Globalization of Science: Evidence from authors in academic journals by country of origin[[1]](#footnote-1)\*

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# Abstract

# The scientific community shares a common sense that by default, science should be globally oriented. This study measures the tendency to publish in globalized journals on a large dataset of journals indexed in the Scopus database. Based on data on 34 964 journals indexed in the Scopus Source List (Scopus 2018), we derived eight globalization indicators. These were subsequently scaled-up to the level of 174 countries and 27 disciplines between 2005 and 2017. The methodology draws from the pioneering work of Zitt and Bassecoulard (1998; 1999). The paper is accompanied by the interactive publication available at <http://www.globalizationofscience.com>

# Advanced countries tend to have high globalization that is not varying across disciplines. Social sciences are similarly globalized as life sciences. The globalization in the former Soviet bloc is lower, especially in social sciences or health sciences. China has profoundly globalized its science system; gradually moving from the lowest globalization rates to the world average. Contrary Russia was constantly among the least globalized during the whole period, with no upward trend.

# Introduction

The scientific community shares a common sense that by default, science should be globally oriented. Academic researchers present their results to their peers across the world to move the research frontiers beyond the existing boundaries. Doing so, they publish in journals contributed by researchers from the whole world.

This paper measures the globalization of science from the perspective of academic journals. On the most general level, the study asks whether researchers publish in journals presenting scientific results to the widest possible audience. The global dimension of the audience is stressed (therefore globalization), but also alternative specifications based on language and institutional concentration are added.

We explore the heterogeneity of globalization of science across countries and disciplines and in time. While the heterogeneity between disciplines can result naturally from different publication patterns of researchers, the cross-country heterogeneity within the same discipline points towards the research evaluation in the country and the research culture in a broader context. Systemic isolation of the country research output is indicative of the incentives provided by the evaluation system. Researchers in such country seem to lack sufficient motivation to publish in globalized journals. The development in time yields important information about the transformation of research in the country.

In Western Europe and North America, research has undergone a dramatic transition from the national to the transnational model of publications already in the 1980s and the beginning of the 1990s (Zitt et al. 1998). Thirty years later, the national journals still play an important role in the countries from the former Soviet bloc (see Moed 2018, Kirchik and Gingras 2012 or Figure 1).

This work follows Zitt and Bassecoulard (1998 and 1999), but since then any systematic evidence is missing. Still, the global research landscape changes. The world research production grows in the traditional research countries, but new research capacities are built from the ground up in the developing countries. The globalization of science adds an important insight into the transformation of research across the world.

Based on data on 34 964 journals indexed in the Scopus Source List (Scopus 2018), we derived 8 globalization indicators. These were subsequently scaled-up to the level of 174 countries and 27 disciplines between 2005 and 2017. The methodology allows for comparability between countries, disciplines, and in time. The main goal of the paper is to identify the most important global trends, but results allow for using the data with much higher granularity.

Globalization of science should not be confused with its quality (or relevance); they are likely to be related in many ways, depending on the discipline, but they are different phenomena.

In the first section, the existing literature is summarized. The second section describes data collection; the third describes the methodology and some of its limitations and the fourth results. The last section concludes. The paper is accompanied by an already released interactive study available at <http://www.globalizationofscience.com> (Macháček and Srholec 2019). Readers can spend their time with the interactive application, as it offers an intuitive way of exploring the results of this paper.

# Globalization of science

The global research system grows both in terms of size (Royal Society 2011), and interconnectedness. New countries incorporate their research into global knowledge flows (Gazni, Sugimoto, Didegah 2012; Wagner et al. 2015). The international collaboration drives the growth of the research output (Adams 2013). Developing countries invest heavily to improve its research infrastructure (Royal Society 2011) and international visibility (Zhou and Glanzel 2010).

The globalization of science (from now on just globalization) contains a piece of useful information about this transformation process. The researchers in the country and discipline with high globalization publish their work in journals operating worldwide. On the contrary, when globalization is low, local researchers rely on journals that significantly deviate from the world distribution of journals. These journals are relevant for only a small group of local researchers.

We perceive globalization in terms of journals. The academic journals are an essential platform for scientific knowledge dissemination. They allow scientists across the world to keep up-to-date with the latest discoveries and to present their results to the global audience. The naïve intuition suggests that the *globalized* journals are likely to be better serving their dissemination goal than journals operating in only a handful of countries (Buela-Casal et al. 2006).

Buela-Casal et al. (2006) warn against certain ambiguity connected with the term internationality. The definition is key to determine journal internationality. The journal can be considered international when contributed by researchers from more than one country or all countries in the world. Another definition considered journal international if its editorial board is international. The journal can be considered international if it publishes in English or even when it has a word “*international”* included in its name. It is also possible to analyze the internationality of citations of the journal. All these definitions often lead to different rankings of journal internationality. It is always necessary to clarify what is meant by internationality.

This key issue is tackled twofold: a) we analyze journals exclusively from the perspective of authors b) the possible ambiguity of results is overcame by employing a variety of indicators. The indicators emphasize country distribution but are also supplemented with indicators based on language and institutional concentration of authors. We refer to the globalization of science to emphasize the global reach of journals that is inherently present in half indicators.

After the fall of the Berlin Wall, the formerly separated research systems on both sides of the iron curtain started to merge. Simultaneously, the transition from the national to the international model of publication was happening at least on the western side of the curtain. The *transnational* English-written journals almost entirely replaced the *national* journals as a major publication platform (Zitt et al. 1998).

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| **Figure 1: Share of research output flowing into domestic journals in Europe in 2015-2017** |
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| *Note: domestic journals defined as journals with at least 33% authors from the same country as the publisher of the journal. Only articles, reviews, and conference papers are included. Publisher country from Scopus Source List is used to identify the domicile of the journal**Source: own calculation, Scopus; Scopus Source List* |

More than 25 years later a similar transition is still not finished in former Soviet bloc. Figure 1 shows that domestic journals are much more prevalent in these countries. For this figure, we define domestic journal as one having more than a third of authors from the same country as a publisher. More than 30 % of Russian research is published in Russian domestic journals. On the contrary, the same figure is around 1 % in Finland, Sweden or Austria. However, the still important role of national journals is not systematically addressed in the literature.

Domestic journals were originally published in national languages. However, they often adjust to the transforming environment by translating their content into English while keeping their author-base local (Kirchik and Gingras 2012, Moed 2018). Language of publication is not necessarily a good indication of the journal’s globalization. Nevertheless, one indicator based on language is included in the paper.

Many journals operate worldwide and forcing a single-country domicile can be too strict. The concept of domestic journals outlined above also does not take into account the size of the research sector in the country. The composition of the editorial board can be a useful measure of journal internationality, but its data availability is limited. Moreover, it is easier to fake than the authors contributing to the journal. The journal's authors provide a direct measure of the journal globalization that is both available and relatively reliable.

The globalization is informative about the incentives provided by the research evaluation system in the country and the power relations in the local research system. Incentives influence researchers’ decision on where to publish (Franzoni et al. 2011). The decision where to submit a paper is a key stage of the research-production process, which involves a highly strategic behavior of the researcher (see Heintzelman and Nocetti, 2009) His decision is linked to the strength of the “adverse mechanisms” - persistent proximity networks hindering the internationalization process (Zitt and Bassecoulard 2004). The local ties between researchers, institutions, research managers, and policy-makers can diverge the knowledge flows from international, to more local paths.

To our knowledge, the only paper providing analyzing globalization in countries is Zitt and Bassecoulard (1999). Based on journal-level indicators suggested in their previous paper (1998), they analyzed countries and discipline according to their internationalization. They acknowledge a “general trend towards internationalization,” with some exceptions such as Russia. Since then, any systematic evidence is missing.

**Data**

The analysis is based on Scopus data. Scopus indexes approximately twice more journals than its main competitor, Web of Science (Mongeon and Paul-Hus 2016). It is more likely to contain the more localized part of the scientific output in the country.

The data for all 34 964 journals indexed in the Scopus Source List (Scopus 2018) were downloaded using Scopus API in August 2018. For each journal in each year between 2005 – 2017, we downloaded the country and institutional distribution of authors and the distribution of languages. Data were limited to articles, reviews, and conference papers.

The Scopus Search API was requested with the following query:

*ISSN(AAAA-BBBB) AND DOCTYPE(AR OR RE OR CP) AND PUBYEAR = YYYY*

in which AAAA-BBBB is the journal's ISSN and YYYY is the year. Rather than publication-level data, the aggregate distribution is collected. For each journal in each year, we collect the number of articles affiliated to each country, language, and institution.

Scopus Source List also contains Scopus Journal Classification (see Scopus 2019) used to assign journals to disciplines. Both more narrow classification (*Major Subject Classification;* referred to as *narrow disciplines*) and broad classification on 4 disciplines (*Broad Subject Clusters*) is used, supplemented by all-encompassing discipline *All* (*broad disciplines*).

Approximately 5 % of publications affiliated to the *undefined* country were excluded from the analysis. Undefined publications were also subtracted from the total number of publications in the journal. The data for Russia and the Russian Federation and Yugoslavia and Serbia were merged.

**Globalization Indicators**

The paper proposes eight *globalization indicators* assessing each country and discipline’s globalization for each year. The two-step methodology builds on the pioneering work of Zitt and Bassecoulard (1998) and (1999). First, we calculate the globalization indicators for each academic journal indexed in the Scopus Source List in each year. Subsequently, the journal-level indicators are scaled up to the level of countries and disciplines.

*Journal-level Indicators*

The indicators evaluate each journal using a relatively simple metric. The variety of indicators increase the robustness of results. For most indicators, the main idea is that most globalized journals have a structure that closely resembles the global structure of the whole discipline. The likelihood to be published should not be affected by the origin of the researcher. The distribution of authors should correspond to the distribution of their respective disciplines.

The indicators of globalization vary in terms of input data (see Table 1). Half of the indicators take into account the whole distribution of the underlying data. Two indicators analyze only the three most important contributors in the journal. Two indicators are a simple share of documents fulfilling some condition. Six indicators analyze the country data. One employ language and one institutional data.

Half indicators compare the country distribution of authors to the distribution common in the discipline. The benchmark distribution is always calculated from all available periods so that the development in time takes into account the world trend. The rest does not consider discipline publication patterns.

, and are the number of documents with authors affiliated to the country *c* or institution *i,* in journal *j* or discipline *d*, in year *y*.

is the number of documents with authors from the same country as the publisher of journal *j* in the year *y*. is the number of English-written documents in the journal *j* in year *y*.

denotes the total number of documents in the journal *j* in year *y*. Note that documents by authors from multiple countries are fully attributed to each country, i.e. .

The vectors and represent the country distribution of authors of the journal and the discipline , in which and . While is calculated separately in each year *y*, relates to the whole period.

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| **Table 1: Globalization Indicators** | | |  |  |  |
| *Indicator* | *Formula* | *Data* | *Bench.* | *Dist.* | *Source* |
| Euclidian distance (*euclid)* |  | Country | Yes | Full | Zitt and Bassecoulard (1998) |
| Cosine distance  (*cosine*) |  | Country | Yes | Full | Zitt and Bassecoulard (1998) |
| GiniSimpson Index (*GiniSimpson)* |  | Country | No | Full | Aman (2016) |
| Weighted Gini  (*wGini*) |  | Country | Yes | Full | -- |
| Largest Contributors Surplus (*top3*) |  | Country | Yes | Partial | -- |
| Institutional Diversity  (*instTOP3*) |  | Institutional | No | Partial | -- |
| English Documents  (*sEnglish*) |  | Language | No | Share | Buela-Casal et al (2006) |
| Local Authors  (*localShare)* |  | Country | No | Share | Zitt and Bassecoulard (1998) |

## Aggregation

In the second stage, the journal-level indicators were aggregated to the level of countries and disciplines. The result is a weighted average of individual journals scaled between 0 and 1, where 0 is the lowest globalization across all years, countries and disciplines within the particular indicator and 1 is the highest.

To increase robustness and decrease volatility, the aggregation was only performed when the authors from the country published in at least 30 journals. This leads to gaps in results, particularly in the small disciplines and small countries.

The globalization of science in country , discipline and year expressed by an indicator is calculated as follows:

is the share of documents with authors from country *c* in journal on all documents from the country , discipline in year , is the globalization indicator *i* of journal in the discipline *d* and year *y*.

Subsequently, the aggregated globalization index was standardized between 0 and 1 and converted to an ascending scale to simplify the interpretation of the results:

in which and is minimum and maximum value of the indicator *i* across all years, countries and disciplines and equals -1 for the minimizing indicators (low values for high globalization) and 1 otherwise.

It is possible to compare globalizations between countries, discipline, and in time. However, the meaningful comparison between indicators is not possible due to the large heterogeneity of underlying distributions. The same value from two indicators cannot be interpreted as corresponding levels of globalization.

## Limitations

The major drawback of the methodology is the representativeness of the underlying data. We refer to the *Globalization of Science*, but it might be more convenient to refer to the *Globalization of Science In Journals Then Indexed By Scopus*. Scopus indexes the research output across units unevenly. Some units are underrepresented in the dataset. The representativeness issue is present in all major dimensions – countries, disciplines, and in time.

It is well possible that Scopus contains a larger part of the content published in the Netherlands than that from India or other developing countries. We are not aware of any study analyzing major databases representativeness across countries. However, it is reasonable to assume that the Scopus database contains the more globalized part of the scientific production within a country. Therefore, the results show the upper bound of globalization of the possibly underrepresented countries.

As the publication behavior varies across disciplines, we use data for all three major document types in the journal articles – articles, reviews, and conference papers. However, publications outside of academic journals are neglected. In this sense, the representativeness can seriously impact the interpretation of disciplines strongly relying on other modes of publications, such as Arts and Humanities.

The results are sensitive to Scopus editorial decisions on indexing of titles. Large year-by-year jumps are not necessarily caused by fundamental changes of the researchers’ behavior but are mostly driven by adding (or removing) journals in Scopus. For example, in 2007, Scopus indexed 184 documents from Romania in Social Sciences. One year later, this figure almost tripled to 471, while the globalization decreased from 0.5 to 0.2. This development is driven by a sudden indexation of several Romanian journals[[2]](#footnote-2) that publish mainly Romanian researchers. Short-term changes have to be interpreted with caution.

The disciplines are still relatively broadly defined. Each discipline can contain many diverse research topics with varying publishing patterns. If these are strongly antagonistic, the aggregate globalization can be distorted.

Globalization can be conflicted with the quality of the research. The strong concentration of high-quality research in only a handful of countries under certain conditions leads to lower globalization just because doing quality research. However, the countries where research is commonly considered as a high quality usually have high globalization. The impact of this issue on results is very limited.

**Results**

The reported results are normalized relative to all observations within a single indicator. and 1 always refer to the least and most globalized country, discipline and the period within all results available within a single indicator. The methodology allows for any comparison within an indicator. However, the comparison between indicators is not possible as the journal-level indicators distributions vary.

After excluding all dependent territories except Hong Kong, the computation algorithm yielded results for 174 countries. The minimum requirement on the number of journals to calculate results lead to gaps in the data. Naturally, the broader the discipline definition and the larger the research production, the more countries are available. In 2017, the data were available for 171 countries in the discipline *All,* but for most of the narrow disciplines, the results are calculated for less than 100 countries. The results availability also grows in time together with output indexed in Scopus.

The results are robust to varying indicators. The correlation coefficients reported in table 2 are generally high. 25 out of 28 coefficients exceed 0.5, and a half coefficients are higher than 0.7. Also, visual check in the interactive application shows that most globalization paths in time and relative rankings are similar across indicators.

The most in-between indicator is Euclidian distance with a correlation coefficient higher than 0.75 in 8 out of 9 indicators. Therefore Euclidian distance is used as a main indicator of globalization. By default, we refer to it when not stated otherwise.

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| **Table 2: Full-Sample Correlation Matrix of Indicators** | | | | | | | |
| *Indicator* | *euclid* | *cosine* | *GiniSimpson* | *wGini* | *top3* | *instTOP3* | *sEnglish* | | *localShare* |
| *euclid* | 1.00 | .83 | .87 | .90 | .93 | .81 | .61 | | .75 |
| *cosine* | .83 | 1.00 | .64 | .93 | .75 | .69 | .47 | | .41 |
| *GiniSimpson* | .87 | .64 | 1.00 | .79 | .72 | .67 | .64 | | .78 |
| *wGini* | .90 | .93 | .79 | 1.00 | .86 | .73 | .55 | | .56 |
| *top3* | .93 | .75 | .72 | .86 | 1.00 | .79 | .51 | | .67 |
| *instTOP3* | .81 | .69 | .67 | .73 | .79 | 1.00 | .43 | | .57 |
| *sEnglish* | .61 | .47 | .64 | .55 | .51 | .43 | 1.00 | | .61 |
| *localShare* | .75 | .41 | .78 | .56 | .67 | .57 | .61 | | 1.00 |

*Pearson correlation coefficients of all available data for each indicator; Source: Scopus; own calculation*

In what follows, only the major trends of globalization are summarized. The data are available in much greater detail in the interactive application, where the readers are invited to explore the situation in country, discipline, or period of their interest. The data are also available in Appendix 1.

The results cover the period between 2005 and 2017. When analyzing cross-country differences, the period 2015 – 2017 is considered. The three-year window allows to partially balance the effect of jumps caused by changes in the Scopus indexation.

The narrow disciplines are neglected. The data availability in smaller countries is lower than in broader disciplines, and the identification of general trends makes more sense in the broader context. Generally, the narrow disciplines usually follow similar paths as the broad disciplines. However, the volatility naturally grows with detail.

Countries were assigned to country groups according to their economic status by IMF (2003) classification. The countries are divided into three categories: (a) *Advanced countries* cover the richest countries in the world in the mainly in Western Europe, North America, and Eastern Asia. (b) *Transition countries* consist mainly of the post-soviet countries in Central and Eastern Europe, Central Asia, and Cuba. (c) *Developing countries* – the rest of the World, including China. See Appendix 2 to see exact classification.

The research is most globalized in *advanced countries*, followed by *developing countries* and *transition countries*. Table 3 presents the means and standard deviations of all globalizations within country groups between 2015 and 2017. In all disciplines, the mean is highest in *advanced countries* and the lowest in *transition countries*. The *life sciences* and *physical sciences* are more globalized than *social sciences* and *health sciences*.

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| **Table 3: Means and standard deviations of globalizations within country groups in 2015-2017 measured by Euclidian distance by disciplines (wider definition)** | | | | | |
| Economic status | All | Life | Physical | Social | Health |
| Advanced countries | .75 | .80 | .79 | .75 | .72 |
| (.03) | (.03) | (.03) | (.05) | (.04) |
| Developing countries | .70 | .74 | .75 | .68 | .68 |
| (.06) | (.07) | (.05) | (.10) | (.08) |
| Transition countries | .61 | .68 | .66 | .53 | .58 |
| (.09) | (.10) | (.11) | (.13) | (.13) |
| *Source: own calculation; IMF (2003); Scopus; Standard deviations in brackets.* | | | | | |

The science in *advanced countries* is not only highly globalized but also relatively invariant. The figures are similar in all disciplines, and their standard deviations are low. In all disciplines, research in advanced countries tends to be globalized. Only research in Japan and South Korea is somewhat lower (globalization 0.66 in discipline *All*). In Germany, France, and Spain, the *life sciences* and *physical sciences* are highly globalized (approx. 0.78), but *social sciences* and *health sciences* tend to be below standards (<0.65).

In *transition countries,* the globalization is generally lower in all disciplines. The means vary between 0.53 in Social Sciences, to 0.68 in Life Sciences. The variance is also larger within disciplines. The standard deviations are approximately three times larger than in advanced countries. It is hard to characterize this diverse group. However, there is only one country whose characteristics fits well with the patterns common in advanced countries – Estonia.

In some countries, the globalization is relatively high in *life sciences* and *physical sciences* (>0.7), but significantly lower in *social sciences* and *health sciences* (<0.55). This applies mainly countries from the former Soviet bloc in Europe, such as Czechia, Poland, Slovakia, Slovenia, or Croatia. However, there are also countries who perform badly in most disciplines – Belarus, Ukraine, Kazakhstan, or Russia.

Russia is a prime example of the strongly isolated research system (see Figure 2). In 2017, Russia ranked as the first or second least globalized country in all broad disciplines. Even when extended to the narrow definition of disciplines, Russia is among the last 3 countries in 23 out of 25 disciplines where the data are available.

Where there is a will, there is a way. At the beginning of the analyzed period, in 2005, China was the least globalized country in the world in *All disciplines,* and among the 5 least globalized in all broad disciplines (see Moed 2002). China invests heavily in the modernization of its science infrastructure (Royal Society 2011). Figure 2 shows a rapid transformation of the Chinese system that resulted in the relatively fast growth of globalization. During the analyzed period, the globalization grew fast across all disciplines. In 2017 China was still less globalized than *advanced countries*, but its progress is visible.

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| **Figure 2: Globalization in broad disciplines in China and Russia in time (Euclidian distance)** |
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| *Source: own calculation, Scopus* |

The map on Figure 3 shows that in all BRIICS[[3]](#footnote-3) countries, the globalization is below (or very close to at maximum) average in all broad disciplines in 2017. The long-term growth trend in the past 12 years is only seen in China. In Indonesia, the globalization even slightly decreases in time in all broad disciplines. The path to globalization is far from being guaranteed for the developing countries.

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| **Figure 3: Globalization of science on the world map (2017; Euclidian distance; All disciplines)** |
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| *Source: own calculation; Scopus; the darker the color, the higher globalization* |

**Conclusions**

The paper measured the globalization of science in 174 countries and 31 disciplines between 2005 and 2017. Using the data on articles, reviews and conference papers from journals indexed in the Scopus Source List we developed a two-step methodology that scales the globalization of individual journals up to the level of countries, disciplines and years. Multiple indicators of globalization (based on country data, language data, and institutional data) were constructed to verify the robustness of our findings. The paper is also accompanied by an interactive application available at <http://www.globalizationofscience.com/>.

The transition from national to the transnational mode of communication took place in the 1980s and 1990s in Western countries. A similar transition is still not finished in the countries of the former Soviet bloc. Especially in the Social Sciences and the Health Sciences, the role of non-globalized journals is high. An example of Russia shows that the lack of globalization can be very persistent. An example of China shows that under certain conditions, the widespread integration into a global research publication flows is possible, and it can even be relatively fast.

The granular data on the globalization of science can serve as a good starting point for further exploration for researchers, research managers, policy-makers, and other research evaluation practitioners. These professionals should be asking whether the level of globalization in their context is adequate. However, further research necessary to understand the role of globalized journals in modern science. The relationship between quality and globalization is far from straightforward.

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# Appendix 1 and 2 – Complete results available in CSV files data.csv and countries.csv. The files are available at: [https://github.com/vitekzkytek/GlobalizationPaper/blob/master/appendix/](https://github.com/vitekzkytek/GlobalizationPaper/blob/master/appendix/data.csv)

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2. Namely Amfiteatru Economic Journal, Transylvanian Review of Administrative Sciences, Journal of Economic Computation and Economic Cybernetics Studies and Research etc. [↑](#footnote-ref-2)
3. Brazil, Russia, India, Indonesia, China and South Africa [↑](#footnote-ref-3)