only comparative analysis (benchmarking) but also highlights tendencies and evolution on a long run. These indicators reflect choices (disciplines, aggregation levels, citation window, etc…) made by OST on a methodological ground. In this manner, simple and intuitive indicators have been calculated for most of the countries in the world and for infra or supra national regions.

Moreover, apart its bibliometric indicators, OST can also provide indicators on technological activities (based on patent databases), on the participation in European Framework Programmes, on international student exchanges. This broad range of indicators allows for a complete characterisation of a country in better way than would be done on the sole basis of bibliometric indicators.

The leaflets elaborated during the ESTIME project show indicators related to the scientific production, its visibility and cooperation as measured through the production of scientific articles. The leaflets permit to look back in time and consider the long term evolution of the indicators. Within the ESTIME project, this quantitative approach based on bibliometrics, should be considered as complementary to the field work undertaken by the other members of the project and as an added-value for cross-country comparison.

6. Annex 1: Definition of the 8 scientific disciplines

The scientific disciplines taken into account for the calculation of indicators are the 8 standard disciplines of the OST. They have been defined as an aggregation of the about 180 subject categories implemented by Thomson Scientific for the natural sciences in the Web of Science®. The following table provides the correspondence between a discipline and the subject categories that it covers.

BIOLOGIE FONDAMENTALE
ANATOMIE, MORPHOLOGIE
BIOCHIMIE, BIOLOGIE MOLÉCULAIRE
BIOINGENIERIE
BIOLOGIE CELLULAIRE, HISTOLOGIE
BIOLOGIE MOLÉCULAIRE ET CELLULAIRE
BIOMATÉRIAUX
BIOMÉTHODES
BIOPHYSIQUE
BIOTECHNOLOGIE ET MICROBIOLOGIE APPLIQUÉE
EMBRYOLOGIE
GÉNÉTIQUE, HÉRÉDITÉ
GÉNIE BIOMÉDICAL
MICROBIOLOGIE
MICROSCOPIE
NEURO-IMAGERIE
NEUROSCIENCES
NUTRITION, DIÉTÉTIQUE
PARASITOLOGIE
PHYSIOLOGIE
PSYCHOLOGIE
SCIENCES COMPORTEMENTALES
SYSTEMES REPRODUCTEURS
TECHNIQUES DU LABORATOIRE
VIROLOGIE

BIOLOGIE APPLIQUÉE-ÉCOLOGIE
AGRICULTURE
AGRICULTURE, MULTIDISCIPLINAIRE
AGRONOMIE GÉNÉRALE
BIODIVERSITÉ, CONSERVATION
BIOLOGIE GÉNÉRALE
BIOLOGIE, AUTRES
BOIS ET TEXTILES
BOTANIQUE, BIOLOGIE VÉGÉTALE
ÉCOLOGIE
ENTOMOLOGIE
HORTICULTURE
MYCOLOGIE
ORNITHOLOGIE
SCIENCES DES PRODUCTIONS ANIMALES
SCIENCES ET TECHNIQUES AGRO-ALIMENTAIRES
SCIENCES ET TECHNIQUES DES PECHES
STATIONS AGRICOLES EXPÉRIMENTALES
SYLVICULTURE
ZOOLOGIE GÉNÉRALE

RECHERCHE MEDICALE
ALLERGOLOGIE
ANDROLOGIE
ANESTHÉSIOLOGIE
CANCÉROLOGIE
CHIMIE, CLINIQUE ET MÉDECINE
CHIRURGIE
SOINS INTENSIFS
DERMATOLOGIE, VÉNÉROLOGIE
ENDOCRINOLOGIE
GASTROENTÉROLOGIE
GÉRONTOLOGIE
GYNÉCOLOGIE, OBSTÉTRIQUE
HÉMATOLOGIE
IMMUNOLOGIE
MÉDECINE INTÉGRATIVE ET COMPLÉMENT
MALADIES INFECTIEUSES
MÉDECINE CARDIOVASCULAIRE
MÉDECINE CARDIOVASCULAIRE 2
MÉDECINE CLINIQUE, AUTRES
MÉDECINE D'URGENCE
MÉDECINE DE LA DÉPENDANCE
MÉDECINE DU SPORT
MÉDECINE EXPÉRIMENTALE
MÉDECINE INTERNE GÉNÉRALE
MÉDECINE LÉGALE
MÉDECINE TROPICALE
MÉDECINE VÉTÉRINAIRE
SANTÉ PUBLIQUE 2
ÉTHIQUE MÉDICALE
NEUROLOGIE CLINIQUE
ODONTOLOGIE
OPHTALMOLOGIE
ORTHOPÉDIE
OTORHINOLARYNGOLOGIE
PATHOLOGIE
PÉDIATRIE
PHARMACOLOGIE-PHARMACIE
PNEUMOLOGIE
PSYCHIATRIE
RADIOLOGIE, MÉDECINE NUCLÉAIRE
RÉHABILITATION
RHUMATOLOGIE
SANTÉ PUBLIQUE
TOXICOLOGIE
TRANSPLANTATIONS
UROLOGIE-NÉPHROLOGIE
SOINS INFIRMIERS

Annex 2 (continued): Definition of the 8 scientific disciplines

CHIMIE
CHIMIE ANALYTIQUE
CHIMIE APPLIQUÉE
CHIMIE GÉNÉRALE
CHIMIE MINÉRALE ET NUCLÉAIRE
CHIMIE ORGANIQUE
CHIMIE PHYSIQUE
CRISTALLOGRAPHIE
ÉLECTROCHIMIE
MATÉRIAUX COMPOSITES
MATÉRIAUX/ANALYSE
SCIENCE DES MATÉRIAUX
SCIENCE DES MATÉRIAUX - BOIS, PAPIER
SCIENCE DES MATÉRIAUX - CÉRAMIQUES
SCIENCE DES POLYMÈRES
TRAITEMENTS DE SURFACE

PHYSIQUE
ACOUSTIQUE
INSTRUMENTATION
OPTIQUE
PHYSICO-CHIMIE
PHYSIQUE APPLIQUÉE
PHYSIQUE DES FLUIDES ET PLASMAS
PHYSIQUE DES PARTICULES
PHYSIQUE DU SOLIDE
PHYSIQUE GÉNÉRALE
PHYSIQUE MATHÉMATIQUE
PHYSIQUE NUCLÉAIRE
PHYSIQUE, AUTRES
SPECTROSCOPIE

SCIENCE DE L'UNIVERS
ASTRONOMIE ET ASTROPHYSIQUE
BIOLOGIE MARINE - HYDROBIOLOGIE
DIV. GÉOPHYSIQUE-GÉOCHIMIE
GÉOGRAPHIE
GÉOLOGIE
GÉOSCIENCES
GÉOTECHNIQUE
LIMNOLOGIE
MÉTÉOROLOGIE
MINÉRALOGIE
OCÉANOGRAPHIE
PALÉONTOLOGIE
RESSOURCES EN EAU
SCIENCES DE L'ENVIRONNEMENT
TECHNOLOGIES DE L'ENVIRONNEMENT

MULTIDISCIPLINAIRE

SCIENCES POUR L'INGÉNIEUR
BIOCYBERNÉTIQUE
COMPOSANTS
REVUES DE SYNTÈSE EN INFORMATIQUE
CONTRÔLE
CONTRÔLE 2
ÉNERGIE ET CARBURANTS
GÉNIE MARITIME
GÉNIE AÉROSPATIAL
GÉNIE CHIMIQUE
GÉNIE CHIMIQUE ET THERMODYNAMIQUE
GÉNIE CIVIL
GÉNIE DE LA CONSTRUCTION
GÉNIE ÉLECTRIQUE ET ÉLECTRONIQUE
GÉNIE INDUSTRIEL
GÉNIE MÉCANIQUE
GÉNIE MÉTALLURGIQUE ET MINIER
GÉNIE MINIER
GÉNIE PÉTROLIER
INFORMATIQUE
INFORMATIQUE (DIVERS)
INFORMATIQUE ET CHIMIE
INFORMATIQUE ET ROBOTIQUE
INFORMATIQUE/APPLICATIONS
INFORMATIQUE/DIVERS 2
INFORMATIQUE/IMAGERIE
INFORMATIQUE/THÉORIE ET SYSTÈMES
INGÉNIERIE/SYSTÈMES
INTELLIGENCE ARTIFICIELLE
MÉCANIQUE
MÉTALLURGIE
PHOTOGRAPHIE, IMAGERIE
RECHERCHE OPÉRATIONNELLE
ROBOTIQUE
SCIENCE - TECHNOLOGIE NUCLÉAIRE
SCIENCES DE L'INFORMATION
SYSTÉMIQUE
TECHNOLOGIES MARINES
TÉLÉCOMMUNICATIONS
TÉLÉDECTION ET TÉLÉCONTROLE
SCIENCES ET TECHNIQUES DES TRANSPORTS

MATHÉMATIQUES
MATHÉMATIQUES
MATHÉMATIQUES APPLIQUÉES
MATHÉMATIQUES GÉNÉRALES
MATHÉMATIQUES THÉORIQUES
MATHÉMATIQUES, AUTRES
MÉTHODES MATHÉMATIQUES (BIOLOGIE ET MÉDECINE)
MÉTHODES MATHÉMATIQUES (SCIENCES PHYSIQUES)
MÉTHODES MATHÉMATIQUES (SCIENCES SOCIALES)
STATISTIQUE ET PROBABILITÉS

NB: The term “multidisciplinary” refers to the multidisciplinary journals of the Web of Science® for which Thomson Reuters has not affected a specific subject category.