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Innovation Research in Management and STEM for Sustainability in Developing Countries Insights from Bibliometrics in the Global South

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Julián David Cortés-Sánchez*
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Abstract

Research on innovation for sustainability in developing countries (*i. e.,* the Global South: GS) is crucial for the global development agenda. Previous research has contributed to establishing the relationship between sustainability and management and outlining fragmented insights on several research topics and industries. However, little is known on the integrative role of innovation in management and STEM (Science, Technology, Engineering and Mathematics) for sustainability in the GS. Here, we present an exploratory bibliometric outlook on the output, impact, and structure of the research innovation in management and STEM for sustainability in the GS based on a sample of 14,000+ documents indexed in Scopus. China is leading the overall output and impact and is setting the research agenda by its priorities. Research topics in the GS are rather peripherical to the Sustainable Development Goals and South-North collaboration is more frequent than South-South.

Keywords

Innovation, sustainability, management, STEM, global South, developing countries, bibliometrics.

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Resumen

La investigación en innovación para la sostenibilidad en países en vías de desarrollo (*i. e.,* el Sur global: SG) es crucial para la agenda de desarrollo global. Investigaciones previas han contribuido en establecer la relación entre sostenibilidad y administración señalando la desfragmentación entre áreas de investigación e industrias. No obstante, poco se sabe sobre el rol integrativo de la innovación en administración y STEM (*science, technology, engineering and mathematics*) para la sostenibilidad en el SG. Este estudio presenta un estudio bibliométrico exploratorio sobre la producción, impacto y estructura de la investigación en innovación y administración y STEM para la sostenibilidad en el SG con base en una muestra de más de 14,000 documentos indexados en Scopus. China es el líder en producción e impacto, además de establecer la agenda de investigación según sus prioridades. Las áreas de investigación en el SG son periféricas a los Objetivos de Desarrollo del Milenio y la colaboración Sur-Norte es más frecuente que la Sur-Sur.

Palabras clave

Innovación, sostenibilidad, administración, STEM, Sur global, países en vías de desarrollo, bibliometría.

Introduction and research background

Commercial and knowledge exchange within the Global South (GS) (*i. e.,* countries mostly located in Asia, Africa, Latin America and the Caribbean [Latam]) is becoming increasingly important (Ortiz-Ospina et al., 2018). Countries of the GS have contributed to more than half of the world's growth, and intra-trade accounts for more than 25 % of worldwide trade (United Nations, 2019b). A sustainable commercial and knowledge exchange agenda in the GS must consider a sustainability perspective and the transversal role of innovation in its achievement (UNDP, 2019; United Nations, 2018). For instance, there is a mention of innovation or technology in ten out of the 17 Sustainable Development Goals (SDGS) (United Nations, 2017).

(Management) Innovation is understood as the invention, improvement, and implementation of specific management practices, processes, structures, or techniques that are new and are intended to further organizational goals (Birkinshaw et al., 2008). Sustainability, on the other hand, depends on the context in which it is applied (Brown et al., 1987). Here, sustainability in the context of s*ustainable development* is "[the development that] meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 41).

The GS, remarkably Asia, has been consistently increasing its participation in the global generation of knowledge inventions despite structural setbacks. Countries from the GS are falling short of the 1.68 % Gross Domestic Product (GDP) world average in R&D (Research and Development) investment (United Nations, 2019a). Despite that, China is the world's largest producer of STEM (Science, Technology, Engineering and Mathematics) research articles and ranked second in R&D investment after the United States (Tollefson, 2018). China might be a particular case as innovation-related research performance in East Asia, Latam, and Africa leaves them at a disadvantage compared to developed countries (Merigó et al., 2016). Nevertheless, their research capabilities and economic growth are expected to increase in the upcoming years (Finardi, 2015).

The GS shows increasing participation in patent applications over the last 40 years. Asia has filled 1.2+ million patent applications, Latam 21,000+,

and Africa 9,500+ (World Intellectual Property Organization, 2019). In terms of global and regional participation, 32% of applications were filed by countries from Asia, 0.6% from Latam, and 0.3% from Africa (World Intellectual Property Organization, 2019). Hence, while, on average, the GS is experiencing structural challenges concerning producing scientific and technological knowledge, trend data indicates that the GS is increasing its knowledge-output.

Several concerns may arise by counting for the thousands the number of research related to sustainability, innovation, or STEM in the GS. Methods from bibliometrics enable to producing analyses over those inquiries (Zupic & Čater, 2015). Bibliometrics could be defined as the quantitative understanding of scholarly communication (*e. g.,* articles, books) and the behavior appertaining to it (Fairthorne, 2005; Pritchard, 1969).

Bibliometric studies on sustainability-related topics and innovation in business and management from/on the GS are increasingly relevant for allocating scarce resources and advising national/local governments, firms, and the non-profit sector on the available knowledge that might contribute to their development. Since the late 1980s, sustainability science showed a productivity explosion; a marked emphasis on the management of human, social, and ecological systems; and a geographic diversity of authors (Bettencourt & Kaur, 2011). Studies also have identified 15 sustainability science related-research clusters (*e. g.,* agriculture, fisheries, ecological economics) and a framework that includes indicator setting, indicators measurement, causal chain analysis, among others (Kajikawa, 2008; Kajikawa et al., 2007).

On the broader scope of the SDGS, Nakamura et al. (2019) argued that there are two major domains: *health and healthcare*, and *environment, agriculture and sustainability science*. Both domains were connected by *water supply and sanitation.* A recent study aimed at interlinking the SDGS with business and management field in the last 30 years, identified a sifting from a nearly exclusive focus on economic growth and consumption to a more integrated framework including economic growth, social development, and environmental protection (Jia et al., 2019).

Further research has focused on outlining guidelines for STI (Science, Technology and Innovation) policy in knowledge-intensive sectors (*e. g.,* bio/nano-technologies, pharmaceutics or removable energy) (Guan & He, 2007; Huang et al., 2014; Li et al., 2017; Li et al., 2015), *Schumpeterian*

innovation and cooperation (Lazzarotti et al., 2011; Lopes & De Carvalho, 2012), innovativeness measures (De Carvalho et al., 2017), industry relations (Manjarrez et al., 2016), business models (Ceretta et al., 2016), financing on innovation (Padilla-Ospina et al., 2018), social innovation (Silveira & Zilber, 2017), regional outlooks (*i. e.,* Latam) (Cortés-Sánchez, 2019), and supply chain management (Tanco et al., 2018).

The focuses of the literature reviewed are twofold: (i) understanding the research on SDGs and sustainability science and its relation with management; and (ii) a motley of fractionated topics, from industrial relations to supply chain management. Nevertheless, little is known on the integrative role of *research on innovation in management and STEM for sustainability in the GS* (henceforth: is-GS). Three research questions guide this study: (i) what is the production dynamic is on is-GS?; (ii) what is the impact of is-GS?; (iii) what are the research structure on is-GS and the South-South collaboration, if any?

Therefore, we aim to conduct an exploratory bibliometric outlook on the output, impact, and structure on is-GS. The methodology section follows this introduction. Results and discussion sections present the overall output by region and countries; the (citations) impact by type of publication; and the structural analysis applying a co-word and co-authorship network analyses. Finally, concluding remarks and limitations are presented.

Methodology

Data

We used the bibliographic database Scopus for conducting the literature search. This source enables to enrich the strata of studies since most of the studies reviewed used the Web of Science (WoS) (Kajikawa et al., 2007; Nakamura et al., 2019). Scopus contains more than 75 million items (*i. e.,* articles, proceedings, and books) published by more than 5,000 publishers and authored by 16 million authors affiliated with more than 70,000 institutions (Scopus, 2019). Compared to Clarivate Analytics' Web of Science, Scopus has broader journal coverage and higher social sciences coverage (Gavel & Iselid, 2008; Mongeon & Paul-Hus, 2016).

We searched for keywords related to *innovation* and *sustainability* among document titles to ensure both topics are central in the documents (Nakamura et al., 2019). For the keywords selection, we consulted two reviews on innovation (Baregheh et al., 2009) and sustainability (Glavič & Lukman, 2007). For combining the subject areas/fields/disciplines of management and STEM, we, first, selected the complete subject areas related to management (*i. e.,* business, management and accounting; and decision sciences), and then, cross-checked each Scopus' journal subject (SCImago, 2018) with the STEM approved fields by the National Science Foundation (2014). Bibliometric studies generally use citation-based indicators extracted from journals, articles, and conference paper(s) (CP) (Durieux & Gevenois, 2010). Book chapters were not selected as added less than 5 % to our query. We limited our query to articles and CP since the latter are of significant importance in STEM (*i. e.,* computer science, engineering, and mathematics) (Lisée et al., 2008).

Articles and CP output, impact and structure analyses were conducted separately since (i) CP coverage is being less in recent years; (ii) the significant citation divergence between both (CP are cited less); and (iii) the coverage and availability are more volatile for CP (Michels & Fu, 2014). We limited the author(s) affiliation(s) to the list of Global South countries, including Latam, Africa, and Asia (except for Hong Kong, Japan, South Korea, Macau, Singapore, and Taiwan) (International Telecommunications Union, ITU, 2018; Wikipedia, 2015).

We framed the search between 1996-2018 since Scopus has been adding literature pre-1996 just recently (Scopus, 2015). After removing 80 duplicates, Scopus found 14,900+ documents: 9,600+ articles and 5,300+ CP (Scopus, 2018). Table 1 summarizes the query's search terms and overall results.

Table 1. Query's search terms and overall results

Keyword(s)	Subject area/Field	Source type	Author(s) affiliation	Year	Results
Innovation-related: *innovat*; new; creation; invention; improv*; research and development; commercialization* Sustainability-related: *sustainable development; cleaner production; environmental accounting; eco*design; shared value; environmental engineering; ethical investment; environmental legal*; environmental management-strategy; environmental technology; eco*efficiency; green chemistry; health and safety; industrial ecology; integrated pollution prevention and control; life cycle assessment; mutualism; minimization of resource usage; purification; pollution control; pollution prevention; responsible; reporting to the stakeholders; recycling; remanufacturing; regeneration; reuse; renewable resources; sustainable consumption; supply chain management; sustainable production; source reduction; corporate social responsibility; voluntary environmental agreement; waste minimization; zero waste*	Business, management and accounting; Decision sciences STEM (Engineering; Environmental science; Energy; Biochemistry; Genetics and molecular biology; Agricultural and biological sciences; Computer science; Mathematics; Earth and planetary sciences; Chemical engineering; Physics and Astronomy; Materials science; Multidisciplinary)	Articles; Conference papers	Global South' 's countries	1996-2018	Total documents: 14,979 Articles: 9,657 Conference Papers: 5,322

Source: The authors' based on Baregheh et al. (2009); Glavič & Lukman (2007); SCImago (2018); National Science Foundation (2014); ITU (2018); Wikipedia (2015); and Scopus (2018).

Methods

We first explored the dataset through bibliometric analysis describing (i) the output by year, type of document, continent, and country (normalized by the average researchers in R&D per million people); and (ii) the impact by countries' citations and average citations by type of document, and cumulative growth of relevant outlets. Subsequently, (iii) the structure analyses consisted of two sections: co-word and co-authorship networks at the country level. The network structure between publications provides insights into how different articles are related to each other in terms of shared words and authors. The goal of such an analysis is to determine similarities between publications (Ni et al. 2017). When conducting co-authorship network analysis, it is possible to visualize 'invisible colleges': groups of similar scholarship in terms of authors and knowledge (Small, 1973).

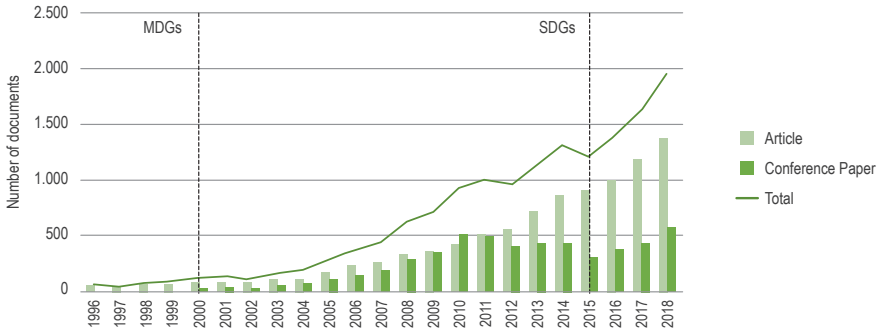
We aim to identify the intellectual structure of the field by highlighting the research clusters, potential knowledge transferring between them, and possible fragmentation of the field (Ni et al., 2017; Raghuram et al., 2019). Therefore, we conducted a co-occurrence analysis of words that appeared in the abstract. A co-appearance analysis assumes that if two articles use similar words in their abstract, they form a knowledge cluster (Qiu et al., 2014; Sedighi, 2016). That is useful to identify the similarity between abstracts and dominant research areas. The data contains 233,606 unique terms. Terms were included if they appeared at least ten times. We further narrowed it down by calculating a relevance score for each term and selected the 60% most relevant terms (2,945 terms). We removed noisy terms (*e. g., world scientific publishing co, elsevier, figure, spss*, among others).

Afterward, to identify strategic countries in the social-capital network, we conducted a co-authorship network. The co-authorship network is considered as one of the most tangible and reliable methods to study scientific collaboration and the creation of social networks of researchers by linking co-authors in a given document (Glänzel & Schubert, 2005). The scientific collaboration reflects individual mobility/research interest, economic/political dependence at the institutional or national level, degree of integration, or a simple result of research activities between institutions (Glänzel & Schubert, 2001). Co-authorship network analysis at the individual level did not produce fruitful insights due to the overrepresentation of researchers from China. Therefore, we conducted it at the country level.

Result analysis

Figure 1 presents the output by year and type of document for 1996-2018. The average annual growth rate was 18 % (articles: 17 %; CP 31 %). There was a noticeable output declining between 2014 and 2015, followed by an increase after 2015, which coincided with the SDGs agenda announcement. According to the articles' subject-best quartile, most of the articles were related to electrical and electronic engineering (6 %); agronomy and crop science (5 %); engineering (miscellaneous) (5 %); business and international management (5 %); and chemical engineering (miscellaneous) (4 %). On the other hand, CP were related to engineering (miscellaneous) (12 %); electrical and electronic engineering (9 %); computer science (miscellaneous) (8 %); computer networks and communications (8 %); and energy engineering and power technology (4 %). The exploration of CP enables us to recognize the relevance of research subjects otherwise obscure in the articles' sample (*e. g.,* computer science/networks and communications).

Figure 1. Output by year and type of document for 1996-2018



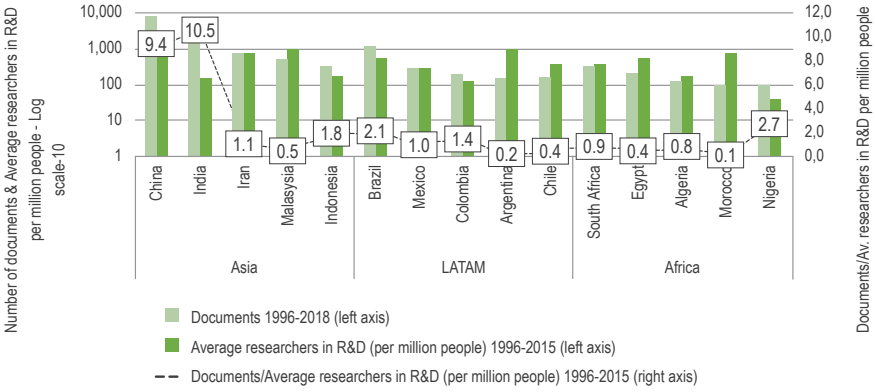
Note: MDGs: Millennium Development Goals; SDGs: Sustainable Development Goals.

Source: The authors' based on Scopus (2018).

Figure 2 presents the top-five productive countries by continent normalized by the average researchers in R&D per million people 1996-2015. The indisputable leader in total output was China (50 %), followed by India (10 %), Brazil (7 %), Iran (5 %), and Malaysia (3 %). The top-five countries of each continent account for more than 90 % of the documents of the sample.

India surpassed China in terms of documents/researcher ratio (China: 9.4; India: 10.5). The leading countries in Africa and Latam for documents/researcher ratio were Nigeria (2.6) and Brazil (2.1), respectively.

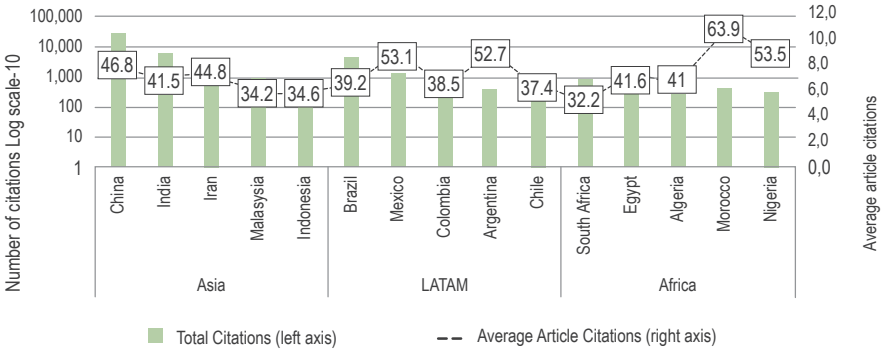
Figure 2. Top-five productive countries by continent normalized by the average researchers in R&D per million people 1996-2015



Source: The authors' based on Scopus (2018) and The World Bank (2018).

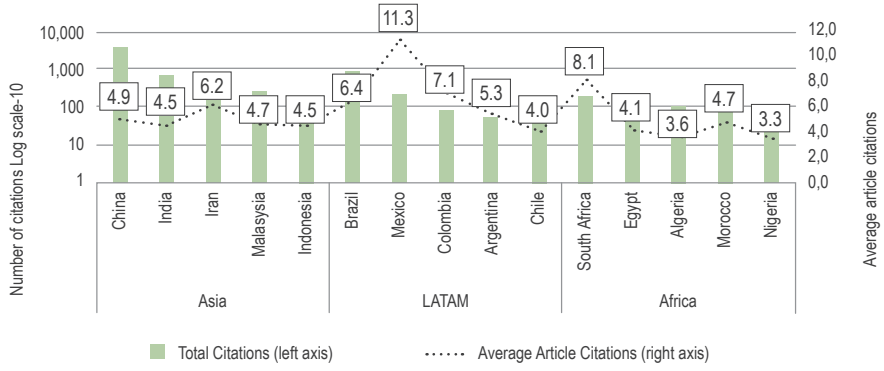
For whole countries' citations, we analyzed the 2,000 most cited articles and CP. Figs. 3 and 4 present the top-five countries by continent for the number of citations and average articles' and CP citations per document. China, by far, amassed the higher number of citations (30,000+). However, four countries from Latam and Africa, namely Mexico (53.1), Chile (52.7), Nigeria (63.9), and Algeria (53.5), surpassed China's average article citations (46.8). A similar scenario was observed for CP. China concentrated the most significant amount of citations (3,700+), yet it was surpassed by other countries such as Mexico (11.2), South Africa (8.1), or Argentina (7.1) on its average CP citation (4.9). Besides, figures 5 and 6 present examples of the cumulative growth of highly reputable outlets.

Figure 3. Top-five countries by continent for total articles' citations and average article citations. Based on the most cited 2,000 articles



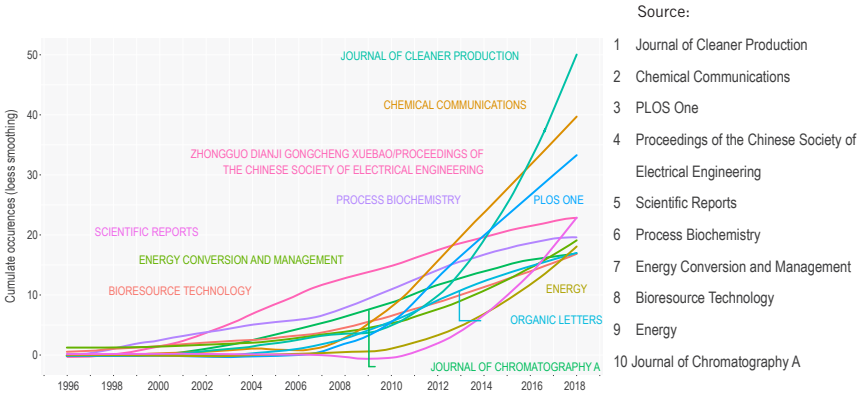
Source: The authors' based on Scopus (2018).

Figure 4. Top-five countries by continent for total CP citations and average CP citations. Based on the most cited 2,000 CP



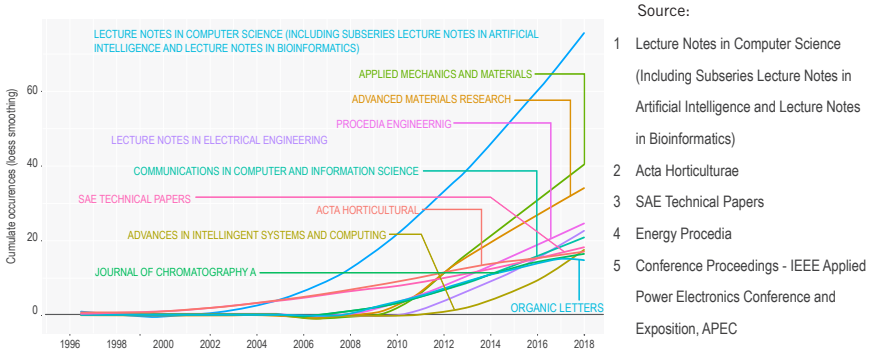
Source: The authors' based on Scopus (2018).

Figure 5. Cumulative growth of the top-ten journals



Source: The authors' based on Scopus (2018) and processed with bibliometrix (Aria & Cuccurullo, 2017).

Figure 6. Cumulative growth of the top-ten CP



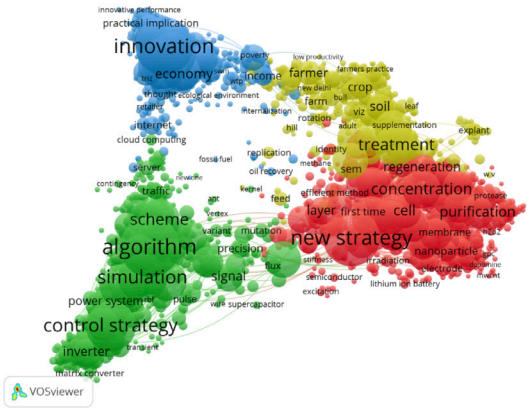
Source: The authors' based on Scopus (2018) and processed with bibliometrix (Aria & Cuccurullo, 2017).

The co-word network has 2,944 terms and 347,726 links between them. The network density measures the proportion of ties among the actors (nodes) of a network that are actually linked. The co-word density is 0,08, meaning that among 2,944 terms, 0.8 % are actually connected. The three top terms were: *algorithm* (1,417), *innovation* (1,279), *new strategy* (1,266), *control strategy* (991), and *company* (931) (Fig. 7). It is composed of four clusters (from top left going clockwise): *innovation* (blue, 788), *soil composition and treatment* (yellow, 466), *chemistry and biochemistry* (red, 884 terms), and *algorithms and electric power grids* (green, 816).

The *innovation* cluster focuses on innovation in companies, specifically: knowledge management and management practices. The second cluster, *soil composition and treatment*, deals with the yields of plants and their treatment. To a smaller extent, it directly addresses farming research. That cluster is strongly linked with the following cluster on *chemistry and biochemistry* thanks to the terms *treatment, concentration, property*, and *new management*. Examples on the latter topic are: *New management structure of active and reactive power of a large wind farm based on multilevel converter;* or *New management operations on classifiers pool to track recurring concepts*. This cluster contains terms such as *new strategy, concentration, purification, formation, regeneration,* and *synthesis*. The term *stability* provides a link to the next cluster on *algorithms*. That cluster seems to contain several subfields, all relying on *simulations* and *algorithms*. One example is *power grids*, thus the allocation of electricity through a power grid. Topics related to information science, such as *cloud computing*, does not have a dominant position.

The co-word network indicates that the *innovation* cluster is linked to the *soil research cluster* through *management practices*, a term that describes the *management of resources, human resources and factory,* or *farm resources*. There is no link between the *innovation* and the *algorithm* cluster. Instead, the *algorithm* cluster is linked to *chemistry and biochemistry* cluster through *new strategy*. At this point, we found that is-GS focuses on *innovation* in *management practices* within companies, *plant* and *farming*, and *algorithms* for specific computing requirements.

Figure 7. Co-word network



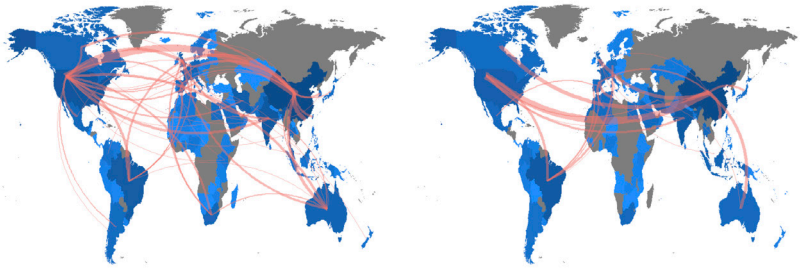
Source: The authors' based on Scopus (2018) and processed with VOSviewer (Van Eck & Waltman, 2010).

Collaboration differed substantially for articles and CP in terms of single authorship and national/international collaboration. Single authored documents are the exception, a higher percentage of articles were developed with international collaborations compared to CP, and a higher percentage of articles were also developed with only national collaboration. Scopus' SciVal reported 6.7% single-authored articles, 31.7% only national collaboration, and 27.1% with international collaboration. For CP, 12.3% were single-authored, 22.8% only national collaboration, and 14.3% with international collaboration.

Figure 8 presents countries with at least five documents co-authored based on the 2,000 most cited documents for both articles and CP. The frequency of co-authored documents is higher for North-South collaboration. There is GS intra-collaboration, but its frequency is not as significant as the North-South. Latam is the GS region with the highest collaboration within its countries and between other GS regions. China has the highest number of documents co-authored with developed countries (articles with the US: 114; and the UK: 33; CP with the US: 44 and the UK: 14) followed by Brazil (articles with the US: 20; CP with the US: 11 and Germany: 9) and South Africa (articles with the US: 13).

The barely noticeable GS intra-collaboration was spotted within Latam (articles: Brazil-Argentina [3]; CP: Brazil-Chile [2]) and Africa (articles: South Africa-Malawi [2]), and between Latam-Asia (articles: Brazil-India [2]; CP: Brazil-India [2]; China-Argentina [2]; Brazil-China [1]), Africa-Asia (articles: South Africa-Japan [1]; CP: South Africa-China [1]), and Latam-Africa (articles: Brazil-Kenia [1]).

Figure 8. International collaboration (left: articles; right: CP).



Source: The authors' based on Scopus (2018) and processed with bibliometrix (Aria & Cuccurullo, 2017).

Discussion

The research output growth on IS-GS is going hand in hand with global growth in scientific output. The average total growth of research documents indexed in Scopus by China (15%), Brazil (11%), and South Africa (8%) between 1996-2018 was closer to the average calculated here (18%) (SCImago, 2018). The noticeable growth of research related to sustainability in a broad sense after the announcement of the SDGS in 2015 was also traceable to other bibliographic databases such as WoS. For example, global research related to the SDGS counted fewer than 100 papers published annually before 2010 to over 500 after 2016 (Nakamura et al., 2019).

Despite the overall growth, significant inter-regional gaps remain a challenge, even within the top-five countries of each continent. In Asia, China published 25 times more documents than Indonesia; in Latam, Brazil published eight times more than Chile; in Africa, South Africa published three times more than Nigeria. Differences in scientific productivity between authors, institutions, and nations have been explained by gender differences (Van Arensbergen et al., 2012); incentives and collaboration dynamics (Defazio et al., 2009); grant funding (Jacob & Lefgren, 2011); cultural factors (Inönü, 2003); and population and national public/private investment in research and development (R&D) as the percentage of GDP (King, 2004), among others. Regarding the latter, this study concurs with the findings of Prathap (2017) on the relationship between R&D and scientific wealth (*i. e.,* production and impact).

Even though China amassed most of the aggregated citations for both articles and CP, several countries (*e. g.,* Mexico, Nigeria, Argentina, or Algeria) surpassed its citation/per article-CP. This geographical diversification fingerprint of sustainability-related research with noticeable participation of several GS countries in terms of both citations and output was previously noticed by Bettencourt and Kaur (2011). Regarding China, Huang (2018) claimed that the average number of citations per article was 9.4, below the world average of 11.8, yet substantially higher than the Latam average of 5.2 on innovation-related research (Cortés-Sánchez, 2019).

The publishing pressure and financial incentives' side effects may partly explain the inferior citation performance of China. Chinese researchers do not secure national-level research funding as principal investigators if they do not publish at least half a dozen articles indexed in the Science Citation Index within a lustrum. Regarding incentives, a researcher could receive between US$900 and US$10,000 for each article published, regardless of journals' reputation (Huang, 2018).

Countries with a higher citation per paper such as Mexico and Nigeria are strengthening their scientific wealth despite setbacks, particularly in STEM. Research on Computer Science, led by the largest university in Latam (*Universidad Nacional Autónoma de México*) and their National Council of Science and Technology (Conacyt), is generating a higher citation per paper average than the world's 100 most productive institutions (Uddin et al., 2015). In Africa, the research output still is concentrated in two countries: South Africa and Egypt, as it was in 2004 (Pouris & Pouris, 2009). In Nigeria, the country with the highest average article citation of the sample, the research production in STEM-related topics (*i. e.,* applied information science and technology) is flourishing but with little international presence (Usman & Ewulum, 2019). On the other hand, the research production in innovation-related topics such as University-industry linkages on Sub-Saharan Africa is currently dominated both as producers and consumers by South Africa and Nigeria (Zavale & Langa, 2018).

Most articles and CP on IS-GS published in highly reputable outlets were more inclined towards STEM than management (*e. g.,* electrical and electronic engineering; agronomy and crop science; chemical engineering; computer science). Zhu and Hua (2017) and Merigó *et al.* (2016) looked at the most reputable outlets on sustainable development and innovation, respectively. Journals such as *Science*, *Nature, Ecological Economics, Energy Policy,* and *PNAS,* figured among the top-20 journals in sustainable development. In contrast, *Research Policy, Strategic Management Journal, Journal of Product Innovation Management,* and *Technovation* figured among the top-tier journals in innovation.

In this study, only the *Journal of Cleaner Production* and *Energy* were the top-ten journals identified with cumulative growth that also happened to appeared in Zhu and Hua's (2017) list. The inherent differences between social (*i. e.,* management) and natural sciences (*i. e.,* STEM) research may cause the

difference in citation dynamics (*i. e.,* impact) of journals and their reputation. For instance, social sciences have tended to be locally oriented and linguistically fragmented compared to natural sciences (Dyachenko, 2014). Furthermore, in computer sciences proceedings peer-reviews, the evidence suggests a bias in favor of authors from English-speaking countries located in the Global North and affiliated with prestigious institutions (Walker et al., 2015).

Previous co-word mapping analysis on innovation in the GS coincides in several findings presented in this study; however, the original contributions here presented are considerably more substantial after integrating the literature on innovation in STEM for sustainability. As stated by Cortés-Sánchez (2019), both *innovation* and *knowledge* were closely related to *management* (*practices* in green supply chain or new product development), a relation also found in the *innovation cluster*.

The same happened with the term *strategy,* which also was among the most mentioned by Cortés-Sánchez (2019). In that study, *strategy* was referring to *strategic management* or *corporate strategy*. In this study, in contrast, the term (new)*strategy* was located in the *algorithms and electric power grids cluster* (i.e., *Multi-stage genetic programming: A new strategy to nonlinear system modeling*). The term *sustainability* was not embedded in innovation for management as it was on innovation for STEM. Conversely, the term *development* was among the most visible, and it was regularly associated with de term *sustainable* or *inclusive* in Cortés-Sánchez' (2019) remarks.

The lack of relatedness between the innovation and the algorithm clusters is a counterintuitive finding, considering the popularity of '4.0 Industry' technologies such as algorithms or cloud computing and their impact on innovation for businesses (World Economic Forum, 2019) since its closer relatedness is with the chemistry and biochemistry cluster. Hence, the '4.0 Industry' technologies seem to be more related to STEM-related fields than business or management.

The low percentage of single-authored documents reaffirms the current dominance of teams in knowledge production (Wuchty et al., 2007). Regarding the North-South co-authorship, Nakamura et al. (2019) also found that research on SDGS published in Africa, the Arab States, and Latam, was co-authored more frequently with Europe than North America. The North-South cooperation overshadowed Co-authorship between the former three developing regions.

One of the strong reasons of historical nature on the dominance of the Global North in innovation studies is that the top-twenty most influential scholars on the topic are (were) affiliated with a reputable institution in the US or Europe, such as Harvard, Stanford, Columbia, or Sussex (Fagerberg et al., 2012). Further, North America (44 %) and Europe (42 %) are the locations of 86 % of the knowledge user of innovation studies (Fagerberg et al., 2012).

For South-Africa, Kozma and Calero-Medina (2019) stated that 50 % of the publications of the 500 most cited African researchers were co-authored with researchers with non-African affiliation. Furthermore, there has been a growing tension produced by western funding agencies (*e. g.,* NASA) that fund research topics of international relevance (*e. g.,* astronomy or astrophysics) with disputable local importance or priority (Kozma & Calero-Medina, 2019).

The superior research internationalization of China with developed and developing countries also has been pointed by Arunachalam and Doss (2000), who found that developing countries in Asia (*e. g.,* India and China) have collaborated more in physics. In contrast, the other eight countries analyzed (*e. g.,* Malaysia or Indonesia) have collaborated more in life sciences. The US was the preferred collaboration partner for that sample of Asian countries.

Finally, Adams (2012) outlined crucial differences between Latam and African research networks. Latam is an emerging network orbiting Brazil, while Africa is developing three different language-similar networks in southern Africa, West Africa (French-speaking countries), and East Africa (English-speaking countries). North-South (disadvantage) interactions may be partly explained by historically rooted and current inequalities (Jentsch & Pilley, 2003). As for today, the commonly assumed roles of the North as a provider of ideas and funding and the South as both fund receiver and data quarry, persist (Jentsch & Pilley, 2003).

Conclusions

IS-GS is crucial for the sustainable development agenda. The output on IS-GS is increasing consistently, with remarkable peaks after the announcements of the MDGS and SDGS. However, the despair allocation of institutional capacity, and financial and human resources, inter-regional gaps are becoming more extensive in both output and impact. Collaboration paths with regional countries on both consolidated and trending topics are vital components to benefit from considering the results and capabilities here discussed. Science mapping (co-word network) results also showed the distances towards topics central to the SDGS research but rather peripherical or still emergent for IS-GS. China is influencing the GS dramatically in overall output, and research topics

Further research could compare bibliographic data from other databases (*i. e.,* WoS; Dimensions; Google Scholar; Microsoft Academic), even including another type of literature (*i. e.,* patents). Alternative metrics (*e. g.,* altmetrics) light the incidence of IS-GS on a broader audience beyond the academic niche. In-depth comparative perspectives between GS and Global North could outline shared or differentiated research resources, capabilities, and priorities. A closer look at national or organizational research policies related to incentives could help explain historical and local particularities, and corporate-academic collaboration oriented towards increasing research output and impact. Finally, practitioners could use the results for decision-making scenarios on defining the next-step research topic to support; to allocate resources; to identify vital neighboring institutions, firms, or countries; or to enrich the organizational incentive policies.

References

Adams, J. (2012). The rise of research networks. *Nature, 490*(7420), 335-336. https://doi.org/10.1038/490335a

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: an R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959-975. https://doi.org/10.1016/j.joi.2017.08.007

Arunachalam, S., & Doss, M. J. (2000). Mapping international collaboration in science in Asia through co-authorship analysis. *Current Science, 79*(5), 621-628.

Baregheh, A., Rowley, J., & Sambrook, S. (2009). Towards a multidisciplinary definition of innovation. *Management Decision, 47*(8), 1323-1339. Scopus. https://doi.org/10.1108/00251740910984578

Bettencourt, L. M. A., & Kaur, J. (2011). Evolution and structure of sustainability science. *Proceedings of the National Academy of Sciences, 108*(49), 19540. https://doi.org/10.1073/pnas.1102712108

Ceretta, G. F., Dos Reis, D. R., & Da Rocha, A. C. (2016). Innovation and business models: a bibliometric study of scientific production on Web of Science database. *Gestao e Producao, 23*(2), 433-444. Scopus. https://doi.org/10.1590/0104-530X1461-14

Cortés-Sánchez, J. D. (2019). Innovation in Latin America through the lens of bibliometrics: crammed and fading away. *Scientometrics, 121*(2), 869-895. https://doi.org/10.1007/s11192-019-03201-0

De Carvalho, G. D. G., Cruz, J. A. W., De Carvalho, H. G., Duclós, L. C., & De Fátima Stankowitz, R. (2017). Innovativeness measures: a bibliometric review and a classification proposal. *International Journal of Innovation Science, 9*(1), 81-101. Scopus. https://doi.org/10.1108/IJIS-10-2016-0038

Defazio, D., Lockett, A., & Wright, M. (2009). Funding incentives, collaborative dynamics and scientific productivity: Evidence from the EU framework program. *Research Policy, 38*(2), 293-305. https://doi.org/10.1016/j.respol.2008.11.008

Durieux, V., & Gevenois, P. A. (2010). Bibliometric indicators: quality measurements of scientific publication. *Radiology, 255*(2), 342-351. https://doi.org/10.1148/radiol.09090626

Dyachenko, E. L. (2014). Internationalization of academic journals: is there still a gap between social and natural sciences? *Scientometrics, 101*(1), 241-255. https://doi.org/10.1007/s11192-014-1357-9

Fagerberg, J., Fosaas, M., & Sapprasert, K. (2012). Innovation: exploring the knowledge base. *Research Policy, 41*(7), 1132-1153. https://doi.org/10.1016/j.respol.2012.03.008

Fairthorne, R. (2005). Empirical hyperbolic distributions (Bradford–Zipf–Mandelbrot) for bibliometric description and prediction. *Journal of Documentation, 61*(2), 171-193. https://doi.org/10.1108/00220410510585179

Finardi, U. (2015). Scientific collaboration between BRICS countries. *Scientometrics, 102*(2), 1139-1166. https://doi.org/10.1007/s11192-014-1490-5

Glänzel, W., & Schubert, A. (2001). Double effort = double impact? A critical view at international co-authorship in chemistry. *Scientometrics, 50*(2), 199-214. Scopus. https://doi.org/10.1023/A:1010561321723

Glänzel, Wolfgang, & Schubert, A. (2005). Analysing scientific networks through co-authorship. In H. F. Moed, W. Glänzel & U. Schmoch (Eds.), *Handbook of quantitative science and technology research: the use of publication and Patent Statistics in studies of S&T systems* (pp. 257-276). Springer Netherlands. https://doi.org/10.1007/1-4020-2755-9_12

Glavič, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production, 15*(18), 1875-1885. https://doi.org/10.1016/j.jclepro.2006.12.006

Guan, J., & He, Y. (2007). Patent-bibliometric analysis on the Chinese science. Technology linkages. *Scientometrics, 72*(3), 403-425. Scopus. https://doi.org/10.1007/s11192-007-1741-1

Huang, F. (2018). *Low quality studies belie hype about research boom in China*. Scientific American. https://www.scientificamerican.com/article/low-quality-studies-belie-hype-about-research-boom-in-china/

Huang, L., Zhang, Y., Guo, Y., Zhu, D., & Porter, A. L. (2014). Four dimensional Science and Technology planning: a new approach based on bibliometrics and technology roadmapping. *Technological Forecasting and Social Change, 81*(1), 39-48. https://doi.org/10.1016/j.techfore.2012.09.010

Inönü, E. (2003). The influence of cultural factors on scientific production. *Scientometrics, 56*(1), 137-146. https://doi.org/10.1023/A:1021906925642

International Telecommunications Union (ITU). (2018). *Country classifications*. https://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx

Jacob, B. A., & Lefgren, L. (2011). The impact of research grant funding on scientific productivity. *Special Issue: The Role of Firms in Tax Systems, 95*(9), 1168-1177. https://doi.org/10.1016/j.jpubeco.2011.05.005

Jentsch, B., & Pilley, C. (2003). Research relationships between the South and the North: Cinderella and the ugly sisters? *Social Science & Medicine, 57*(10), 1957-1967. https://doi.org/10.1016/S0277-9536(03)00060-1

Jia, Q., Wei, L., & Li, X. (2019). Visualizing sustainability research in business and management (1990-2019) and emerging topics: a large-scale bibliometric analysis. *Sustainability, 11*(20), 5596. https://doi.org/10.3390/su11205596

Kajikawa, Y. (2008). Research core and framework of sustainability science. *Sustainability Science, 3*(2), 215-239. https://doi.org/10.1007/s11625-008-0053-1

Kajikawa, Y., Ohno, J., Takeda, Y., Matsushima, K., & Komiyama, H. (2007). Creating an academic landscape of sustainability science: an analysis of the citation network. *Sustainability Science, 2*(2), 221. https://doi.org/10.1007/s11625-007-0027-8

King, D. A. (2004). The scientific impact of nations. *Nature, 430*(6997), 311-316. https://doi.org/10.1038/430311a

Kozma, C., & Calero-Medina, C. (2019). The role of South African researchers in intercontinental collaboration. *Scientometrics, 121*(3), 1293-1321. https://doi.org/10.1007/s11192-019-03230-9

Lazzarotti, F., Dalfovo, M. S., & Hoffmann, V. E. (2011). A bibliometric study of innovation based on schumpeter. *Journal of Technology Management and Innovation, 6*(4), 121-135. https://doi.org/10.4067/S0718-27242011000400010

Li, N., Chen, K., & Kou, M. (2017). Technology foresight in China: academic studies, governmental practices and policy applications. *Technological Forecasting and Social Change, 119,* 246-255. Scopus. https://doi.org/10.1016/j.techfore.2016.08.010

Li, X., Zhou, Y., Xue, L., & Huang, L. (2015). Integrating bibliometrics and roadmapping methods: a case of dye-sensitized solar cell technology-based industry in China. *Technological Forecasting and Social Change, 97,* 205-222. https://doi.org/10.1016/j.techfore.2014.05.007

Lisée, C., Larivière, V., & Archambault, É. (2008). Conference proceedings as a source of scientific information: A bibliometric analysis. *Journal of the American Society for Information Science and Technology, 59*(11), 1776-1784. https://doi.org/10.1002/asi.20888

Lopes, A. P. V. B. V., & De Carvalho, M. M. (2012). The evolution of the literature on innovation in cooperative relationships: a bibliometric study for the last two decades. *Gestao e Producao, 19*(1), 203-217. Scopus.

Manjarrez, C. C. A., Pico, J. A. C., & Díaz, P. A. (2016). Industry interactions in innovation systems: a bibliometric study. *Latin American Business Review, 17*(3), 207-222. https://doi.org/10.1080/10978526.2016.1209036

Merigó, J. M., Cancino, C. A., Coronado, F., & Urbano, D. (2016). Academic research in innovation: a country analysis. *Scientometrics, 108*(2), 559-593. https://doi.org/10.1007/s11192-016-1984-4

Michels, C., & Fu, J.-Y. (2014). Systematic analysis of coverage and usage of conference proceedings in web of science. *Scientometrics, 100*(2), 307-327. https://doi.org/10.1007/s11192-014-1309-4

Nakamura, M., Pendlebury, D., Schnell, J., & Szomszor, M. (2019). *Navigating the structure of research on sustainable development goals*. Web of Science Group. https://clarivate.com/webofsciencegroup/campaigns/sustainable-development-goals/

National Science Foundation. (2014). *NSF approved fields of study*. https://www.btaa.org/docs/default-source/diversity/nsf-approved-fields-of-study.pdf?sfvrsn=1bc446f3_2

Ortiz-Ospina, E., Beltekian, D., & Roser, M. (2018). *Trade and globalization. Our world in data*. https://ourworldindata.org/trade-and-globalization

Padilla-Ospina, A. M., Medina-Vásquez, J. E., & Rivera-Godoy, J. A. (2018). Financing innovation: a bibliometric analysis of the field. *Journal of Business and Finance Librarianship, 23*(1), 63-102. Scopus. https://doi.org/10.1080/08963568.2018.1448678

Pouris, A., & Pouris, A. (2009). The state of science and technology in Africa (2000-2004): a scientometric assessment. *Scientometrics, 79*(2), 297-309. https://doi.org/10.1007/s11192-009-0419-x

Prathap, G. (2017). Scientific wealth and inequality within nations. *Scientometrics, 113*(2), 923-928. https://doi.org/10.1007/s11192-017-2511-y

Pritchard, A. (1969). Statistical bibliography or bibliometrics. *Journal of Documentation, 25*(4), 348-349.

Qiu, J.-P., Dong, K., & Yu, H.-Q. (2014). Comparative study on structure and correlation among author co-occurrence networks in bibliometrics. *Scientometrics, 101*(2), 1345-1360. https://doi.org/10.1007/s11192-014-1315-6

SCImago. (2018). *SCImago Journal Ranking*. https://www.scimagojr.com/

Scopus. (2015). *Breaking the 1996 barrier: Scopus adds nearly 4 million pre-1996 articles and more than 83 million references*. https://blog.scopus.com/posts/breaking-the-1996-barrier-scopus-adds-nearly-4-million-pre-1996-articles-and-more-than-83

Scopus. (2018). *Search*. https://www.scopus.com/

Sedighi, M. (2016). Application of word co-occurrence analysis method in mapping of the scientific fields (case study: The field of Informetrics). *Library Review, 65*(1/2), 52-64. https://doi.org/10.1108/LR-07-2015-0075

Silveira, F. F., & Zilber, S. N. (2017). Is social innovation about innovation? A bibliometric study identifying the main authors, citations and co-citations over 20 years. *International Journal of Entrepreneurship and Innovation Management, 21*(6), 459-484.

Small, H. (1973). Co-citation in the scientific literature: a new measure of the relationship between two documents. *Journal of the American Society for Information Science, 24*(4), 265-269. https://doi.org/10.1002/asi.4630240406

Tanco, M., Escuder, M., Heckmann, G., Jurburg, D., & Velazquez, J. (2018). Supply chain management in Latin America: current research and future directions. *Supply Chain Management, 23*(5), 412-430. Scopus. https://doi.org/10.1108/SCM-07-2017-0236

The World Bank. (2018). *World Bank open data | Data*. https://data.worldbank.org/

Tollefson, J. (2018). China declared world's largest producer of scientific articles. *Nature, 553,* 390. https://doi.org/10.1038/d41586-018-00927-4

Uddin, A., Singh, V. K., Pinto, D., & Olmos, I. (2015). Scientometric mapping of computer science research in Mexico. *Scientometrics, 105*(1), 97-114. https://doi.org/10.1007/s11192-015-1654-y

UNDP. (2019). *Southern development solutions for the sustainable development goals*. UNDP. https://www.latinamerica.undp.org/content/rblac/en/home/library/poverty/southern-development-solutions-for-the-sustainable-development-g.html

United Nations. (2017). *SDG Indicators. SDG indicators global indicator framework for the sustainable development goals and targets of the 2030 Agenda for Sustainable Development.* https://unstats.un.org/sdgs/indicators/indicators-list/

United Nations. (2018). *Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*. https://sustainabledevelopment.un.org/sdg9

United Nations. (2019a). *Special edition: Progress towards the Sustainable Development Goals*. United Nations. https://undocs.org/pdf?symbol=en/E/2019/68

United Nations. (2019b). *What is "South-South cooperation" and why does it matter?* UN DESA | United Nations Department of Economic and Social Affairs. https://www.un.org/development/desa/en/news/intergovernmental-coordination/south-south-cooperation-2019.html

Usman, M. K., & Ewulum, O. (2019). A bibliometric analysis of Nigeria's Library and Information Sciences literature: a study of journal of applied information science and technology. *COLLNET Journal of Scientometrics and Information Management, 13*(1), 53-64. https://doi.org/10.1080/09737766.2018.1541042

Van Arensbergen, P., Van der Weijden, I., & Van den Besselaar, P. (2012). Gender differences in scientific productivity: a persisting phenomenon? *Scientometrics, 93*(3), 857-868. Scopus. https://doi.org/10.1007/s11192-012-0712-y

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Walker, R., Barros, B., Conejo, R., Neumann, K., & Telefont, M. (2015). Personal attributes of authors and reviewers, social bias and the outcomes of peer review: a case study [version 2; peer review: 2 approved]. *F1000Research, 4*(21). https://doi.org/10.12688/f1000research.6012.2

Wikipedia. (2015). *List of countries by regional classification*. https://meta.wikimedia.org/wiki/List_of_countries_by_regional_classification

World Economic Forum. (2019). *Future technologies will drive industry 4.0 | World Economic Forum*. https://www.weforum.org/agenda/2019/01/future-technologies-will-drive-industry-4-0/

World Intellectual Property Organization. (2019). *Patent Cooperation Treaty Yearly Review 2019*. WIPO.

Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The increasing dominance of teams in production of knowledge. *Science, 316*(5827), 1036-1039. Scopus. https://doi.org/10.1126/science.1136099

Zavale, N. C., & Langa, P. V. (2018). University-industry linkages' literature on Sub-Saharan Africa: systematic literature review and bibliometric account. *Scientometrics, 116*(1), 1-49. https://doi.org/10.1007/s11192-018-2760-4

Zhu, J., & Hua, W. (2017). Visualizing the knowledge domain of sustainable development research between 1987 and 2015: a bibliometric analysis. *Scientometrics, 110*(2), 893-914. https://doi.org/10.1007/s11192-016-2187-8

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods, 18*(3), 429-472. https://doi.org/10.1177/1094428114562629