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Disciplinarity and interdisciplinarity in citation and reference dimensions: knowledge importation and exportation taxonomy of journals

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Abstract This work proposes an entropy-based disciplinarity indicator (EBDI) which allows the classification of scientific journals in four classes: knowledge importer, knowledge exporter, disciplinary and interdisciplinary with regards to the discipline(s) in which they are classified. Assuming that the set references in the papers published in a journal represent a significant part of their knowledge basis, the diversity (measured with Shannon's entropy) and ratio between internal and external (to the discipline in which the journal is classified) references can provide a measure of the disciplinarity/interdisciplinarity of the journal in the reference dimension. The homologous analysis can be applied to the set of citations received by the papers published in the journal. In this article, an entropy-based indicator for the measurement of the disciplinarity of scientific journals is developed, applied (to the cited and citing dimensions) and discussed. The indicator can take finite values and it is found to be theoretically consistent when tested against two definitions for bibliometric indicators. The combinations of disciplinarity values in the citing and cited dimensions permits the classification of journals according to their knowledge importing/exporting profile (separately, with regards to the social sciences or the sciences), providing a taxonomy of the role of journals according to their importing, exporting, interdisciplinary or specialized profile with regards to the subject category in which they are classified. The indicator, EBDI and the resulting taxonomy is proposed and tested for the set of journals in LIS subject category in JCR 2013 and for the sets of journals in Andrology and Legal Medicine in JCR 2015. Evidence of concurrent validity with journal co-classification patterns is found in the three sets of journals.

Keywords Disciplinarity · Specialization · Journal taxonomy · Entropy

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Introduction

In recent decades, the study of interdisciplinarity/disciplinarity has emerged as a core topic in science and technology studies and information and library science. IDR, Inter Disciplinary Research (Wagner et al. 2011), is a key aspect both for policymakers and researchers (National Academies 2005; Uddin et al. 2015; Vugteveen et al. 2014). The increase in the number of journals has been observed, yet not exponentially (Mabe and Amin 2001), having specialization as one of the possible factors, as Ziman (1980) puts it 'The impression of excessive proliferation arises mainly from the differentiation of journals to accommodate rapid expansion in specialized fields of research'.

A wide number of procedures and approaches have been designed in order to define and measure interdisciplinarity or disciplinarity (Tobi 2014), as well as related concepts such as cross-disciplinarity (Porter and Chubin 1985: COC and citation dispersal, continued by Tomov and Mutafov 1996, developers of I_{id} indicator) or trans-disciplinarity (Croyle 2008; Hall et al. 2008). The concept of interdisciplinarity can be understood at various levels, from the individual paper to the set of articles of a journal. It has also been applied to specific sets of journals within a given field, and some also at the institutional level. In order to better understand the levels at which the various methods have been applied, in the following lines, those levels will be linked to each method/indicator. The methods developed range from using pre-defined classifications (*classification-based*), mainly Thomson Reuters ISI Subject Categories (SC hereafter), i.e. van Raan and van Leeuwen (2002)-who apply the frequency analysis at the institutional level focusing on the diversity of fields in which the journals where researchers publish their research are classified, as well as the disciplinary origin of citing publications- to the development of procedures for ad hoc classification relying on factorization and clustering methods or *bottom-up approach* (i.e. Leydesdorff 2007, in which network analysis is applied separately to citing and cited journals. In Rafols and Meyer (2010), diversity and coherence, as concepts, were made operative through network analysis at the level of individual articles. The studies in this topic used approaches in terms of task (Porter et al. 2007), process, and/or product. Regarding the sources and nature of information, different inputs have been used, such as: word co-occurrence and neural networks (Tijssen 1992, at the level of journals considering the co-occurrence of subject classifications, or Zitt and Bassecoulard 2006, applying lexical-citaion metrics to individual articles), co-classification of journals in pre-defined systems (Morillo et al. 2003, applied at the journal level) or citations (most of the studies rely on this latter aspect, such as Leydesdorff and Schank 2008, applying network analysis at the article and journal level, Rafols and Meyer 2010; Stirling 2007, who provides a theoretical approach to the measurement of diversity or Leydesdorff and Rafols 2011, at the level of journals). It seems likely that citation has been widely explored since the interest in the cited work by the citing author is understood as underlying the citation process (Atkinson 1984).

A comprehensive work by Leydesdorff and Rafols (2011) compares the performance of various indicators aimed at the measurement of interdisciplinarity, among which there are network-based indicators such as Betweenness centrality (Leydesdorff 2007), Rao–Stirling

measures (Rao 1982; Stirling 2007; Porter and Rafols 2009) and vector-based indicators (Gini Index and Entropy), applied to a set of journals in JCR.

More recently, Mugabushaka et al. (2015) proposed Leinster–Cobbold diversity measures (Leinster and Cobbold 2012) as an optimal indicator for the measurement of interdisciplinarity understood as diversity. In their paper, they provide a comprehensive, comparative overview of the different families of indicators and apply the indicator proposed to a set of articles (replicating measures of diversity in Rafols and Meyer, at the level of individual article). Also, the analysis of the interdisciplinarity of journals through the measurement of variety, balance and disparity among the subject fields of cited items has been carried out by Zhang et al. (2015), also using Hill-number type indicators (the indicators are applied at the level of journals).

Several of the indicators previously developed include distance/similarity metrics which intend to account for the cognitive distance between fields in the citing or cited dimensions with regards to the item under study. The reasons for not including those metrics in this study and the alternative approach taken here are detailed in the methodology section.

The concept of Inter Disciplinary Research or IDR has been the object of an extensive review by Wagner et al. (2011); a general definition of the field, as provided by Porter et al. (2007) and mentioned in Wagner et al. (2011) implies the integration of 'perspectives, concepts, theories, tools, techniques and or information/data from two or more bodies of specialized knowledge or research practice'. The conceptual framework of IDR is diverse in terms of sources, but the tree main concepts which seem to better describe it are: interdisciplinarity, interdisciplinarity, and transdisciplinarity (Wagner et al. 2011). The three concepts are defined in their article; stemming from the general definition of IDR, interdisciplinarity implies that the 'research product is no more and no less than the simple sum of its parts', while transdisciplinarity, including that same feature, involves 'comprehensive frameworks that transcend the narrow scope of disciplinary worldviews though an overarching synthesis'. Finally, interdisciplinarity entails the integration of 'separate disciplinary data, methods, tools, concepts and theories in order to create a holistic view or common understanding of a complex issue, question or problem'. As will be detailed in the following paragraphs, the level at which the indicator is to be applied is the journal one, considering for its calculation the distribution among fields of the citations and references.

A citation implies reading a previous work which is understood as useful for the research in which it is cited. It also involves integrating relevant parts of the conclusions, methodologies, or any other useful information into the research reported in the citing document; the term 'knowledge base' has been frequently used to describe this specific sense of the concept of cited–citing relationship (Rafols et al. 2012; Martin et al. 2012). The citation of previous works does not produce a mere 'sum of parts', as in the case of a interdisciplinary approach, since the information from the cited document is not just added but integrated in the citing research, and the existence of a 'comprehensive framework' (which is part of the definition of transdisciplinarity) which transcends the scope of the field is contingent but not necessary. Considering the core concepts of IDR applied to the journal level, the definition which better fits what the indicator and taxonomy proposed in this article are intended to capture is interdisciplinarity (the indicator, as will be detailed below, is intended to directly measure disciplinarity which is understood as opposite to interdisciplinarity).

Considering the level of measurement at which the different methodologies and indicators have been applied, journals, together with individual articles have been the most frequent. Journals have a specific thematic scope which is usually stated by the publishers; this is used by authors, readers and indexation systems as a reference for their coverage and

goodness of fit in a given field. This is the first of the reasons why the journal level was chosen for the purpose of developing a disciplinarity indicator. The second reason is related to the validation process carried out in this article; there are more previous studies on journal interdisciplinarity that applied to other levels of analysis, and that makes the validation process more reliable (co-classification, in this case). Finally, journals are the units used for the classification of papers into disciplines in most information systems such as WoS and Scopus (an individual article is attached to a field because of the classification of the journal in which it has been published); this also makes the development of the indicator and derived taxonomy potentially usable for the improvement of such classification procedures.

The measurement of the interdisciplinarity of a journal has been the subject of several refinements and improvements in their methodological approach. Nevertheless, there can be identified two aspects which have not been fully integrated in the analyses and which are the main contribution of this article to the field: the first one is the consideration of the proportion of internal citations (citations from or to the same discipline in which the journal or article is classified) as a variable which, once included in the interdisciplinarity indicator can affect its values and interpretation. The second aspect is the possible meaning of the combination of values in the reference and citation dimensions simultaneously. The use of citation networks has allowed, in example, the characterization of journals as closer or more distant from or to other nodes (among other parameters), and the relatedness indicator developed by Pudovkin and Garfield (2002) has facilitated a summarization of the degree of interaction between specific journals according to their citation and referencing pattern but, as well as the previously developed methodologies (in example, COC indicator, by Porter and Chubin 1985), a usable taxonomy with reference to the overall pattern of the research field combining citations and references into a single measure has not been explicitly produced or discussed.

The main objective of this article is to develop and test a vector-based indicator for the disciplinarity of journals (the latter corresponding to the definition in Rafols and Meyer 2010), including citing and cited dimensions and using the minimum necessary information. It is also an objective to achieve as much reliability and simplicity in its formulation as possible, in order to facilitate its replication and improve its usability. Since consistency definitions for bibliometric indicators have been developed and are present in the literature, the indicator will be also tested against those definitions. Testing the concurrent validity of the indicator is also an objective of this work, starting from previous developments. Finally, it is among the objectives of this research to explore the possible interpretations which could be attributed to the combinations of interdisciplinarity values in the cited and citing dimensions of journals as well as to discuss the potential applications of the indicators and the taxonomy of roles proposed.

Methodology

Source of information In order to test the indicator, a set of journals with sufficient citing and cited data was selected, also taking into account the need of proper thematic classification of both, the set of journals and the set of citing and cited journals. Journal Citation Reports 2013 and 2015 were selected as a suitable source of information since it fulfills the two previously mentioned conditions.

Set of journals The journals from any discipline might have been used. Library and Information Science Journals (LIS hereafter) were chosen, nevertheless, as the most appropriate set of journals for this study. The reason for choosing that subject category is an expectable intuitive knowledge of their degree of specialization by potential readers of this paper. Also, the aim of this research is not the characterization of large sets of scientific journals but the presentation and discussion of the methodology and the indicator. All journals classified in the 2014 release of JCR (Journal Citation Reports) LIS subject category have been the object of the application of the indicator. Also, in order to identify potential pitfalls of the indicator in other sets of journals, and to increase the generalizability of the conclusions, two other full sets of journals have been analyzed: the first is Andrology and the reason for including this field is the reduced number of journals, which would serve as test for the range of values which the indicator provides and its applicability in small sets of journals; the second is Legal Medicine, which being a synthetic field (in the epistemological sense of the word) is expected to offer an ample casuistic and, therefore, a better testing base for potential problems of the indicator in practice. For these two fields, data from 2015 JCR edition was used.

Application of the indicator/taxonomy to fields belonging to the SSCI and/or SCI classification The indicator has been calculated considering citations from/to fields belonging to the SSCI classification on the one hand and to the SCI classification on the other for Library and Information Science. In the case of Andrology, the level of interaction with Social Sciences' fields is extremely low and therefore the indicator has been calculated only for the SCI fields. In the case of Legal Medicine, the interaction with fields belonging to the Social Sciences shows a very limited diversity and degree; for this reason, the indicator has been calculated also for SCI fields in order to retain only the most significant results and conclusions.

Classification of internal citations and internal citations/references In order to define whether a citation from a journal is considered external or internal, the 'or' Boolean operator has been applied: a (citing or cited) journal can be classified in more than one discipline, whenever the citing or cited journal is classified in the same SC as the unit of analysis or the SC of the unit of analysis is among the disciplines in which the journal is classified (an example is set in Table 1), it has been counted as an internal citation, while in any other case it has been classified as an external citation.

Definition of external citations/references Citing or cited journals which are not considered internal citations can also be co-classified in different subject categories. For analysis purposes, in each set of references or citing journals for a given unit of analysis, each unique combination of co-classification has been considered a distinct unit. A unique

Table 1 Examples of the internal/external citations or references as considered in this work

Subject category/categories of the citing or cited journal	Subject category of the journal under analysis	Type of citation/reference
A	*A*, *B*	*Internal*
A, *B*	*A*	*Internal*
B	*A*	*External*
B, *C*	*A*	*External*

Table 2 Examples of unique SC combinations for references in Scientometrics (2013 JCR data)

Some unique combinations of subject categories of the references. Scientometrics 2013	No. references
ASTRONOMY & ASTROPHYSICS	3
AUTOMATION & CONTROL SYSTEMS/COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE	5
BEHAVIORAL SCIENCES/NEUROSCIENCES	4
BIOCHEMICAL RESEARCH METHODS/BIOTECHNOLOGY & APPLIED MICROBIOLOGY/MATHEMATICAL & COMPUTATIONAL BIOLOGY	2
BIOCHEMICAL RESEARCH METHODS/MATHEMATICAL & COMPUTATIONAL BIOLOGY	3
BIODIVERSITY CONSERVATION/COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE/ECOLOGY/ENVIRONMENTAL SCIENCES	4
BIODIVERSITY CONSERVATION/ECOLOGY/ENVIRONMENTAL SCIENCES	4

combination of co-classification is understood here as follows: for the set different journals {D, E, F} in which citations/references to/from the journal under analysis (J) are found to be published, in a classification system with n subject categories are available, $\boldsymbol{C_{n,r}}$ (combinations of $\boldsymbol{r}$ journals from a set of $\boldsymbol{n}$ journals) combinations can be found, from which the number of different SC's combinations is counted (Table 2 contains an example of this procedure).

This aggregation procedure has been chosen for two reasons:

(a) The implications of using a fractional counting on the diversity of citing and cited journals have not been sufficiently analyzed in previous works and its application would be experimental. If, by the opposite, no fractional counting were to be applied, the criteria for choosing one single discipline would also be experimental and would have a strong effect on the final results since the diversity in the citing/reference dimensions directly depends on the number of different thematic classifications.

(b) Since co-classification of journals has been proposed by previous research (Morillo et al. 2003) as an approach to the measurement of their interdisciplinarity and this is a relevant variable for the measurement of the disciplinarity/interdisciplinarity of the citations to and by a journal, the application of that counting scheme seems to be congruent both with previous research and with the objectives of this research.

Data gathering and variables considered For the whole set of journals in the SC (74) the 'citing' and 'cited' journals' data was recovered. This data consists of the following variables: abbreviated title of the citing or cited journals and number of citations by year (all years, 2013, 2012…2004 and 'Rest', from 2015 in the case of Andrology and Legal Medicine).

The thematic classification of the citing and cited journals within the JCR scheme of Subject Categories was matched with the titles of the citing and cited journals, both in the case of Social Sciences and Sciences. The citations from/to each unique combination of SC's of citing/cited journals were then summarized. The result is a database containing, for

each journal, the number of citations from/to each set of unique SC combinations which is also segmented into two branches: citing/cited journals classified in Social Sciences disciplines and citing/cited journals classified in Sciences disciplines. Table 2 resumes the frequency of some of the references in Scientometrics to papers published in journals with different combinations of subject categories classifications.

Segmentation of citing and cited journals by branch of knowledge Given the epistemological and methodological differences, as well as those related to their bibliometric behavior (Nederhof 2006) between the sciences and the social sciences, the two branches of knowledge have been segmented in terms the citations received and emitted by Library and Information Science journals. This facilitates a differential analysis, given the fact that distance metrics are not included in the indicator formulation, thus allowing further precision over the raw set of citations. Journals in Andrology and Legal Medicine have been analyzed only with regards to journals in SCI, since their interaction with journals classified in SSCI fields is very limited.

Previous assumptions

The assumptions underlying this work need to be clearly stated, in order to facilitate a better understanding of the methodological developments presented in this article.

Assumption 1 The percentage of citations coming or directed to journals classified in the same SC as the citing or cited journal (internal citations hereafter) is a proxy for a journal's disciplinarity in the SC in which it has been classified. A journal citing or cited only by journals classified in its own SC is extremely monodisciplinary (Leydesdorff and Rafols 2011, when referring to self-citations), although the interpretation of the monodisciplinarity of the journal when considering citations from and citations to other journals might differ (as detailed in lines below).

Assumption 2 Evenness and diversity of the distribution of citations, from or to a given journal are the two main proxies for its interdisciplinarity from a citation-based perspective.

Shannon entropy as percentage of $H_{\max;\ \text{empirical}}$ $H_{\max}$ It remains problematic to determine up to which point the percentage of external citations hereafter can be resumed into a measure in which both, diversity and evenness or unevenness of the distribution are captured for a single journal. The external citations can come from a variable number of different SC, and the distribution among the variable number of SC might differ in its evens (from linear to a power-law).

Assumption 3 Disciplinarity or specialization is opposite to interdisciplinarity. Disciplinarity is understood as self containment of the knowledge base on the one hand, and usefulness of publications for further research, on the other within one single discipline. Interdisciplinarity has been defined in the introductory section, and it is not only incompatible with disciplinarity but opposite in the quantitative sense (zero fields involved against other fields involved in a given set of publications). Thus the indicator can be understood (in its current formulation) as an indicator of disciplinarity or specialization and/or interdisciplinarity. Considering that the two concepts are assumed as opposites, the degree of interdisciplinarity of a given item inversely proportional to the indicator's values. An alternative formulation and the name of the indicator (exchanging the place of numerator and denominator) would result in the inverse conclusion, its values being

inversely proportional to the disciplinarity or specialization. The interpretation does not change, nevertheless, the results of the taxonomy proposed in this article, provided that the interpretation of the positions over and below the cutting point are reversed accordingly. The indicator formulation in its current form responds to the intuitive interpretation of the thematic scope of a journal classified in a discipline, considering it to be an ideal classification; the a priori assumption is that the journal is specialized in that field and it is the initial condition or hypothesis which corresponds to the indicator formulation in its current form; empirical observations against it would contradict that hypothesis.

On the inclusion of distance/similarity metrics in the design of the indicator

Several of the indicators developed for the measurement of the interdisciplinarity of journals include distance/similarity metrics. These metrics intend to provide a value to the 'cognitive distance' between the discipline of the journal/article/institution under analysis and the disciplines of the citing or cited elements. Distance/similarities have not been included in the formulation of the indicator proposed here, although the citations and references to or from fields belonging to the social sciences and the sciences are calculated as separate sets, thus providing two taxonomies for each journal (one with regards to the sciences and the other with regards to the social sciences). The reasons for not including distance/similarity metrics are developed in the following lines.

The first reason why, despite providing valuable information to an interdisciplinarity indicator, distance/similarity metrics are not proposed in this case is the existence of parameters which affect their value, and these are chosen according to the researcher's preferences. In the case of Rao–Stirling Index, which adds to Simpson's diversity distance/similarity parameters (α and β), as Rafols and Meyer (2010) put it, 'The choice of the metric used to define distance is inevitably value laden' since these two parameters are to be fixed manually and their values have a direct effect on the results of the indicator. In the case of Leinster–Cobbold (LCDiv) diversity indices, the original indicators developed the field of biology (Ricotta and Szeidl 2006; Chao and Jost 2012) used a phylogenetic tree as the source of data for computing the distance between species. As Mugabushaka points out 'As such it is a measure specifically tailored for ecological analysis and cannot be directly used for other contexts'. Nevertheless, as he also develops, Leinster and Cobbold (2012) provide a measure of distance $(Z_p)i$ which can be extrapolated to other fields. This measure includes a sensitivity parameter (q) ranging from 0 to infinity which, as Mugabushaka et al. explain: '(…) is called a sensitivity parameter and control the relative emphasise that the user wishes to place on common and rare elements.' All methods for the calculation of distance/similarity metrics seem to be subject to the choice of parameters by the researcher. As he Mugabushaka et al. demonstrates, and despite the limited range of the differences observed, the choice of different parameters affects the value of the measures for the same set of items, ordinally. It allows the possibility of the following statement by Waltmann et al. (2011), concerning one the consistency of an indicator: 'if adding the same publication to two different sets of publications never changes the way in which the indicator ranks the sets of publications relative to each other' not being applicable to the indicator with satisfactory results.

The second reason for not including distance/similarity metrics in the calculation of the indicator proposed in this article is the fact that the origin of these measures and their further incorporation to bibliometric indicators is the field of ecology, where the phylogenetic distance (Weitzman 1992), in a distance matrix is included as a variable (Ricotta

and Szeidl 2006; Chao and Jost 2012). The stability (in terms of cohort variability) of genetic distance over time is hardly comparable with the plausible higher variability of cognitive distance between fields of science. As Mugabushaka (op. cit.) points out 'There is a need in bibliometrics, to investigate to which extent the interdisciplinarity scores depends on the choice not only of the similarity basis (direct citation, bibliographic coupling etc.…) but also of the distance/proximity measures used.'

The third reason is the limited difference in the values of entropy and distance/similarity metrics when they have been compared in the literature. In Rafols 2010 and Meyer, they apply several indicators of interdisciplinarity (Variety, Shannon entropy, Simpson index, mean sinkage strength and mean path length). The correlation matrix for the six indicators yields the highest correlation (0.95) for Shannon (the basic indicator used in this article) and Stirling (an indicator which includes distance/similarity). The authors state 'Since Shannon H gives more weight to the small terms in its sum through its logarithmic factor, while Stirling Δ gives more weight to the combinations of disparate SCs, we believe that the high correlation between H and Δ is due to the fact that many SCs with small proportions happen also to be distant from the core SCs.' This, although for a limited number of papers (which not being the level of analysis of this article can, nevertheless, be assimilated to the behavior of journals), points out to the possible limited added value of distance related metrics in some cases: in the case of the entropy based indicator, a citation from/to an infrequent field will contribute much largely to its value (by the mere count as a further element) than a higher number of citations from/to a common field. That frequency in the overall citation matrix is what serves as basis for the computation of the cognitive distance. In Mugabushaka's paper, Leinster–Cobbold Diversity indices are applied to the set of papers analyzed in Rafols and Meyer's (2010) article. The indices are calculated for different values of the parameter q and with and without distance/similarity metrics. When the values of the indices are correlated, for the same set of papers and with the same value of q, these correlations (Spearman) range from 0.51 in the case of $q =$ infinite to 0.95 in the case of $q = 1$. From this observation, it can be concluded that, in some cases, using distance/similarity metrics might play or not an important role in terms of differentiation depending on the parameters, as chosen by the researcher.

The fourth reason is that, despite the unresolved problems of distance/similarity metrics, the expected result (an influence of the cognitive distance on the values of the indicator) is desirable and an approach free from parameter fixation, although less granular, can be applied. In this sense, the approach taken in this article is the application of the indicator separately to the set of citations and references to or from the subject categories belonging to branches of the Social Sciences and the Sciences. Thus, a journal can be classified as importer or exporter from or to its discipline and from or to the sciences or the social sciences and core or peripheral with regards to that broad distinction. A citation from a Library and Information Science journal to a journal in Physics would not, therefore, count more or less than a citation to a journal in Management: they would be resumed in two different indicators (namely, EBDI Sciences and EBDI Social Sciences).

Finally, the computation of most distance metrics requires full data on the citation matrix; distance is understood as an empirical observation at a given point in time (such as cosine measures) which involves the whole citation matrix of the database (i.e. Chavarro et al. 2014). This might compromise the easiness of use of the indicator by audiences wider than those with full access to the whole citation matrix of a given database, which is one of the desired properties of the indicator.

Development of the indicator

A suitable indicator which captures both diversity or degree and evenness in the frequency distribution is Shannon's entropy. The attribution of the measurement of diversity and evenness of a citation distribution to Shannon's entropy has been discussed by Leydesdorff and Rafols (2011), who propose the use of the 'local' entropy associated to the distribution of a given unit of analysis as a percentage of the maximum entropy of the distribution (H_{max}; log n) in order to avoid size sensitivity when used as a raw measure. Given the relevance of size sensitivity when applied on a potentially variable (in size, understood as number of cases) distribution, the approach proposed by the above mentioned authors has been used here with a modification.

Instead of the maximum number of citing journals as the basis for H_{max} calculation proposed by the aforementioned authors, the 'n' in the $H_{max} = \log n$ formulation is in this work the empirical maximum number of different combinations of subject categories in each distribution (SSCI citing, SSCI cited, SCI citing and SCI cited). The reason for this modification is that if the n in the log n formula equals the number of potentially citing journals, the maximum entropy would be applicable only to those journals classified in a single discipline: the citing or cited unit in this work is not the journal, but each unique combination of disciplines and this implies that n (≥ 1) journals can show the same combination of classifications. Together with the constrains to the application of the H_{max} calculation as proposed in the previous work to the counting procedure used in this work, the empirical maximum entropy taking as n the empirical maximum of each discipline is also a normalization source (in the indicator, as will be detailed in the following paragraphs, the denominator is a percentage of H_{max}, thus setting its maximum value for each distribution in 100).

The entropy associated to a frequency distribution can be formulated as follows:

$$H = -\sum_{i=1}^{n} p_i \ln (p_i)$$

where $p_i = \frac{x_i}{X}$ and $X = \sum_{i=1}^{n} x_i$.

H increases both with diversity of SC's in the external citations and with the evenness of the distribution. For a given journal, the frequency distribution of citations (*from* or *to* that unit) has associated entropy. The interpretation in terms of information could be exemplified as follows: if a journal is cited only from journals belonging to one single SC in the classification system used, the uncertainty in that distribution is minimum as it is its associated entropy (Leydesdorff and Rafols 2011). Changes in both, the number of SC's from which the citations come from, and unevenness in the frequency distribution would increase the uncertainty in the distribution up to a maximum as well as the entropy associated.

Considering only the sources of the external citations, the entropy associated to the citation frequency distribution among SC's would:

- [**statement 1**] increase when more SC's are added into the formula (a bigger "raw diversity"), and
- [**statement 2**] decrease with the unevenness of that distribution.

Both properties reflect the degree of interdisciplinarity: this affirmation is maybe clearer for **[1]** than for **[2]**. It seems understandable that the more diversity in the SC of the sources

of external citations involves greater "multi"-disciplinarity (supposing a comparative situation in which the percentage of internal citations is the same for both units) (Table 1).

In the case of **[2]**, any degree of unevenness in the distribution involves a stronger citation pattern between the studied unit and certain specific disciplines rather than with others. *Ceteris paribus*, if journal A has the same frequency of external citations along SC's, while B's frequency distribution of citations along SC's is strongly uneven, B could be considered more disciplinary, since it is more strongly related to *fewer* SC's than A (Table 3).

Indicator formulation Taking into account that it is assumed that internal citations are proportional to disciplinarity and that the percentage of the maximum entropy is a measure of interdisciplinarity, the indicator proposed in this work has the following formulation:

$$\text{Entropy-Based Disciplinarity Indicator: EBDI} = \frac{\%\text{IC}}{\%H_{\text{MAX(EC)}+1}}$$

$\%IC$ is the percentage of citations from or to journals classified at least in the same subject category as the unit on which the indicator is being calculated (percentage of internal citations).

$\%H_{\text{MAX(EC)}+1}$ is the percentage of the maximum entropy of the external citations.

Indicator interpretation As pointed out in the introductory section, the condition of 'specialized' of a journal when it has been classified in a discipline is the expectable feature in an ideal classification system, being 'interdisciplinary' a possibility for which the indicator has to provide evidence. For this reason, the scale (0 indicates extreme disciplinarity and 100 indicates extreme interdisciplinarity) points zero as the expectable condition. Nevertheless, since the disciplinarity and interdisciplinarity are considered opposite in this work, the inversion of the numerator and denominator in the indicator would produce the same results in the taxonomy, provided that the interpretation of the levels of interdisciplinarity are reversed consequently.

If all citations are internal, the indicator value is equal to the percentage of internal citations and its value is 100, indicating extreme disciplinarity.

In the case of references from the journal under study to other journals, it can be deduced that the authors publishing in that journal can find the knowledge base for their research in their own discipline.

Table 3 Interpretation of changes in the frequency distribution of external citations and associated entropy values

Change in frequency distribution of external citation	Change in entropy values	Interpretation
Number of SC's involved (in the diversity of sources)	ΔH	Increase in interdisciplinarity
Unvenness of the distribution of citations among SC'S	$-\Delta H$	Decrease in interdisciplinarity

In the case of citations received by the journal under study, it can be concluded that the journal contents are only relevant to researchers publishing their research within the discipline.

If all citations are external, the indicator would be 0, indicating extreme interdisciplinarity. Therefore, the indicator ranges from 100, indicating extreme monodisciplinarity to 0, indicating extreme interdisciplinarity. The indicator can be applied to the cited and citing dimensions simultaneously. If it is acceptable to affirm that the set of cited works in a paper constitute the scientific basis of that work, that basis can be 'imported' from other disciplines in a variable degree; the same would apply to the citations received by the papers published in a journal belonging to a given discipline, in this case 'exporting' knowledge to other disciplines. The results of the indicator in both dimensions can take aligned or non aligned values which can lead to further interpretation. The interpretation of the combination of high or low levels of disciplinarity in the citing and cited dimensions is interpreted in this work as explained in Table 4. The cutting point for high and low levels considered here is the median of the rank-ordered distribution of Entropy-Based Disciplinarity Indicator (EBDI) values: since the distribution is skewed and there are some values close to the maximum, the mean cannot be considered an appropriate central tendency indicator.

Indicator properties

The reproducibility of an indicator by a wide range of subjects (specialists or not) is a desirable characteristic (Archambault et al. 2009). It guarantees the possibility of exercising criticism and empirical contrast. Certain bibliometric indicators which require the whole network of citations cannot be reproduced without the whole set of citing–cited

Table 4 Taxonomy of studied units' role according to the combination of categorized levels of EBDI

Disciplinarity: citing dimension	Disciplinarity: cited dimension	
	HIGH	LOW
HIGH	The papers published in the journal transform knowledge from its SC into knowledge which is mainly interesting for specialists in its own SC, adding a time differential. Its role might be defined as a **disciplinary core** journal	The journal takes knowledge from its own SC and transforms it into an output which is mainly interesting for researchers publishing in other SCs journals. Its role might be defined as a **knowledge exporting** journal
LOW	The journal imports knowledge from other SCs and transforms it into an output which is mainly interesting for researchers publishing in its discipline. Its role might be defined as a **knowledge importing** journal	The journal research front is not clearly in that SC. It takes knowledge from SCs other than the one in which it is classified and transforms it in an output which is also highly relevant to researchers publishing in journals belonging to other SCs. Its role might be defined as a **thematically peripheral** journal

The taxonomy is based on the degree of disciplinarity as computed with the EBDI indicator in its current formulation, its value being directly proportional to the degree of disciplinarity. An inverse taxonomy would result from the application of a modified EBDI which values would be directly proportional to the level of interdisciplinarity instead

vectors contained in the citation matrix derived from the source database (or at least large pieces of it, which extent is not known a priori) which might be understood as a drawback both for its reproducibility and further uses of the indicator.

The robustness of an indicator has several definitions and approaches (Archambault et al. 2009, Op. Cit.) but as a common core of their content, a low sensitivity to outliers is related to robustness and vice versa. The use of percentages in the numerator and the denominator is the basis for the robustness of this indicator, since any extreme value would affect the indicator in a limited and proportional amount. Apart from this, since there are no factors in the indicator (there are, nevertheless, in the Entropy formulation), the multiplicative risk of overweighting outliers is not directly involved in its calculation.

The validity of the indicator is tested in this article, by comparing it with the co-classification pattern identified among the journals classified as disciplinary or interdisciplinary by the indicator.

Concerning consistency, an indicator is consistent, specifically when it is a bibliometric indicator of total performance and according to Waltmann et al. (2011), *if adding the same publication to two different sets of publications never changes the way in which the indicator ranks the sets of publications relative to each other.*

Regarding Waltman et al.'s definition when applied to the indicator developed here, if EBDI takes the general form $\text{EBDI} = a/b + 1$, being a and b positive natural numbers, then

[1] $a/(b + 1) > (a + n)/(b + 1) \leftrightarrow n < 0$.

Where n is a percentage of internal citations and cannot take negative values. If n' is the result of adding a natural positive number and the value of the indicator resulting from this operation is denominated EBDI′, then:

[2] $n > 0$: $n < n'!$ $\text{EBDI}' > \text{EBDI}$ (QED)

Therefore EBDI′ cannot occupy a position smaller than EBDI in a decreasing ranking.

According to Rousseau and Leydesdorff (2011), a bibliometric indicator is consistent if the rank of two sets, not necessarily with the same number of elements, does not vary when items with 0 values are introduced. In the case of Rousseau and Leydesdorff definition, two sets ordered according to EBDI values, would not imply changes in their rank when 0 values are included.

Validation

A first informal validation of the indicator will consist on finding possible clues in the titles of the journals classified as disciplinary or interdisciplinary consistent with the assumption that journals with the name of the field in which they are classified are possibly more central to the field than journals in which the name of the field is not found.

Assuming that co-classification of journals in subject categories is directly related to their disciplinary of interdisciplinary scope (Morillo et al. 2003) and assuming, as well, that the indicator captures a measure of the disciplinarity–interdisciplinarity of a journal in terms of citation patterns (from and to the journal), an association should be observed between both variables. Hence, the proportion of co-classified journals in the set of journals labeled as 'interdisciplinary' by EBDI should be significantly higher than the proportion of co-classified journals in the set of journals labeled as 'disciplinary' by the indicator. For the purpose of validating the indicator, and given the nature of the variables involved (dichotomous in both cases, either disciplinary or interdisciplinary and co-

classified or classified only in Library and Information Science) Chi square tests for independence will be carried out. The results are intended to serve as concurrent validation of the indicator.

Results

The results of the application of EBDI to the set of journals studied are plotted in the tables in "Appendix" section. The citing and cited dimension threshold which determines "high" or "low" levels of disciplinarity in the rank ordered EBDI distribution for each dimension, cited or citing is the median.

General results In Annex I the indicator calculated for fields belonging to the Social Sciences and the Sciences can be found in two separate tables (applied to LIS journals). The journals are ordered according to the value of the values of EBDI in the citation dimension. The most specialized journals appear at the top. In the adjacent column, the values of EBDI for the references dimension are plotted.

Some specific cases of disciplinary and interdisciplinary journals belonging to LIS subject category are included in the validation section in order to facilitate an assessment of the coherence of the results for that discipline. The distributions for Andrology and Legal Medicine are smaller and the results of the classification are included in the validation section.

Validation of the indicator

Library and Information Science journals As can be observed in the tables ("Appendix" section), most of the titles of the journals classified as disciplinary contain nouns within the semantic field of Library and Information Science such as Library, which occurs in 57% of the cases among journals labeled 'Disciplinary' by the taxonomy and in none of the cases labeled 'Interdisciplinary' by the taxonomy (in which the more generic term 'information' occurs in 60% of the titles).

There is also concurrent evidence when co-classification is considered (co-classification of the journals analyzed is reported in the "Appendix" section). Taking as null hypothesis the independence between the classification as 'Disciplinary' or 'Interdisciplinary' and the existence or not of co-classification of the journals in each set among fields other than LIS, there is sufficient evidence to reject the null hypothesis since χ^2 (1, $N = 52$) = 9.369, $p = 0.002$; $p = 0.003$ for Fisher's exact test.

Table 5 Observed and expected counts of co-classified and no co-classified journals for journals classified as disciplinary or interdisciplinary by the taxonomy

Library and Information Science

	No co-classified	Co-classified
Disciplinary		
Count	14	13
Expected count	8.8	18.2
Intertidisciplinary		
Count	3	22
Expected count	8.2	16.8

The direction of the non independent relation between EBDI taxonomy and co-classification can be exemplified by the following case (see Table 5): among the most interdisciplinary journals, there are 17 indexed only in Library Information Science, while 8 would be expected in the case of non association between the two variables.

Some cases of disciplinary journals in LIS

In order to analyze some of the cases which might be representative of the two extreme values of the indicator, in the following tables, cases of highly specialized and highly interdisciplinary journals in the field of Library and Information Science are detailed. The journals in the table below (Table 6) can be considered disciplinary/specialized in LIS since, according to the median of the disciplinarity indicator, they are above that threshold both in the citations and references (the journals selected are those which sum of EBDI values in the citations and references dimensions is the higher in the distribution).

Some cases of highly interdisciplinary journals in LIS

The journals in the table below (Table 7) can be considered interdisciplinary (respect LIS) since, according to the median of the disciplinarity indicator, they are below that threshold both in the citations and the references (the journals selected are those which sum of EBDI values in the citations and references dimensions is the lower in the distribution).

Andrology journals

Although the sample is too small for obtaining valid results from the application of the Chi square test (even Fisher's exact test might be too conservative for such a small sample), it can be observed how all journals classified as specialized by the taxonomy and indicator are classified only in Andrology, whereas the two journals classified by the taxonomy as interdisciplinary are classified also in fields other than Andrology. No exporter or importer journals were identified. This will be developed in the discussion section (Table 8).

Legal Medicine journals

The classification of journals according to the value of the median of the distribution (1 if equal of over the median and 0 if below the median value for each dimension) results in a

Table 6 Examples of disciplinary journals (SSCI)

Full title	EBDI SSCI citations	EBDI SSCI references
Interlending & Document Supply	5.02	100
Library Journal	4.51	94.73
Investigacion Bibliotecológica	89.97	1.42
Library And Information Science	3.78	71.42
Learned Publishing	2.01	63.06
African Journal Of Library Archives And Informatio…	62.89	1.88
Australian Library Journal	56.25	1.58

Table 7 Examples of interdisciplinary journals (SSCI)

Full title	EBDI SSCI citations	EBDI SSCI references
Data Base For Advances In Information Systems	0.48	0.34
Journal Of Information Science	0.25	0.42
Journal Of Health Communication	0.56	0.07
Social Science Information Sur Les Sciences Social…	0.4	0.16
Information Technology & People	0.03	0.51
Social Science Computer Review	0.21	0.2
International Journal Of Computer-Supported Collab…	0.37	0.01

Table 8 EBDI value, taxonomy classification and co-classification of Andrology journals

Journal	EBDI citing	EBDI cited	Taxonomy	Co-classified
ANDROLOGÍA	0.12	0.52	SPECIALIZED	NO
ANDROLOGY	0.10	0.44	SPECIALIZED	NO
ASIAN JOURNAL OF ANDROLOGY	0.08	0.25	INTERDISCIPLINARY	YES
REVISTA INTERNACIONAL DE ANDROLOGÍA	0.45	2.01	SPECIALIZED	NO
SYSTEMS BIOLOGY IN REPRODUCTIVE MEDICINE	0.05	0.23	INTERDISCIPLINARY	YES

taxonomy in which, for this particular distribution, the four types of journals are represented (Table 9).

As in the case of Library and Information journals, there is sufficient evidence to reject the null hypothesis of independence between the co-classification pattern and the results of the taxonomy produced by the application of the indicator since χ^2 $(1, N = 11) = 7.543$, $p = 0.006$; $p = 0.015$ for Fisher's exact test. Also, the frequency of the presence of the term 'Legal Medicine' among the journals classified as disciplinary is slightly higher than in the case of journals classified as interdisciplinary, although is just an adjacent observation (Table 10).

Discussion

The indicator is easily reproducible in terms of straightforward calculation and also concerning the absence of the need of the whole citation matrix for the analysis of a given set of journals. Its robustness has been tested against a operative definition specifically designed for bibliometric indicators with satisfactory results. Finally, some evidence concerning its validity has been found. Nevertheless, the application of the indicator to sets of journals with very different profiles (epistemologically speaking, and also regarding the

Table 9 EBDI value, taxonomy classification and co-classification of Legal Medicine journals

Journal	EBDI cited	EBDI citing	Co-classified	Taxonomy
FORENSIC SCIENCE INTERNATIONAL	1.32	1.56	NO	SPECIALIZED
INTERNATIONAL JOURNAL OF LEGAL MEDICINE	1.35	1.42	NO	SPECIALIZED
JOURNAL OF FORENSIC AND LEGAL MEDICINE	1.67	1.27	NO	SPECIALIZED
JOURNAL OF FORENSIC SCIENCES	0.94	0.97	NO	INTERDISCIPLINARY
AUSTRALIAN JOURNAL OF FORENSIC SCIENCES	1.92	0.89	NO	KNOWLEDGE IMPORTER
ROMANIAN JOURNAL OF LEGAL MEDICINE	1.47	1.63	NO	SPECIALIZED
LEGAL MEDICINE	1.19	1.21	NO	KNOWLEDGE EXPORTER
MEDICINE SCIENCE AND THE LAW	1.43	1.86	NO	SPECIALIZED
RECHTSMEDIZIN	2.60	1.35	NO	SPECIALIZED
JOURNAL OF LAW MEDICINE & ETHICS	0.50	0.56	YES	INTERDISCIPLINARY
REGULATORY TOXICOLOGY AND PHARMACOLOGY	0.28	0.28	YES	INTERDISCIPLINARY
AMERICAN JOURNAL OF FORENSIC MEDICINE AND PATHOLOGY	0.97	1.15	YES	KNOWLEDGE IMPORTER
FORENSIC SCIENCE MEDICINE AND PATHOLOGY	1.12	0.53	YES	INTERDISCIPLINARY
FORENSICE SCIENCE INTERNATIONAL-GENETICS	1.11	1.56	YES	KNOWLEDGE IMPORTER
SCIENCE AND JUSTICE	1.07	0.98	YES	INTERDISCIPLINARY

Table 10 Observed and expected counts of co-classified and no co-classified journals for journals classified as disciplinary or interdisciplinary by the taxonomy

	No co-classified	Co-classified
Disciplinary		
Count	6	0
Expected Count	3.82	2.18
Intertidisciplinary		
Count	1	4
Expected Count	3.18	1.82

Legal Medicine

number of items) has revealed some limitations and shortcomings of the indicator and the taxonomy.

Limitations and shortcomings

The implementation of the indicators has shown some extreme values in both dimensions which can significantly affect the cutting points; the median was used here, but the suitability of the cutting point to the specific parameters of the distribution (which has a strong

effect on its interpretation) might be subject to discussion. The initial choice of this cutting point is related to its usefulness as a central tendency measure in non-normal distributions: normal distributions are uncommon in citation distributions but empirical evidence for this case might shed light into the suitability of this or other cutting points. The indicator has meaning only in comparison with other journals in the field; nevertheless it keeps the advantage of being a vector-based indicator, thus making it unnecessary to count with a citation network. As observed in the field of Andrology, chosen by the limited number of journals, in such cases the indicator seems to show a tendency towards extreme values, either classifying journals as interdisciplinary or disciplinary; this might be related to the above mentioned cutting point chosen for the classification, although the polarization of journals in small samples might simply be the result of less diversity in the profiles of the journals. Concerning the validation procedures, in the case of LIS journals the results seem to be coherent with the experience as user and the co-classification patterns are not independent from the indicator, but further research would be needed in order to cross-validate the indicator.

Possible applications and further research

The classification of journals in subject categories remains a persistent problem all along the different systems. Citations from or to a journal have been used for decades as a basis, jointly with other variables, as reliable evidence towards a satisfying classification. The taxonomy here proposed, particularly in the case of low values of disciplinarity in cited and citing dimensions might be helpful as a possible evidence of weak thematic relationship to the SC in which the journal has been classified, thus possibly contributing to a more depurated classification system/procedure. In the opposite side of the spectrum, journals with high levels of disciplinarity in the two dimensions might be considered as a "reference point" from which distance measures could be taken in order to set what can be considered the core of journals in a discipline. The implementation of entropy-based disciplinarity indicators in networks might also be a possible approach when the whole matrix of co-citations is to be characterized or studied. Finally, the taxonomy of cited-citing disciplinarity and the associated roles might be an interesting segmentation variable for identifying specific needs of geographically, thematically or institutionally defined 'journal populations' and their consumers, as well as for the commercial fulfillment of those needs; i.e. 'knowledge importer' journals consumers or authors might find more attractive more variety in the thematic diversity of the journal packages commercially available than those publishing in 'knowledge exporter' journals, while the latter might find more useful to count with a 'thematic core' set of subscripted journals. The applicability of the indicator at levels other than journal needs cannot be directly extrapolated and would need further research.

Conclusions

The use of easily available data in a straight-forward computation indicator such as EBDI might be considered a desirable property. When applied to journals in the Information Science and Library Science SC in JCR, the classification in four possible combinations of the indicator yields a granular taxonomy with variable but not extreme number of cases in each category. The theoretical consistency of the indicator has been prove and the

application of the indicator to a well known set of journals has resulted in a taxonomy which allows the categorization of journals according to their profile regarding their behavior in the cited and the citing dimensions. The results of the application of the indicator are fully reproducible and might be useful for the characterization of sets of journals according to the various profiles they can fit in. The indicator might also be useful in order to study of the scientific production of units of study others than scholarly journals. As further research, it remains unknown up to which point the indicator can be suitable for the classification of other units subject to citation and reference such as individual articles, authors or research units. Finally, the indicator might be useful for the segmentation of the population conformed by database and subscription consumers of journals according to their potentially differential interests (in example, by classifying the output of a research unit as disciplinary in a field, specific sets of journals could be identified as matching the specific interests of that unit as a potential customer).

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Appendix: Classification of individual titles in Library and Information Science (regarding Social Sciences fields and Sciences fields separately)

Classification of journals in LIS (2013) according to their role as knowledge importers or exporters regarding SSCI classified journals (EBDI SSCI Citations received median = 1.16; EBDI SSCI references median = 0.7).

Full title	EBDI SSCI citations received	EBDI SSCI references	Category
Investigacion Bibliotecologica	89.97	1.42	DISCIPLINARY. LIS.
African Journal Of Library Archives And Informatio…	62.89	1.88	DISCIPLINARY. LIS.
Australian Library Journal	56.25	1.58	DISCIPLINARY. LIS.
Transinformacao	50	1.95	DISCIPLINARY. LIS.
Journal Of Librarianship And Information Science	39.45	1.75	DISCIPLINARY. LIS.
Interlending & Document Supply	5.02	100	DISCIPLINARY. LIS.
Library Quarterly	4.73	4.85	DISCIPLINARY. LIS.
Library Journal	4.51	94.73	DISCIPLINARY. LIS.
Library Collections Acquisitions & Technical Servi…	4.03	2.66	DISCIPLINARY. LIS.
Library And Information Science	3.78	71.42	DISCIPLINARY. LIS.
Portal-Libraries And The Academy	3.58	2.83	DISCIPLINARY. LIS.
Australian Academic & Research Libraries	2.93	1.26	DISCIPLINARY. LIS.

Full title	EBDI SSCI citations received	EBDI SSCI references	Category
Information & Culture	2.82	0.83	DISCIPLINARY. LIS/History of Social Sciences
Library Resources & Technical Services	2.52	3.04	DISCIPLINARY. LIS.
Program-Electronic Library And Information Systems	2.35	0.81	DISCIPLINARY. LIS/Computer Science
Knowledge Management Research & Practice	2.31	0.35	IMPORTER. LIS. Management
Libri	2.18	4.07	DISCIPLINARY. LIS.
Learned Publishing	2.01	63.06	DISCIPLINARY. LIS.
College & Research Libraries	1.92	2.29	DISCIPLINARY. LIS.
Telematics And Informatics	1.92	0.23	IMPORTER. LIS.
Journal Of Knowledge Management	1.91	0.43	IMPORTER. LIS. Management
Library Trends	1.89	1.24	DISCIPLINARY. LIS.
Malaysian Journal Of Library & Information Science	1.89	0.74	DISCIPLINARY. LIS.
Canadian Journal Of Information And Library Scienc…	1.72	0.99	DISCIPLINARY. LIS.
Library & Information Science Research	1.7	0.59	IMPORTER.LIS.
Information Technology For Development	1.6	0.7	IMPORTER. LIS.
Profesional De La Informacion	1.59	0.84	DISCIPLINARY. LIS.
Health Information And Libraries Journal	1.59	0.8	DISCIPLINARY. LIS.
Aslib Proceedings	1.42	0.62	IMPORTER. LIS. Computer Science
Journal Of Organizational And End User Computing	1.34	0.55	IMPORTER- LIS. Computer Science
International Journal Of Information Management	1.34	0.36	IMPORTER. LIS.
Library Hi Tech	1.31	0.86	DISCIPLINARY. LIS.
Informacao & Sociedade-Estudos	1.29	1.17	DISCIPLINARY. LIS.
European Journal Of Information Systems	1.26	0.56	IMPORTER. LIS. Computer Science
Information Technology & Management	1.22	0.35	IMPORTER. LIS. Management
Knowledge Organization	1.2	3.45	DISCIPLINARY. LIS.
Information Society	1.19	0.51	IMPORTER. LIS.
Journal Of Strategic Information Systems	1.17	0.53	IMPORTER. LIS. Computer Science
Information Systems Research	1.16	0.34	DISCIPLINARY. LIS. Management

Full title	EBDI SSCI citations received	EBDI SSCI references	Category
Information And Organization	1.13	0.9	EXPORTER. LIS. Management
Journal Of Global Information Management	1.1	0.58	INTERDISCIPLINARY. LIS.
Online Information Review	1.1	0.38	IMPORTER. LIS. Computer Science
Mis Quarterly Executive	1.09	1.22	EXPORTER. LIS. Computer Science
Revista Espanola De Documentacion Cientifica	1.08	1.28	EXPORTER. LIS.
Electronic Library	1.08	1.01	EXPORTER. LIS.
Information Processing & Management	1.01	0.32	INTERDISCIPLINARY. LIS. Computer Science
International Journal Of Geographical Information…	0.9	0.3	INTERDISCIPLINARY.LIS. Computer Science/Geography, Physical
Information & Management	0.87	0.51	INTERDISCIPLINARY. LIS. Computer Science/ Management
Scientometrics	0.84	0.45	INTERDISCIPLINARY. LIS. Computer Science, Interdisciplinary Applications
Journal Of Informetrics	0.82	0.51	INTERDISCIPLINARY. LIS.
Journal Of Computer-Mediated Communication	0.81	0.4	INTERDISCIPLINARY. LIS. Communication
Telecommunications Policy	0.81	0.49	INTERDISCIPLINARY. LIS. Telecommunications. Communication
Information Systems Journal	0.79	0.83	EXPORTER.LIS. Computer Science
Journal Of Management Information Systems	0.78	0.58	INTERDISCIPLINARY. LIS. Management
Government Information Quarterly	0.77	0.63	INTERDISCIPLINARY.LIS.
Journal Of Information Technology	0.73	0.98	EXPORTER. LIS. Computer Science, Information Systems
Journal Of Documentation	0.73	0.91	EXPORTER. LIS.
Journal Of Scholarly Publishing	0.7	1	EXPORTER. LIS.
Mis Quarterly	0.7	0.53	INTERDISCIPLINARY. LIS. Computer Science Management.
Ethics And Information Technology	0.67	0.52	INTERDISCIPLINARY. LIS. Ethics

Full title	EBDI SSCI citations received	EBDI SSCI references	Category
Journal Of The American Medical Informatics Associ…	0.63	0.3	INTERDISCIPLINARY. LIS. Medical informatics. Health Care Sciences and Services. Computer Science, Interdisciplinary applications. Computer Sciences, Information Sciences
Journal Of The Medical Library Association	0.58	0.97	EXPORTER. LIS.
Information Research-An International Electronic J…	0.56	0.56	INTERDISCIPLINARY. LIS.
Journal Of Health Communication	0.56	0.07	INTERDISCIPLINARY. LIS. Communication
Journal Of The American Society For Information Sc…	0.5	0.41	INTERDISCIPLINARY. LIS. Computer Science, Information Systems
Information Development	0.49	0.63	INTERDISCIPLINARY. LIS.
Serials Review	0.49	2.53	EXPORTER. LIS.
Data Base For Advances In Information Systems	0.48	0.34	INTERDISCIPLINARY. LIS. Computer science, Information systems
Research Evaluation	0.45	0.44	INTERDISCIPLINARY. LIS.
Journal Of Academic Librarianship	0.42	1.12	EXPORTER. LIS.
Social Science Information Sur Les Sciences Social…	0.4	0.16	INTERDISCIPLINARY. LIS. Social Sciences, Interdisciplinary
International Journal Of Computer-Supported Collab…	0.37	0.01	INTERDISCIPLINARY. LIS. Education & Educational Research
Journal Of Global Information Technology Managemen…	0.32	0.71	EXPORTER. LIS.
Journal Of The Association For Information Systems	0.28	0.56	INTERDISCIPLINARY. LIS. Computer Science, Information Systems
Journal Of Information Science	0.25	0.42	INTERDISCIPLINARY. Computer Science, Information Systems
Social Science Computer Review	0.21	0.2	INTERDISCIPLINARY. LIS. Computer Science, interdisciplinary applications
Information Technology & People	0.03	0.51	INTERDISCIPLINARY. LIS.

Classification of journals in LIS (2013) according to their role as knowledge importers or exporters regarding SCI classified journals (EBDI SCI Citations received median = 1.19; EBDI SCI references median = 0.765).

Full title	EBDI SCI citations received	EBDI SCI references	
Investigacion Bibliotecologica	89.97	1.24	DISCIPLINARY
Information & Culture	75.92	0.85	DISCIPLINARY
African Journal Of Library Archives And Informatio…	62.89	2.05	DISCIPLINARY
Portal-Libraries And The Academy	5.89	6.12	DISCIPLINARY
Interlending & Document Supply	5.02	100	DISCIPLINARY
Informacao & Sociedade-Estudos	4.93	2.18	DISCIPLINARY
Australian Library Journal	3.26	2.45	DISCIPLINARY
Library Hi Tech	3.23	0.84	DISCIPLINARY
Library And Information Science	3.07	71.42	DISCIPLINARY
Library Quarterly	2.95	93.75	DISCIPLINARY
Library Resources & Technical Services	2.89	58.82	DISCIPLINARY
Libri	2.81	2.02	DISCIPLINARY
Knowledge Organization	2.5	1.33	DISCIPLINARY
Journal Of Librarianship And Information Science	2.48	2.13	DISCIPLINARY
Aslib Proceedings	2.36	0.72	IMPORTER
Library Trends	2.35	1.62	DISCIPLINARY
Malaysian Journal Of Library & Information Science	2.26	1.37	DISCIPLINARY
Australian Academic & Research Libraries	2.25	1.47	DISCIPLINARY
Telematics And Informatics	2.17	0.25	IMPORTER
Library Collections Acquisitions & Technical Servi…	2.08	86.88	DISCIPLINARY
Library & Information Science Research	1.93	0.84	DISCIPLINARY
Canadian Journal Of Information And Library Scienc…	1.89	1.25	DISCIPLINARY
Library Journal	1.81	94.73	DISCIPLINARY
Ethics And Information Technology	1.79	0.52	IMPORTER
Scientometrics	1.75	0.63	IMPORTER
Telecommunications Policy	1.58	0.87	DISCIPLINARY
Journal Of Informetrics	1.57	0.78	DISCIPLINARY
Journal Of Organizational And End User Computing	1.55	0.65	IMPORTER
Knowledge Management Research & Practice	1.48	0.32	IMPORTER
Learned Publishing	1.45	1.23	DISCIPLINARY
Online Information Review	1.42	0.37	IMPORTER
College & Research Libraries	1.39	1.91	DISCIPLINARY
Research Evaluation	1.36	0.56	IMPORTER

Full title	EBDI SCI citations received	EBDI SCI references	
Profesional De La Informacion	1.34	1.43	DISCIPLINARY
Program-Electronic Library And Information Systems	1.32	0.65	IMPORTER
Information Technology & Management	1.27	0.35	IMPORTER
Journal Of Global Information Management	1.21	0.54	IMPORTER
Information Society	1.19	0.75	
Journal Of Knowledge Management	1.19	0.4	
Journal Of Scholarly Publishing	1.08	1.49	EXPORTER
International Journal Of Information Management	1.06	0.31	INTERDISCIPLINARY
Health Information And Libraries Journal	1	0.57	INTERDISCIPLINARY
Government Information Quarterly	0.96	0.69	INTERDISCIPLINARY
Journal Of Documentation	0.95	1.19	EXPORTER
Electronic Library	0.94	1.05	EXPORTER
Information Processing & Management	0.91	0.35	INTERDISCIPLINARY
Journal Of Strategic Information Systems	0.91	0.6	INTERDISCIPLINARY
European Journal Of Information Systems	0.89	0.54	INTERDISCIPLINARY
Information Research-An International Electronic J…	0.83	0.63	INTERDISCIPLINARY
Information Systems Research	0.83	0.36	INTERDISCIPLINARY
Journal Of Computer-Mediated Communication	0.83	0.45	INTERDISCIPLINARY
Information Development	0.81	0.64	INTERDISCIPLINARY
Revista Espanola De Documentacion Cientifica	0.8	1.47	EXPORTER
Information Technology For Development	0.79	1.04	EXPORTER
Information & Management	0.74	0.5	INTERDISCIPLINARY
Journal Of Information Technology	0.66	0.98	EXPORTER
Information And Organization	0.65	0.98	EXPORTER
Social Science Information Sur Les Sciences Social…	0.65	0.2	INTERDISCIPLINARY
International Journal Of Computer-Supported Collab…	0.64	0.02	INTERDISCIPLINARY
Mis Quarterly Executive	0.62	1.23	EXPORTER
Serials Review	0.62	2.52	EXPORTER
Journal Of The American Society For Information Sc…	0.61	0.5	INTERDISCIPLINARY
Journal Of Academic Librarianship	0.58	1.15	EXPORTER
Journal Of Management Information Systems	0.56	0.55	INTERDISCIPLINARY
Mis Quarterly	0.55	0.53	INTERDISCIPLINARY
Information Systems Journal	0.54	0.83	EXPORTER

Full title	EBDI SCI citations received	EBDI SCI references	
Journal Of Health Communication	0.52	0.06	INTERDISCIPLINARY
Journal Of The American Medical Informatics Associ…	0.49	0.22	INTERDISCIPLINARY
International Journal Of Geographical Information…	0.46	0.15	INTERDISCIPLINARY
Journal Of The Medical Library Association	0.43	0.69	INTERDISCIPLINARY
Data Base For Advances In Information Systems	0.39	0.38	INTERDISCIPLINARY
Social Science Computer Review	0.34	0.3	INTERDISCIPLINARY
Journal Of Information Science	0.32	0.54	INTERDISCIPLINARY
Journal Of Global Information Technology Managemen…	0.29	0.81	EXPORTER
Journal Of The Association For Information Systems	0.21	0.57	INTERDISCIPLINARY
Information Technology & People	0.03	0.57	INTERDISCIPLINARY

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