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TESIS DOCTORAL

La aportación científica a la innovación tecnológica: análisis de estrategias de investigación en bases de datos de referencia

Scientific contribution to technological innovation: analysis of research strategies in reference databases

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Resumen

Las publicaciones científicas son el medio de comunicación de la evolución de la investigación desarrollada en nuestro entorno. A través de ellas podemos analizar el progreso de la Ciencia y de la innovación tecnológica. Por otro lado, al hablar de innovación tecnológica hemos de considerar las patentes como elemento clave para proteger esa innovación y como instrumento para fomentar el desarrollo tecnológico. Ciencia, innovación y desarrollo son conceptos totalmente conectados que establecen la base de los parámetros desarrollados en esta tesis doctoral. El objetivo de la misma, es demostrar la relación entre la investigación básica desarrollada y su transferencia en el ámbito industrial a través de su contribución al desarrollo de patentes. Para ello, la Bibliometría y los indicadores bibliométricos nos permiten evaluar y medir la producción científica en todos sus aspectos. Un indicador bibliométrico es un parámetro que mide algún aspecto de la actividad científica.

Tomando como base la Bibliometría, se contextualizan las publicaciones realizadas entre 1996 y 2020 para analizar si existe algún sesgo hacia alguna categoría científica, países o instituciones que hayan contribuidos a este tipo de estudios bibliométricos. Para ello se han utilizados las dos bases de datos de referencia en investigación: Web of Science y Scopus. El resultado de este análisis nos lleva a centrarnos en el caso de la Medicina y Ciencias Medioambientales.

A partir de esta visión global, enfocamos el estudio del grado de transferencia entre la investigación básica y la investigación aplicada en el campo de la Salud y de la Agronomía. Se ha utilizado el indicador bibliométrico "Patent-Cited Scholarly Output" de SciVal que nos permite medir el grado de transferencia entre las publicaciones totales y las publicaciones citadas en patentes. En base al resultado de este indicador, se ha hecho un estudio de la calidad de estas publicaciones, países que más contribuyen, evolución, impacto, visibilidad. Para complementar esta investigación se propone el nuevo indicador TIP que mide el porcentaje de publicaciones citadas en patentes con respecto al total de publicaciones indexadas para una institución. El TIP permite medir el impacto de la producción científica de las universidades en su transferencia respecto a las patentes, estableciendo así una relación entre la investigación básica y la investigación aplicada para una determinada institución.

Por último, también se analiza toda la literatura científica sobre desalación a nivel mundial para analizar las tendencias de la investigación en este campo. Para ello, se ha realizado un estudio bibliométrico, analizando la evolución de las publicaciones por años, los países y afiliaciones que más contribuyen a este campo científico, y a través de las palabras clave de los artículos, analizar las comunidades científicas en las que se pueden agrupar estos trabajos.

Abstract

Scientific publications are the means of communication of the evolution of the research carried out in our environment. Through them, we can analyse the progress of science and technological innovation. On the other hand, when talking about technological innovation, we must consider patents as a key element for protecting this innovation and as an instrument for promoting technological development. Science, innovation and development are totally connected concepts that establish the basis of the parameters developed in this doctoral thesis. The aim of this thesis is to demonstrate the relationship between the basic research developed and its transfer to the industrial field through its contribution to the development of patents. To this end, Bibliometrics and bibliometric indicators allow us to evaluate and measure scientific production in all its aspects. A bibliometric indicator is a parameter that measures some aspect of scientific activity.

Taking Bibliometrics as a basis, we contextualise the publications carried out between 1996 and 2020 to analyse whether there is any bias towards any scientific category, countries or institutions that have contributed to this type of bibliometric studies. For this purpose, the two reference databases in research have been used: Web of Science and Scopus. The result of this analysis leads us to focus on the case of Medicine and Environmental Sciences.

Based on this global vision, we focus on the study of the degree of transfer between basic research and applied research in the fields of Health and Agronomy. The SciVal bibliometric indicator "Patent-Cited Scholarly Output" has been used to measure the degree of transfer between total publications and publications cited in patents. Based on the results of this indicator, a study has been made of the quality of these publications, the countries that contribute most, their evolution, impact and visibility. To complement this research, the new TIP indicator is proposed, which measures the percentage of publications cited in patents with respect to the total number of publications indexed for an institution. The TIP makes it possible to measure the impact of the scientific production of universities in terms of its transfer in relation to patents, thus establishing a relationship between basic research and applied research for a given institution.

Finally, all the scientific literature on desalination worldwide is also analyzed in order to analyse research trends in this field. To this end, a bibliometric study has been carried out, analysing the evolution of publications by year, the countries and affiliations that contribute most to this scientific field, and through the key words of the articles, analysing the scientific communities in which these works can be grouped.

Capítulo 1. Introducción

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1.1 Antecedentes

La Real Academia Española [1] define la Ciencia como el "conjunto de conocimientos obtenidos mediante la observación y el razonamiento, sistemáticamente estructurados y de los que se deducen principios y leyes generales con capacidad predictiva y comprobables experimentalmente". Por otro lado, define la innovación como la "creación o modificación de un producto, y su introducción en un mercado" y la tecnología como el "conjunto de teorías y de técnicas que permiten el aprovechamiento práctico del conocimiento científico".

Ambos conceptos, Ciencia e Innovación tecnológica, están estrechamente relacionados con la forma en que se transfiere la Ciencia. Las publicaciones científicas son el canal de transferencia de la Ciencia a la sociedad ya que la investigación genera hallazgos de los que hay que informar a través de publicaciones. De esta forma, la Ciencia como bien público y dinámico accesible a la sociedad adopta como canal de comunicación las publicaciones científicas.

La innovación tecnológica está inevitablemente asociada a las patentes ya que son el instrumento que permiten fomentar no sólo el desarrollo tecnológico sino también el económico, promoviendo la competencia y la motivación financiera. Ciencia, innovación y desarrollo son conceptos totalmente conectados que establecen la base de los parámetros desarrollados en esta tesis doctoral, cuyo objetivo, como se desarrollará más adelante, pretende demostrar la relación entre la investigación básica desarrollada y su transferencia en el ámbito industrial a través de su contribución al desarrollo de patentes.

La base de este estudio está en la Bibliometría, entendida como la disciplina que permite medir el desarrollo de la Ciencia a través del impacto de las publicaciones científicas y su aplicación al ámbito de la innovación en forma de patentes.

Desde su origen, a principios del siglo XX, a la actualidad los estudios de bibliometría se han centrado en diferentes puntos de vista. En 1917 Cole y Eales [2] realizan el primer estudio bibliométrico mediante el análisis estadístico de publicaciones sobre anatomía comparada, iniciándose así el uso de la Bibliometría para la medición de la actividad científica. Siguiendo esta misma línea, en 1926 Lotka [3] centra su trabajo en analizar la producción científica de los investigadores con la denominada Ley de productividad de Lotka, ley que determina que el mayor número de autores publican el menor número de publicaciones, mientras que el menor número de autores publican el mayor número de publicaciones. Es en 1963 cuando Price [4] introduce un nuevo elemento en el desarrollo de la Bibliometría al relacionar el crecimiento de la ciencia con la comunicación científica. Previamente, en 1956 formula la Ley de Crecimiento Exponencial de la Información Científica constatando que ésta crece a un ritmo muy superior al de otros procesos sociales. Price también expone que la literatura científica pierde vigencia más rápidamente, aunque no de forma uniforme en función de las diferentes disciplinas. De esta forma, mientras que en las ciencias experimentales y en la tecnología el crecimiento en número de publicaciones es mayor y más rápido su obsolescencia es más rápida, al contrario del comportamiento observado en las humanidades y ciencias sociales.

Una segunda vertiente de la Bibliometría se orienta al estudio de las publicaciones, de la literatura científica. En 1927 Gross y Gross [5] realizaron el primer recuento de referencias que aparecían en el Journal of the American Chemical Society para estudiar la frecuencia de su aparición y las fuentes de procedencia de estas, aplicando el estudio a la selección de la lista de suscripciones de interés. En 1934 Bradford [6] analiza la distribución de los artículos en las revistas formulando la Ley de Dispersión de Bradford, según la cual se evidencia que un reducido número de revistas concentraba el porcentaje mayoritario de la bibliografía de una materia. Si las revistas científicas se disponen en orden decreciente de productividad de artículos sobre una materia determinada, puede distinguirse un núcleo de revistas más especializadas en esa materia y varios grupos que contienen aproximadamente el mismo núcleo, pero distribuido en un número de revistas cada vez mayor.

El tercer punto de vista se centra en el estudio del impacto y la visibilidad de la investigación a través del análisis de citas. Ya en 1873 Shepard elaboró un índice de citas siguiendo la codificación que se aplicaba a las sentencias de juicios federales en Estados Unidos. En 1936 Cason y Lubotky [7] crean por primera vez una red de citas determinando las relaciones de conexión entre las revistas de Psicología. Pero sin duda, el precursor del análisis de citas es Garfield [8] publicando en 1955 en la revista Science la propuesta de un índice de citas, basado en la idea de Sherpad, que permitía *relacionar un artículo con otros que le citaban. De esta forma era posible evaluar la importancia de un trabajo y su impacto y que los investigadores conocieran el uso que se hacía de sus publicaciones. Estamos hablando del famoso Science Citation Index (SCI) creado por Garfiled desde el ISI (Institute for Scientific Information), institución también fundada por el propio Garfield. A principios de los 60, Garfield junto con Sher diseñan el Factor de Impacto. La importancia del Factor de Impacto se centra en ser el instrumento metodológico que permite seleccionar las revistas que forman parte del Science Citation Index ya que era inviable poder incluir todas las revistas científicas existentes en el mismo. Años más tarde, junto al Science Citation Index (centrado en Ciencias Experimentales y Tecnológicas), crea el Social Science Citation Index (orientado a las Ciencias Sociales) y el Arts and Humanities Citation Index (AHCI) para Artes y Humanidades. Estas tres bases de datos han supuesto un hito en la Bibliometría y se han convertido en referentes en la evaluación de publicaciones, investigadores e instituciones. Forman parte de la plataforma de bases de datos Web of Science, conocida en sus orígenes como ISI Web of Knowledge y propiedad en la actualidad de Clarivate Analytics.*

Como hemos visto, la Bibliometría ha evolucionado desde sus orígenes hasta la actualidad. En estos momentos, nos encontramos con un importante incremento de las publicaciones sobre esta disciplina, estrechamente ligado al crecimiento exponencial de la Ciencia. Esta tendencia se ha clasificado en tres grandes enfoques siguiendo a López-Robles, José-Ricardo [9]:

1. *Estudios bibliométricos de rendimiento sobre autoría y producción: se centran en analizar los perfiles de los autores atendiendo a elementos como su filiación, país o género, y la producción de artículos, examinando cuáles son los más citados o relevantes;*
2. *Estudios bibliométricos sobre temáticas: se centran en abordar cuáles son los principales temas tratados, así como sus relaciones o evolución;*
3. *Estudios sobre metodologías de investigación: se centran en cuáles son los métodos y técnicas de investigación con los que se han construido los trabajos publicados en las revistas.*

Desde una perspectiva científica, diferentes análisis han utilizado técnicas de bibliometría demostrado el impacto de las redes de cooperación en I+D en la producción de publicaciones científicas. Como manifiesta A. Hidalgo [10], uno de los fenómenos más importantes que caracterizan el proceso innovador en la sociedad actual es el derivado de la globalización. Este hecho afecta directamente a la interacción entre empresa y distintas instituciones de investigación, tanto públicas como privadas, y entre ellas a las universidades. La necesidad y la utilidad entre el entorno científico y empresarial, está impulsada por una serie de factores, entre los que podemos destacar:

- *La necesidad de aunar todos los recursos disponibles para hacer frente a los continuos cambios tecnológicos*
- *El uso más eficiente de los recursos para la transferencia de tecnología y propiedad industrial entre la universidad, organismos públicos de investigación y las empresas*
- *El desarrollo de las nuevas tecnologías introduce un nuevo tipo de relación entre el conocimiento científico y la actividad productiva que debe de hacer frente a la rapidez de los cambios, a la globalización e internacionalización de la economía, así como a nuevas formas de control y gestión ante situaciones de mayor incertidumbre, complejidad y opciones no convencionales.*

Como afirma Hidalgo [10], la cooperación tecnológica con otras empresas y en particular con los agentes del entorno científico (universidades y centros públicos de I+D) es un medio poderoso para incrementar el éxito de la innovación.

Y, ¿cómo proteger esa innovación? Los derechos de propiedad industrial están regulados en base a la Ley 24/2015, de 24 de julio, de Patentes [11]. El artículo 1 de la mencionada Ley establece que "Para la protección de las invenciones industriales se concederán, de acuerdo con lo dispuesto en la presente Ley, los siguientes títulos de Propiedad Industrial:

a) Patentes de invención.

b) Modelos de utilidad.

c) Certificados complementarios de protección de medicamentos y de productos fitosanitarios".

El registro de los títulos reconocidos en esta Ley tiene carácter único en todo el territorio español y su concesión corresponde a la Oficina Española de Patentes y Marcas, salvo lo previsto en los tratados internacionales en los que España es parte o en el derecho de la Unión Europea (artículo 2.1). Y son patentables, en todos los campos de la tecnología, las invenciones que sean nuevas impliquen actividad inventiva y sean susceptibles de aplicación industrial (artículo 4.1).

Por lo tanto, las patentes son un indicador del rendimiento de las organizaciones y aportan información muy relevante sobre el grado de colaboración y los resultados obtenidos de la misma. Como indicadores de actividad tecnológica, en 1966 Schmookler llevo a cabo uno de los primeros estudios en el que las patentes eran analizadas con este fin. Desde entonces hasta ahora las patentes se han utilizado como indicador para analizar la innovación y la capacidad tecnológica de cualquier organización.

Las fuentes de datos son generalmente organismos oficiales como la Oficina Española de Patentes (OEPM) [12], la Oficina Europea de Patentes (EPO) [13] o la Oficina Norteamericana de Patentes (USPTO) [14] a través de bases de datos de libre acceso como Espacenet [15] o Patentscope [16], aunque también existen herramientas comerciales que permiten acceder a patentes como Derwent Innovation Index [17] de Clarivate.

Si bien estas bases de datos permiten analizar múltiples indicadores extraídos del documento de una patente (como por ejemplo tasa de denegación, causas de esta, fondos de proyectos…), es complicado establecer una clara relación entre el documento de patente y las publicaciones científicas que han aportado conocimiento para dar lugar a esa patente. Es decir, ver la relación existente entre la investigación básica y la investigación aplicada.

La motivación para llevar a cabo este trabajo está precisamente en este aspecto: ¿cómo relacionar la investigación básica y la investigación aplicada?, ¿cómo analizar la aportación de la investigación básica a la investigación aplicada medida en forma de patentes?, ¿en qué medida se contribuye a la generación de patentes?, ¿qué países, instituciones lideran o en qué temas se produce esta transferencia? Y, sobre todo, ¿cómo medirlo?

1.2 Motivación y Justificación

Bibliometría e indicadores bibliométricos forman un todo que nos sirve para evaluar y medir la producción científica en todos sus aspectos. Un indicador bibliométrico es un parámetro que mide algún aspecto de la actividad científica. Y para medir, tenemos que medir sobre un conjunto de datos que están recogidos en bases de datos especializadas en dar visibilidad a las publicaciones científicas y en valorar el impacto de la investigación en los diferentes campos de la ciencia. Las dos bases de datos que permiten este análisis son Web of Science y Scopus, ambas con un sesgo claramente comercial. Basadas en estas dos bases de datos, tanto Clarivate como Elsevier han desarrollado aplicaciones que permiten a las instituciones evaluar su investigación desde varias perspectivas con el objeto de poder establecer y valorar estrategias basadas en datos confiables.

InCites [18] utiliza datos desde 1980 procedentes de la Web of Science Core Collection para facilitar el análisis de organizaciones: actividad, impacto, colaboraciones permitiendo realizar comparaciones. Permite la búsqueda por investigadores o grupos de investigación con el objeto de analizar su producción. La búsqueda por áreas de conocimiento da una visión de los campos emergentes. También es posible hacer un análisis de las revistas en las que se publica y de las agencias financiadoras. Todas estas variables (institución, investigador, área, fuente de publicación, financiación) son fácilmente combinables para poder realizar análisis aplicando y combinando diferentes métricas (de productividad, de impacto, de colaboración, de acceso abierto) y generar todo tipo de informes. Como novedad, desde diciembre de 2020, InCites permite el análisis de topics, clasificándolos en macro, meso y micro topics gracias a la colaboración entre el ISI y Centre for Science and Technology Studies (CWTS) y la utilización del algoritmo desarrollado por CWTS que permite detectar y conectar comunidades [19].

Basada en el análisis de los datos procedentes de Scopus [20], SciVal ofrece acceso a más de 50 millones de registros de publicaciones (posteriores a 1996) de más de 22,000 revistas de más de 5,000 editoriales en todo el mundo. Analiza la producción científica de más de 230 países y 14.000 instituciones permitiendo visualizar el rendimiento de la investigación, hacer comparativas, analizar tendencias y evaluar colaboraciones. También permite el análisis de topic, clasificándolos en topic name y topic clúster.

Al igual que InCites, Scival permite generar informes de análisis y visualización de datos combinando una gran cantidad de métricas que valoran el impacto económico, la productividad, el impacto de las citas, el uso, las colaboraciones y la comunicación.

Cuando hablamos de indicadores bibliométricos, el factor de impacto es el principal referente desde la década de 1960, en base también a la relación que en 1979 Garfield [21] estableció entre el carácter de la investigación y su potencialidad para recibir citas, sin embargo, es objeto de múltiples críticas. Ya en 1986 Tomer [22] consideraba que " No hay distinción en cuanto a la naturaleza y los méritos de las revistas de citación ". Anteriormente en 1976 Pinski y Narin [23] advirtieron de la existencia de un sesgo a favor de los reviews, que tienden a tener mayor factor de impacto y en el *cálculo del factor de impacto todas las citas se ponderan por igual. Para corregir esta desviación sugieren la "influence methodology" dotando a cada revista de un peso independientemente de su tamaño. Estos desacuerdos se han dilatado a lo largo del tiempo, en 2001 Tijssen, Visser y Van Leeuwen [24] cuestionaron el análisis de citas como medida para la calidad de la investigación ya que la influencia de la cita varía en las distintas áreas evidenciando diferencias considerables. Las limitaciones como la asimetría entre el numerador y el denominador, las diferencias entre las disciplinas, la insuficiente ventana de citación y la asimetría de las distribuciones de citación subyacentes también ha sido analizada por Larivière y Sugimoto en 2019 [25].*

El JCR Impact Factor (SCI, SSCI) no es la única métrica que mide el factor de impacto. El SJR (Scimago Journal Rank), desarrollado por SCImago España muestra la visibilidad de las revistas contenidas en Scopus desde 1996. Esta métrica se aplica a revistas, series de libros y actas de congresos. Basada en las citas, muestra la calidad y reputación de la revista en campos temáticos, realizando un cálculo de las citas recibidas a artículos de una revista para un periodo de tres años dando un mayor peso a las citas procedentes de revistas de alto prestigio. El SJR Indicator trata de corregir estas desviaciones ponderando los vínculos en base a la cercanía de la citación, ampliando el número de años considerados en la citación y poniendo umbrales a la autocitación dentro de la propia revista [26].

A finales de 2016 [27], Scopus establece un nuevo indicador métrico, el CiteScore que amplía el rango de años en la citación (4 años), pero al incluir todo tipo de documentos, por un lado, se eliminan las diferencias entre los distintos tipos de documentos, aunque por otro lado algunos críticos manifiestan que este indicador favorece a las publicaciones de Elsevier que tienden a publicar una proporción menor de artículos que otras editoriales [28].

Y, como última novedad [29], la transición a un modelo en el que se va a tener en cuenta la fecha de la publicación en línea y no la fecha de la publicación impresa va a afectar en el cálculo del Journal Impact Factor (JIF). Este cambio supone un problema para las bases de datos que no dispongan de fecha de publicación en línea, como es el caso de Web of Science en la que la mitad de las revistas que indexan carecen de este dato. Si una publicación se publica en línea el mismo año que de forma impresa, no existe ningún tipo de desajuste ya que el JIF es del mismo año. No es el caso de revistas publicadas en línea en un año y de forma impresa en otro. Desde Clarivate se están considerando los efectos de adoptar dos nuevos modelos de conteo: uno anterior a 2020 y otro posterior a 2020 [30].

Pero no sólo contamos con el factor de impacto como indicador bibliométrico para medir el impacto de la investigación. Son múltiples los indicadores que nos permiten analizar la investigación, como se muestra en el siguiente cuadro:

Tabla 1. Principales indicadores científicos

InCites Indicators	***SciVal Indicators***
Impact Indicators *Times Cited* *% Documents Cited* *Documents Cited* *Citation Impact* *Average Percentile* *Journal Normalized Citation Impact* *Impact Relative to World* *H-index* *1 Year Citing All Prior Years Cumulative* *Category Normalized Citation Impact (CNCI)*	***Collaboration Indicators*** *Collaboration* *Collaboration Impact* *Academic-Corporate Collaboration* *Academic-Corporate Collaboration Impact*
Productivity Indicators *Web of Science Documents* *ESI Most Cited* *% Documents in Top 1%* *% Documents in Top 10%* *Documents in Top 1%*	***Published indicators*** *Scholarly Output* *Subject Area Count* *Scopus Source Title Count* *h-indices*

Documents in Top 10% *% Highly Cited Papers* *Highly Cited Papers* *% Hot Papers* *Hot Papers* *Documents in JIF Journals* *Documents in Q1 - Q4 Journals* *% Documents in Q1 - Q4 Journals*	
Collaboration Indicators *Industry Collaboration* *% Industry Collaborations* *International Collaboration* *% of International Collaborations*	***Viewed Indicators*** *Views Count* *Outputs in Top Views Percentiles* *Views per Publication* *Field-Weighted Views Impact*
Open Access Indicators *All Open Access Documents* *DOAJ Gold Documents* *Other Gold Documents* *Green Accepted Documents* *Green Published Documents* *Bronze Documents* *% All Open Access Documents* *% DOAJ Gold Documents* *% Other Gold Documents* *% Green Accepted Documents* *% Green Published Documents* *% Bronze Document*	***Cited Indicators*** *Citation Count* *Field-Weighted Citation Impact* *Outputs in Top Citation Percentiles* *Publications in Journal Quartiles* *Publications in Top Journal Percentiles* *Citations per Publication* *Cited Publications* *h-indices* *Number of Citing Countries* *Collaboration Impact* *Academic-Corporate Collaboration Impact* *Citing-Patents Count* *Patent-Cited Scholarly Output* *Patent-Citations Count* *Patent-Citations per Scholarly Output*
Author Position Indicators *First Author (2008-2020)* *Last Author (2008-2020)* *Corresponding Author (2008-2020)* *% First Author (2008-2020)* *% Last Author (2008-2020)* *% Corresponding Author (2008-2020)*	***Economic Impact Indicators*** *Academic-Corporate Collaboration* *Academic-Corporate Collaboration Impact* *Citing-Patents Count* *Patent-Cited Scholarly Output* *Patent-Citations Count* *Patent-Citations per Scholarly Output*
Journal Citation Reports Data Indicators *Journal Impact Factor Quartile* *Cited Half-life* *Article Influence* *Immediacy Index* *Eigenfactor* *5-Year Journal Impact Factor* *Journal Impact Factor Without Self Cites* *Journal Impact Factor*	***Societal Impact Indicators*** *Mass Media* *Media Exposure* *Field-Weighted Mass Media*
Reputation Indicators *Acad staff int / Acad staff* *Acad staff / Stdnt* *Doctoral degree / Acad staff norm* *Doctoral degree / Undergrad degree* *Inst income / Acad staff*	***Awarded Grants Indicators*** *Awards Volume*

Category normalized citation impact - country / region adj *Papers / Acad and res staff - norm* *Papers int co-author / Papers* *Res income / Acad staff - norm* *Res income ind / Acad staff* *Res reputation - global* *Stdnt int / Stdnt* *Teaching reputation - global*	
Other Indicator *Organization Name* *Country/Region* *Rank* *Organization Type* *Level* *State/Province*	

Esta amplia gama de indicadores bibliométricos que nos permiten evaluar la actividad científica, pero es importante hacer un uso responsable de las métricas. Hay que tener en cuenta qué se quiere medir, aplicar la métrica adecuada, detectar posibles desviaciones, hacer un adecuado análisis, etc. En este sentido el Manifiesto de Leiden de 2015 [31] establece 10 principios básicos que no debemos olvidar en la utilización de las métricas y la Declaración de San Francisco [32] sobre la Evaluación de la Investigación establece 18 recomendaciones en el mismo sentido.

A pesar de esta extensa variedad de indicadores se echa en falta formas de medir la relación entre la investigación básica y la investigación aplicada. Tomando como base el indicador de SciVal Patent-Cited Scholarly Output, que permite buscar las publicaciones que han sido citadas en al menos una patente, se ha generado un nuevo indicador al que se ha denominado TIP (Índice de Transferencia en Patentes). El TIP permite establecer una relación entre la investigación básica y la investigación aplicada para una determinada institución.

Igualmente, partiendo de los resultados obtenidos con la aplicación del indicador Patent-Cited Scholarly Output, se han analizado las tendencias en cuanto a instituciones, países, topic clusters, impacto real y esperado de las publicaciones, para determinados campos de la Ciencia: Medicina, Agronomía, Ciencias Medioambientales y Desalinización, partiendo de un enfoque global enmarcando la Bibliometría desde las primeras publicaciones en esta disciplina a la actualidad.

1.3 Objetivos

El objetivo principal de esta tesis doctoral se centra en analizar la transferencia entre la investigación básica materializada en publicaciones científicas y la investigación aplicada concretada en patentes. Para ello se han aplicado diferentes indicadores bibliométricos que permiten medir tanto el impacto de la investigación básica en el desarrollo de patentes, así como la calidad de las publicaciones y su visibilidad a nivel de países, instituciones, colaboraciones internacionales, publicación en acceso abierto, financiación y desarrollo temporal.

Este objetivo principal se ha desarrollado a través de tres publicaciones. La primera publicación ("The Bibliometric Literature on Scopus and WoS: The Medicine and Environmental Sciences Categories as Case of Study") contextualiza todos los trabajos bibliométricos realizados desde 1996 a 2020 para analizar si existe algún sesgo hacia alguna categoría científica, o si hay países o instituciones que dedican un mayor esfuerzo a este tipo de publicaciones. Así mismo analiza qué consideración tienen mayormente estos trabajos tanto si se consideran como revisiones o como artículos, y qué nivel de citas alcanzan según la categoría en la que están indexadas. Para llevar a cabo este estudio, se parte de las publicaciones indexadas en Scopus y Web of Science bajo el criterio de búsqueda "bibliometric" en palabras clave del autor y título. Una vez procesados los datos con diferentes herramientas (Scopus API, Microspft Excel, Gephi y ArcGIS) y analizados con SciVal Benchmarking e InCites Analyze, se muestran los resultados de la evolución temporal y tipo de documento; países, afiliaciones y colaboraciones internacionales; categorías y áreas; temática analizada a través de los topic name y topic cluster de SciVal y los macro topic, meso topic y micro topic de InCites; cluster de citas y palabras clave; y revistas en las que se ha publicado, analizando en este caso el impacto conseguido en JCR (Journal Citation

Report) y SJR (SCImago Journal Rank) y el impacto esperado a través del FWCI (Field-Weighted Citation Impact) de SciVal y el CNCI (Category Normalized Citation Impact) de InCites. Por último, el artículo se completa con el estudio de caso de las categorías de Medicina y Ciencias Ambientales.

La segunda publicación ("The Contribution of Spanish Science to Patents: Medicine as Case of Study") tiene un doble objetivo. Por un lado, ofrecer una perspectiva global de la transferencia de conocimiento que realizan las universidades españolas, entendida como la influencia de sus publicaciones científicas en patentes, es decir, aquellas publicaciones que han sido citadas en patentes. Dentro de esta perspectiva global, se analiza el impacto de esta transferencia en el campo de la Medicina, ya que es una de las actividades de investigación más destacadas en España. Por otro lado, se propone la elaboración de un índice que clasifica las universidades en función de su transferencia y, en particular, de las publicaciones citadas en patentes. Este nuevo indicador TIP (Índice de Transferencia en Patentes) permite establecer una relación entre la investigación básica y la investigación aplicada para una determinada institución. Esta investigación se ha realizado en base a datos obtenidos de Scopus analizados a través del indicador bibliométrico Patent-Cited Scholarly Output de SciVal, que permite obtener las publicaciones que han sido citadas en patentes. Los datos analizados comprenden la ventana temporal de 1998 a 2018 para todo tipo de documentos y todas las oficinas de patentes recogidas en SciVal (EPO – European Patent Office, USPTO – U. S, Patent Oficce, UK IPO – UK Intellectual Property Office, JPO – Japan Patent Office, WIPO – World Intellectual Property Organization). Los resultados presentan el análisis de las publicaciones (evolución temporal, países, afiliaciones y colaboraciones, áreas temáticas generales y en particular las centradas en el campo de la Medicina), de las revistas científicas en las que se ha publicado señalando el impacto de las mismas y de las instituciones que han aportado a la transferencia y la innovación en este sentido. Los indicadores bibliométricos que se han utilizado han permitido medir el impacto de las publicaciones (FWCI, Topic Prominence y Topic Cluster Prominence), de las revistas en las que se ha publicado (SJR Rank, SJR Category, Impact SJR, Scopus Cite Score, JCR Rank, JCR Category, Impact factor JCR, 5 year Journal Impact Factor JCR) y el nivel de publicación en cada institución. Para complementar esta investigación se propone el nuevo indicador TIP que mide el porcentaje de publicaciones citadas en patentes con respecto al total de publicaciones indexadas para una institución. El TIP permite medir el impacto de la producción científica de las universidades en su transferencia respecto a las patentes, estableciendo así una relación entre la investigación básica y la investigación aplicada para una determinada institución.

Con respecto a la tercera publicación ("Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27") el objetivo se centra en el estudio del impacto que ha tenido en patentes la investigación llevada a cabo en Agronomía por los países de la Unión Europea. Para ello se analizan todas las publicaciones en el campo científico de la Agricultura y Ciencias Biológicas de la Europa de los 27 (EU-27): Alemania, Austria, Bélgica, Bulgaria, Chipre, Croacia, Dinamarca, Eslovaquia, Eslovenia, España, Estonia, Finlandia, Francia, Grecia, Hungría, Irlanda, Italia, Letonia, Lituania, Luxemburgo, Malta, Países Bajos, Polonia, Portugal, República Checa, Rumanía y Suecia. Teniendo en cuenta el concepto de "Patentometrics" y "Triple Helix", conceptos que hacen referencia al análisis estadístico de las patentes y a la teoría académica que sostiene que el potencial de desarrollo de la economía del conocimiento en regiones o países reside en la estrecha colaboración de empresas, universidades y gobiernos basada en nuevas fórmulas institucionales diseñadas para la producción, transferencia y aplicación del conocimiento, se analizan los resultados obtenidos a partir de dos estrategias de búsqueda. La primera se centra en todas las publicaciones indexadas en Scopus para la Subject Area Agricultural and Biological Sciences en el periodo 1999-2019 en los países de la UE-29. La segunda búsqueda extrae de la búsqueda anterior las publicaciones que han sido citadas en patentes (Patent-Cited Scholarly Output) para todo tipo de documentos y todas las oficinas de patentes recogidas en SciVal (EPO – European Patent Office, USPTO – U. S, Patent Oficce, UK IPO – UK Intellectual Property Office, JPO – Japan Patent Office, WIPO – World Intellectual Property Organization). El procesamiento de los datos, a través de herramientas como Scopus API, Microsoft Excel y ArcGIS, muestran resultados de tendencia temporal global; países, afiliaciones y colaboraciones; revistas principales utilizadas para las publicaciones citadas en patentes; calidad de los artículos; acceso abierto y las agencias de financiación europeas; y temas de las publicaciones citadas en patentes. Destacar en esta publicación la aplicación del TIP (Índice de Transferencia en Patentes) en la relación entre todo lo publicado en el campo de la Agricultura y Ciencias Biológicas y su transferencia a patentes para las Top 20 instituciones en transferencia en esta materia y el análisis de las publicaciones que han sido financiadas por programas europeos y de las que están en acceso abierto.

La cuarta publicación ("Worldwide Research Trends on Desalination"), en revisión en la revista Desalination, tiene como objetivo examinar toda la literatura científica sobre desalación a nivel mundial para analizar las tendencias de la investigación en este campo. Para ello, se ha realizado un estudio bibliométrico, analizando la evolución de las publicaciones por años, los países y afiliaciones que más contribuyen a este campo científico, y a través de las palabras clave de los artículos, analizar las comunidades científicas en las que se pueden agrupar estos trabajos. Este análisis se ha basado en la base de datos Scopus. Aunque el contenido histórico de Scopus se remonta a 1788, la búsqueda se ha limitado de 2000 a 2020, utilizando el término de búsqueda "desalination" en TITLE-ABS-KEY. Se han utilizado la API de Scopus para la recuperación automática de datos y el procesamiento de los datos se ha realizado con diferentes herramientas: Microsoft Excel, Gephi y ArcGIS para el análisis y la representación de los resultados

1.4 Metodología

Todo este planteamiento se ha materializado en 3 artículos científicos publicados en revistas internacionales indexadas en Journal Citation Report (JCR) y en Scimago Journal Rank (SJR) cuya metodología especifica se cita en cada uno de estos trabajos.

***Publicación científica 1**.*

"The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study" publicado en International Journal of Environmental Research and Public Health.

En esta publicación, descrita en el capítulo 2, se analiza la evolución de las publicaciones en las que la Bibliometría aparece como palabra clave descrita por el autor o en el título de la publicación, destacando el papel predominante de las publicaciones en el campo de la Medicina y Ciencias Mediambientales

Referencia de la publicación:

***Título**: "The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study"*

***Autores**: Cascajares, M.; Alcayde, A.; Salmerón-Manzano, E.; Manzano-Agugliaro, F*

***Revista científica**: International Journal of Environmental Research and Public Health*

***Volumen**: 18, 5851*

***Páginas**: 1-31*

***Año:** 2021*

***ISSN**: 1661-7827, 1660-4601*

***DOI**: 10.3390/ijerph18115851*

Datos JCR (Journal Citation Reports):

***Journal Impact Factor (2019):** 2.849*

***Categoría**: PUBLIC ENVIRONMENTAL & OCCUPATIONAL HEALTH*

***Ranking categoría**: 32/171*

***Cuartil**: Q1*

Datos SJR (Scimago Journal Rank):

***SJR Indicator**: 0.739*

***Categoría**: Public Health, Environmental and Occupational Health*

***Ranking categoría**: 165/559*

***Cuartil**: Q2*

***Editor**: MDPI*

***País**: Switzerland*

Publicación científica 2.

"The Contribution of Spanish Science to Patents: Medicine as Case of Study", publicado en International Journal of Environmental Research and Public Health.

En el capítulo 3 se presenta esta publicación, cuyo objetivo es analizar la investigación en I+D que se ha reflejado en patentes a nivel global en el periodo 1998-2018 y su aplicación concreta al campo de la Medicina.

Referencia de la publicación:

***Título**: "The Contribution of Spanish Science to Patents: Medicine as Case of Study"*

***Autores**: Cascajares, M.; Alcayde, A.; Garrido-Cardenas, J.A.; Manzano-Agugliaro, F.*

***Revista científica**: International Journal of Environmental Research and Public Health*

***Volumen**: 17, 3638*

***Páginas**: 1-24*

***Año:** 2020*

***ISSN**: 1661-7827, 1660-4601*

***DOI:** 10.3390/ijerph17103638*

Datos JCR (Journal Citation Reports):

***Journal Impact Factor (2019):** 2.849*

***Categoría**: PUBLIC ENVIRONMENTAL & OCCUPATIONAL HEALTH*

***Ranking categoría**: 32/171*

***Cuartil**: Q1*

Datos SJR (Scimago Journal Rank):

***SJR Indicator**: 0.739*

***Categoría**: Public Health, Environmental and Occupational Health*

***Ranking categoría**: 165/559*

***Cuartil**: Q2*

***Editor**: MDPI*

***País**: Switzerland*

Publicación científica 3.

"Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27" publicado en Agronomy

En el capítulo 4 se presenta esta publicación, cuyo objetivo es visualizar el nivel de transferencia de la investigación básica a patentes en el campo de la Agricultura en la Europa de los 27.

Referencia de la publicación:

***Título**: "Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27"*

***Autores**: Cascajares, M.; Alcayde, A.; Salmerón-Manzano, E.; Manzano-Agugliaro, F.*

***Revista científica**: Agronomy*

***Volumen**: 11, 252*

***Páginas**: 1-25*

***Año:** 2021*

***ISSN**: 2073-4395*

***DOI:** 10.3390/agronomy11020252*

Datos JCR (Journal Citation Reports):

***Journal Impact Factor (2019):** 2.063*

***Categoría**: AGRONOMY*

***Ranking categoría**: 18/91*

***Cuartil**: Q1*

Datos SJR (Scimago Journal Rank):

***SJR Indicator**: 0.700*

***Categoría**: Agronomy and Crop Science*

***Ranking categoría**: 72/363*

***Cuartil**: Q1*

***Editor**: MDPI*

***País**: Switzerland*

***Publicación científica 4**.*

“Worldwide Research Trends on Desalination”, en revisión en la revista Desalination

En el capítulo 5 se presenta esta publicación, cuyo objetivo es examinar toda la literatura científica sobre desalación a nivel mundial para analizar las tendencias de la investigación en este campo.

Referencia de la publicación:

***Título**: “Worldwide Research Trends on Desalination”*

***Autores**: Antonio Zapata-Sierra, Mila Cascajares, Alfredo Alcayde, Francisco Manzano-Agugliaro*

***Revista científica**: Desalination*

***ISSN**: 0011-9164*

Datos JCR (Journal Citation Reports):

***Journal Impact Factor (2019):** 7.098*

***Categoría**: ENGINEERING, CHEMICAL*

***Ranking categoría**: 11/143*

***Cuartil**: Q1*

***Categoría**: WATER RESOURCES*

***Ranking categoría**: 2/94*

***Cuartil**: Q1*

Datos SJR (Scimago Journal Rank):

SJR Indicator*: 1.814*

Categoría*: Chemical Engineering (miscellaneous)*

Ranking categoría*: 15/376*

Cuartil*: Q1*

Categoría*: Chemistry (miscellaneous)*

Ranking categoría*: 38/463*

Cuartil*: Q1*

Categoría*: Mechanical Engineering*

Ranking categoría*: 27/797*

Cuartil*: Q1*

Categoría*: Water Science and Technology*

Ranking categoría*: 7/263*

Cuartil*: Q1*

Categoría*: Materials Science (miscellaneous)*

Ranking categoría*: 54/625*

Cuartil*: Q1*

Editor*: Elsevier*

País*: Netherlands*

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Capítulo 2.

The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study

2 Capítulo 2. The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study

2.0 Abstract

Nowadays science is understood as those works published in scientific journals. And scientific Today, science is understood as manuscripts published in scientific journals. Scientific journals are considered as such if they are indexed in scientific databases. Therefore, research and dissemination of scientific knowledge are essential activities for the growth of science itself. The aim of this manuscript is to assess the situation of medicine and environmental sciences among the bibliometric literature and to put it in perspective with the overall bibliometric publications in all scientific fields. The main countries publishing bibliometric manuscripts are China, USA and Spain. The latter country is ranked 3 out of the top 5 institutions according to the Scopus and WoS databases. In both databases, the average scientific collaboration of the top 20 institutions offers the same result, 41%. According to Scopus, the main subject categories in which this research falls are social sciences (38%), computer science (26%) and medicine (23%), while the environmental sciences category has 8%. In the analysis of the Medicine category alone, it has been observed that 136 countries have contributions in this field. The main countries are United States, China and United Kingdom. In the field of medicine, the main areas studied were: Epidemiology, Pediatrics, Orthopedics, Cardiology, Neurosurgery, Radiology, Ophthalmology, Oncology, Plastic Surgery, and Psychiatry. With respect to environmental sciences, less international dissemination has been found, with only 83 countries having worked in this field. The main ones are China, Spain and United States. Regarding the top 10 institutions, it can be stated that only Spain and China are relevant. Spain focuses on sustainability and China on the environment. The result of an independent keyword analysis of all published bibliometric manuscripts has shown that the main clusters are: Mapping Science (29%), Research Productivity (23%), Medicine (20%), Environmental Sciences (12%), Psychology (7%), Nursing (6%) and Engineering (4%). In short, medicine and environmental sciences are the most relevant areas in the field of bibliometrics after social sciences and computer sciences.

2.1 Introduction

Bibliometrics, as a science-related discipline, aims to provide a set of tools for the assessment of scientific production. From its origin at the beginning of the 20th century to the present day, bibliometric studies have focused on different points of view. In 1917 Cole and Eales carried out the first bibliometric study through the statistical analysis of publications on comparative anatomy [1], thus initiating the use of Bibliometrics for the measurement of scientific activity. Following this same approach, in 1926 Lotka focused his work on analyzing the scientific production of researchers with the so-called Lotka's Law of Productivity, a law that determines that the greatest number of authors publish the least number of publications, while the least number of authors publish the greatest number of publications [2]. In 1956, Price formulated the Law of Exponential Growth of Scientific Information, stating that it grows at a much faster rate than other social processes. Price also states that the scientific literature loses relevance more rapidly, although not in a uniform manner depending on the different disciplines. Thus, while in the experimental sciences and technology the growth in number of publications is greater and faster, their decline is more rapid, in contrast to the behavior found in the humanities and social sciences. Later, it was in 1963 when Price introduced a new element in the development of Bibliometrics by relating the growth of science to scientific communication [3].

A second aspect of Bibliometrics is oriented to the analysis of the publications' references in the scientific literature. Thus, in 1927 Gross and Gross made the first count of references appearing in the Journal of the American Chemical Society to study the frequency of their appearance and the sources of their origin, applying the study to the selection of the list of subscriptions of interest [4]. In 1934 Bradford analyzed the distribution of articles in journals by formulating Bradford's Law of Dispersion, according to which it was evident that a small number of journals accounted for the largest percentage of the bibliography of a specific topic [5]. If scientific journals are arranged in decreasing order of productivity of articles on a given subject, one can distinguish a core of journals more specialized in that subject and *several groups containing approximately the same core but distributed in an increasing number of journals. It can be understood as the background of the classification of journals by scientific categories.*

The third point of view focuses on the analysis of the impact and visibility of research through citation activity. As early as 1873 Shepard developed a citation index following the codification applied to federal court judgments in the United States. But it was not until 1936 that Cason and Lubotky created for the first time a citation network, identifying the links between psychology journals [6]. But undoubtedly, the precursor of citation analysis is Garfield, who published in 1955 in the Science journal the proposal for a citation index [7], based on Sherpad's concept, which made it possible to relate an article to other articles citing it. In this way it was possible to assess the significance of a research paper and its impact, and for researchers to know how their publications were being used. This is the renowned Science Citation Index (SCI) created by Garfield himself from the ISI (Institute for Scientific Information). In the early 1960s, Garfield and Sher designed the Impact Factor.

The purpose of the Impact Factor was to be the methodological instrument for selecting the journals that belong to the Science Citation Index, since it was unfeasible to include all the existing scientific journals in it. Years later, in addition to the Science Citation Index (focused on Experimental and Technological Sciences), it created the Social Science Citation Index (oriented to the Social Sciences) and the Arts and Humanities Citation Index (AHCI) for the Arts and Humanities. These three databases have been a milestone in Bibliometrics and have become benchmarks in the evaluation of publications, researchers, and institutions. They are part of the Web of Science database platform, originally known as ISI Web of Knowledge and currently owned by Clarivate Analytics.

Although they have been the main benchmark since the 1960s, based also on the relationship that Garfield established in 1979 between the nature of the research and its potential to be cited, they have nevertheless been the focus of multiple criticisms [8]. Earlier in 1976 Pinski and Narin warned of the bias in favor of reviews, which tend to have a higher impact factor and in the calculation of the impact factor all citations are weighted equally [9]. To correct this deviation, they suggest the "influence methodology", giving each journal a weight regardless of its size. As early as 1986 Tomer thought that "There is no distinction in regard to the nature and merits of the citing journals"[10]. These disagreements have been ongoing for a long time, and they are still relevant today.

E.g. 2001 Tijssen, Visser and Van Leeuwen questioned citation analysis as a measure of research quality since the influence of citation varies in different disciplines, showing considerable differences [11]. Today, shortcomings such as asymmetry between numerator and denominator, differences between disciplines, insufficient citation window and asymmetry of underlying citation distributions has also been analyzed by Larivière and Sugimoto in 2019 [12].

The JCR Impact Factor (SCI, SSCI) is not the only metric that measures the impact factor. The SJR (Scimago Journal Rank), developed by SCImago Spain, shows the visibility of the journals contained in Scopus since 1996. This metric applies not only to journals, but also to book series and conference proceedings. Based on citations, it shows the quality and reputation of the journal in thematic fields, computing the citations received to articles of a journal for a period of three years, giving a greater weight to citations coming from high reputed journals. The SJR index attempts to correct for these deviations by weighting links based on citation proximity, extending the number of years considered in the citation, and setting thresholds for self-citation within the journal itself [13].

By the end of 2016 [14], Scopus establishes a new metric index, the CiteScore, which extends the range of citation years (4 years), but by including all types of documents, on the one hand it eliminates the differences between the different types of documents, although on the other hand some critics state that this index benefits Elsevier publications, which tend to publish a lower proportion of articles than other publishers [15].

And, as a last novelty, there is the transition of the impact factor computation with respect to the date of online publication and not the date of print publication, as until now. In the current system, there are journals that have up to more than a year to publish the article online so that it can obtain citations, and when it is published in print, its number of citations is higher than those of other journals. Therefore, there is a trend towards a model in which the online publication date will be considered for the computation of the Journal Impact Factor (JIF) [16].

This change implies a problem for databases that do not have an online publication date. Web of Science Core Collection has begun to index online-first articles since December 2017 [17]. For example, in the case of Web of Science, half of the journals indexed lack this data [16]. If a publication is published online in the same year as in print, there is no mismatch since the JIF is from the same year. This is not the case for journals published online in one year and in print in another. Clarivate is considering the effects of adopting two new counting models: one pre-2020 and one post-2020 [18].

So far Bibliometrics has progressed from its origins to the present day. At present, there is a significant increase in the number of publications on this discipline, closely linked to the exponential growth of science. This trend has been classified into three major approaches [19]:

1. Bibliometric performance studies on authorship and production: they focus on analyzing the profiles of authors according to elements such as their affiliation, country, and the production of articles, examining which are the most cited or relevant.

2. Bibliometric studies on topics: they focus on the main topics dealt with, as well as their relationships or evolution in a specific topic.

3. Studies on research methodologies: they focus on the research methods and techniques used to develop the research papers published in the journals.

Taking all these approaches into account, how can Bibliometrics be defined? From a quantitative point of view Pritchard in 1969 describes it as "studies aimed at quantifying the processes of written communication" [20]. In 1987, Broadus defined Bibliometrics as the "branch of research concerned with the quantification of the physical units of publications, bibliographic citations and their surrogates" [21]. A broader concept is included here, since it establishes relationships between publications and bibliographic links or co-citation. Moed in 1989 defines it as the "discipline that deals with the collection, processing and management of bibliographic data from the scientific literature" [22]. From this second point of view, Bibliometrics has been defined as a tool for analysis and evaluation. In 1989 White and McCain defined it as "the quantitative study of publications as reflected in the literature, in order to provide evolutionary models of science, technology and research" [23]. Spinak in 1996 refers to Bibliometrics as the study of the organization of scientific and technological sectors from bibliographic sources and patents, to identify authors, their relationships, and trends [24]. In the same line, other authors describe Bibliometrics as the discipline that tries to measure scientific and social activity and predict its trend by analyzing the literature [25].

Other concepts related to Bibliometrics are Scientometric or Infometric. Scientometric applies bibliometric techniques to science and examines scientific development and policies. Infometric is more focused on quantitative aspects of measurement and the application of mathematical models.

Bibliometrics and bibliometric indexes form a whole that serve to assess and measure scientific production in all its aspects. To measure, it is necessary to evaluate a set of data that are collected in databases specialized in giving visibility to scientific publications. A bibliometric index is a parameter that measures some aspect of scientific activity and allows to assess the impact of research in the different fields of science. The two databases that allow this analysis are Web of Science and Scopus, both with a clearly commercial bias. Based on these two databases, both Clarivate and Elsevier have developed applications that allow organizations to assess their research from different perspectives to be able to establish and evaluate strategies based on reliable data.

InCites [26] uses data from the Web of Science Core Collection since 1980 to facilitate the analysis of organizations: activity, impact, collaborations, allowing to make comparisons. It allows searching by researchers or research groups to analyze their production. The search by areas of knowledge gives an overview of emerging fields. It is also possible to analyze the journals in which they are published and the funding agencies. All these variables (affiliation, researcher, area, source of publication, funding) can be easily combined to perform analyses by applying and combining different metrics (productivity, impact, collaboration, open access) and generate all kinds of reports. As a novelty, since December 2020, InCites allows the analysis of topics, classifying them into macro, meso and micro topics thanks to the collaboration between ISI and Centre for Science and Technology Studies (CWTS) and the use of the algorithm developed by CWTS that allows to detect and connect communities [27].

Based on the analysis of data from Scopus [28], Scival offers access to more than 50 million publication records (post-1996) from over 22,000 journals from more than 5,000 publishers worldwide. It analyzes the scientific output of more than 230 countries and 14,000 institutions allowing to visualize research performance, make comparisons, analyze trends, and evaluate collaborations. It also allows the analysis of topics, classifying them into topic name and topic cluster. As InCites, Scival allows to generate data analysis and visualization reports combining many metrics that assess economic impact, productivity, citation impact, usage, collaborations and communication.

There are a large number of bibliometric metrics that allow the evaluation of scientific activity, but it is important to use these metrics correctly. It is necessary to consider what is to be measured, apply the appropriate metric, detect possible deviations, make an adequate analysis, etc. In this regard the 2015 Leiden Manifesto sets out 10 basic principles that the *use of metrics should not be forgotten [29], and the San Francisco Declaration on Research Assessment sets out 18 recommendations in the same direction [30].*

The first goal of this research is to analyze the context of all the bibliometric studies carried out from 1996 to 2020. To analyze if there is any bias towards any scientific category, or if there are countries or institutions that devote a great effort to this issue, and finally to analyze what consideration these works have mostly whether they are considered as reviews or articles, and what level of citations they have in comparison according to the categories in which they are indexed. As a second main goal, it is the case study of the categories of medicine and environmental sciences.

2.2 Materials and Methods

This analysis was based on searches of the Scopus and Web of Science databases. A previous study has pointed out that WoS is a confusing concept, as many institutions may subscribe to only a customized subset of the entire Web of Science Core Collection. It should be made clarified that our study is conducted for the whole of WoS [31]. Although the historical content of Scopus dates to 1788, the search was limited from 1996 (when the analysis of Scopus data in SciVal began) to 2020. In the case of Web of Science, the origin of the data collected in this database begins in 1960 and the analyses in InCites begin in 1980. In order to carry a correlation in the results presented in this work, it has also been limited from 1996 to 2020.

The search was performed using the same criteria: the term "bibliometric" in the title of the publication and in the keywords assigned by the author. The results of both searches were exported from Scopus to SciVal Benchmarking and from WoS to InCites Analyze.

Data processing, both from Scopus and WoS and from SciVal and InCites, was carried out with different tools. The Scopus API was used for automatic data retrieval [32], Microsoft Excel, Gephi and ArcGIS for the analysis and representation of the results, see figure 1.

Topic classification is done on the document [33]. A topic in SciVal covers a collection of documents with a common intellectual interest [34]. Over time, new topics appear and, as topics are dynamic, they evolve. Each document is assigned a topic consisting of three elements, for example: Intellectual Structure, Co-citation Analysis, Scientometrics. The topics are based on the citation network grouping of 95% of the Scopus content (all documents published since 1996), taking as a reference the direct analysis of citations using the reference lists of the documents. As new published documents are indexed, they are added to Topics using their reference lists. This makes the Topics dynamic and most increase in size over time. New topics represent research areas that have experienced a significant acceleration of growth in recently published articles and have attracted funding. These new Topics are derived from the existing stem Topics and are formed by the new citation relationships that have occurred in the last year. Once a year, the Topics SciVal algorithm is run to identify the new Topics that have emerged [35].

Like SciVal Topics, the InCites Topics ranking is also done on the document. It is based on a CWTS algorithm [27] considering the citations (cited and citing) between documents, based on the "strength" of the citation relationships. In this way, clusters are created: macro, meso and micro topics.

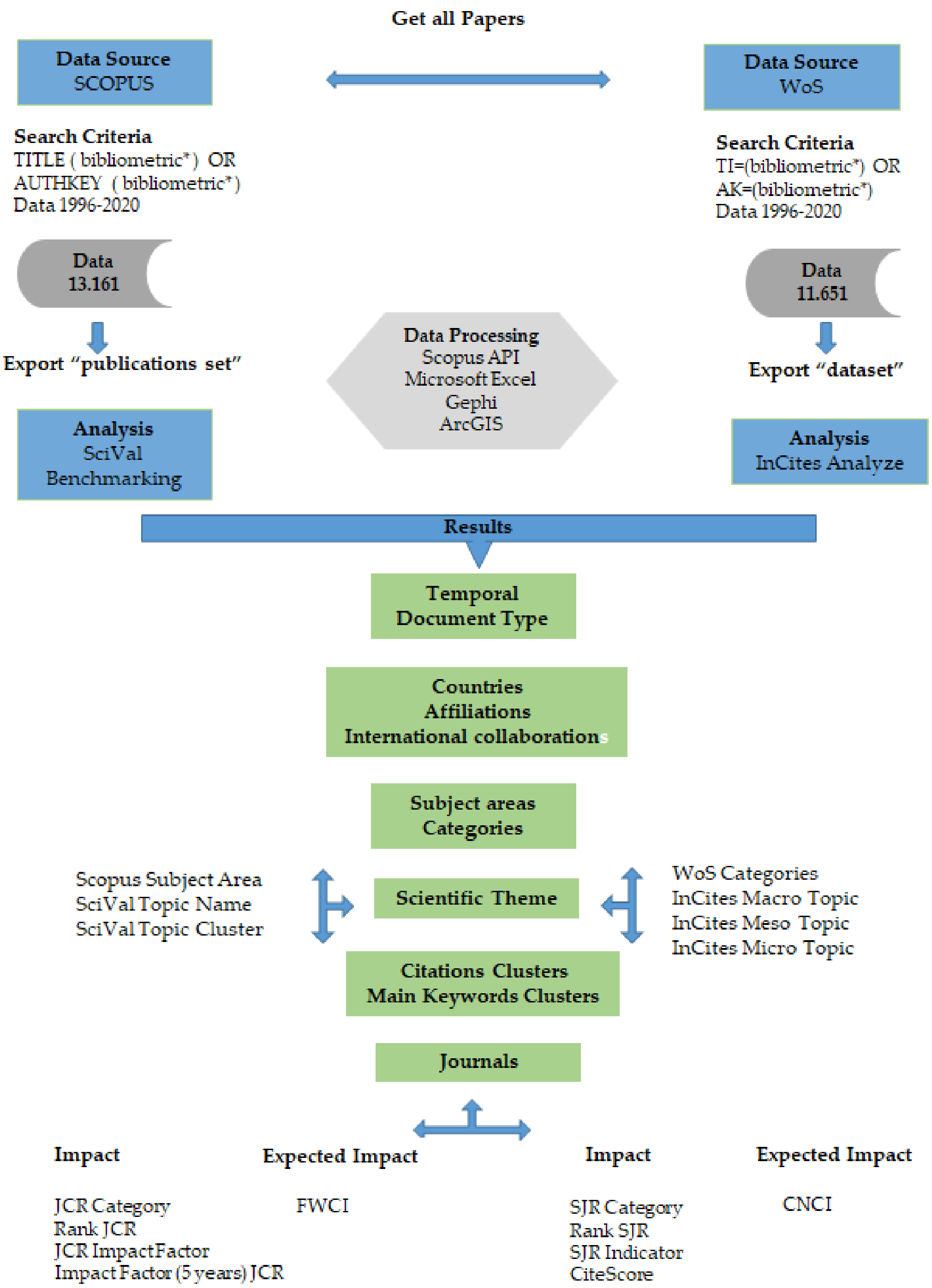

Figure 2-1. Methodology

An independent analysis, based on scientific communities or clusters and the relationships between them based on citation and main keywords, has also been considered in this research.

Finally, continuing with the issue of quality, the sources (journals) have been analyzed with the following metrics:

- *Number of publications in WoS and Scopus*
- *Number of citations in WoS and Scopus*

- *Quartile in JCR and SJR*
- *Journal Impact Factor JCR. It uses for the citations, articles, reviews, and proceedings papers [36].*
- *5-Year Journal Impact Factor JCR, available from 2007 onward [36].*
- *Impact SJR [37].*
- *Cite Score [35].*

On the other hand, the analysis of the sources has been completed with two other metric values:

- *Field-Weighted Citation Impact (FWCI) the SciVal [38].*
- *Category Normalized Citation Impact (CNCI) the InCites [36].*

2.3 Results of bibliometric literature on Scopus and WoS

2.3.1 Trend in scientific production

According to Scopus, with the search criteria used, between 1996 and 2020, 13161 results have been obtained. The temporal evolution is shown in Figure 2 from the year 2000, since before that date there are few papers per year. The trend line has been represented, showing that the annual growth is exponential. It can be observed that in 2020 there will be more than 2500 published documents.

Figure 2 shows that 72% of the documents are mainly classified as articles. To a lesser extent, reviews in 13% of the cases and contributions to conferences in 10%. The number of reviews shows that this type of documents is the result of an analysis of a specific topic. In this case the most cited article [39] has considerably more citations than the most cited review [40].

In Web of Science (WoS), with the same search criteria, 11,651 results were obtained between 1996 and 2020, slightly less than in Scopus. The temporal evolution is shown in Figure 3 from the year 2000, since before that date there are few papers per year, as was the case in the other database. The trend line has been plotted, showing that annual growth is exponential. It can be observed that in the year 2020 there will be more than 2000 published documents.

Figure 3 shows that 68% of the works are classified as articles. To a lesser extent, reviews in 14% of the cases and contributions to congresses in 11%. In general, there are no differences between the two databases in the distribution of documents by type. In this case the most cited article and review are the same as in Scopus.

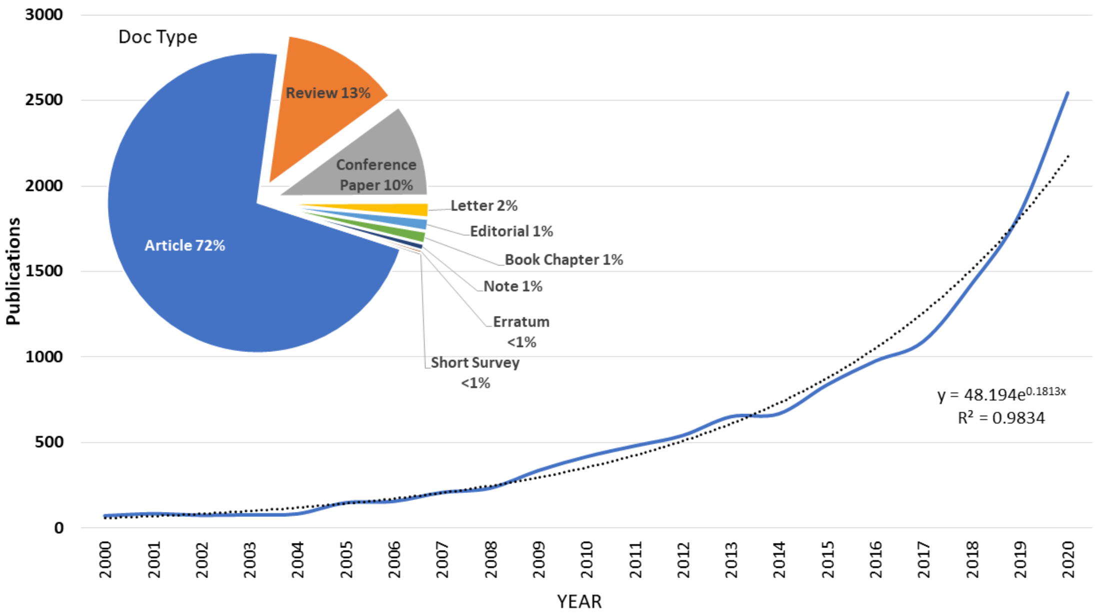

Figure 2-2. Bibliometric publications trend (Source Scopus)

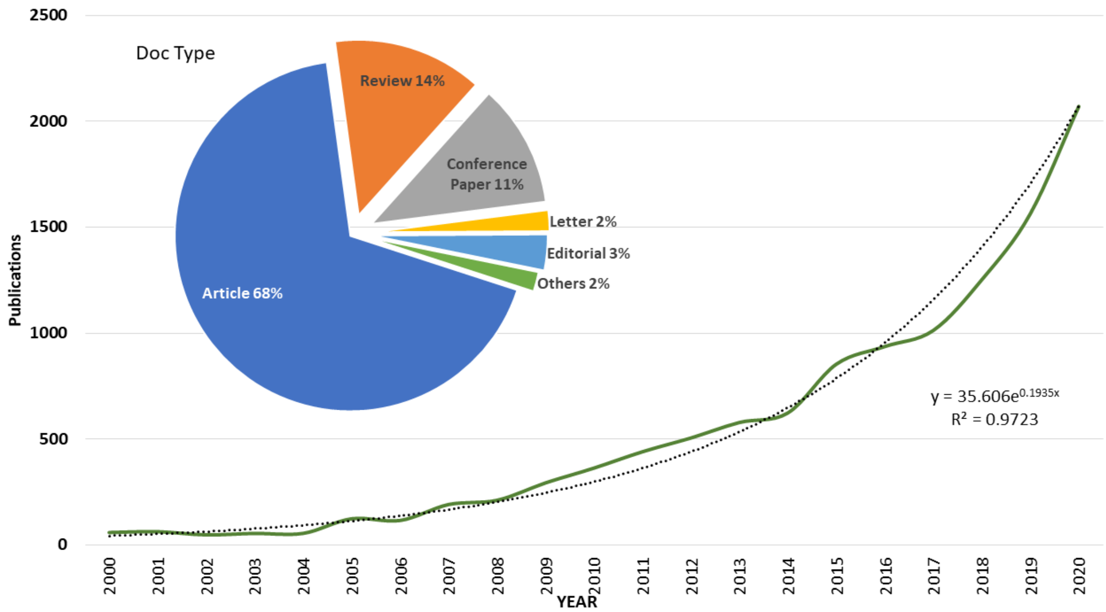

Figure 2-3. Bibliometric publications trend (Source WoS)

2.3.2 Countries

The countries that have devoted most effort to bibliometric studies are China with 16% of the total number of publications, followed by the USA with 15%, and in third place Spain with 12.5%. Further behind with 6% are Brazil, UK and India. Given that China and the USA are the world leaders in scientific production, these results in the first two *positions are not surprising. It should be noted that a recent study has shown that China has overtaken the United States in terms of the number of articles indexed in the SCI in 2018 [41]. However, what is particularly notable is the great effort made by Spain in this area. Figure 4 shows a worldwide map with the geographical distribution by countries according to their publications related to bibliometrics.*

The most cited bibliometric document from China is related to energy [42]. For the USA, it is the one cited above as the most cited review, and it is about economics [40], the same subject line as for the most cited from Spain [43].

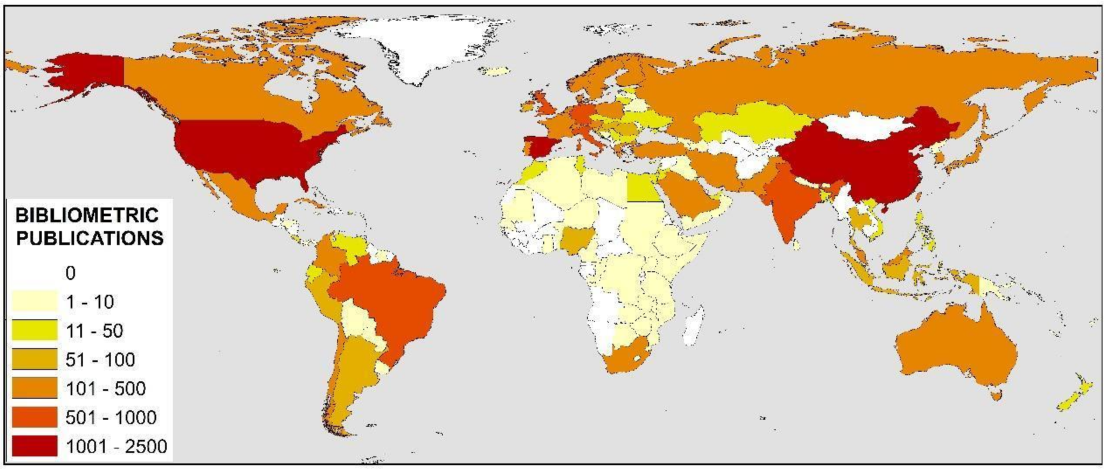

Figure 2-4. Worldwide distribution by country of scientific production on bibliometrics.

2.3.3 Institutions according to Scopus and WoS

Table 1 shows the top 20 institutions that publish the largest number of bibliometric publications, according to Scopus and WoS. A first analysis of the table shows that the difference between the two databases is only in four institutions. The institutions that appear in Scopus in the top 20 and are not in WoS are: An-Najah National University (18), Sichuan University (16), Universidad de Chile (14), and Universidade Federal de Santa Catarina (19). On the other hand, the 4 institutions that appear in WoS and not in Scopus are: Harvard University (16), University System of Georgia (13), University of London (8), and Istituto di Analisi dei Sistemi ed Informatica Antonio Ruberti (IASI-CNR) (17).

These differences are undoubtedly due to the different sources indexed in the two databases. Of the differences in this top 20, there is only one institution in the top 10 of WoS and not in Scopus, the University of London. It can be seen that the first 5 institutions are the same in both databases, although in different order: Universidad de Granada (Spain), University of Valencia (Spain), Consejo Superior de Investigaciones Científicas (CSIC) (Spain), Chinese Academy of Sciences (China), and Leiden University (Netherlands). It is remarkable that 3 institutions from Spain are in the top 5, and this probably contributes, as already mentioned, to the fact that Spain accounts for 12.5% of the total number of publications in this field.

The most cited documents from these institutions were: University of Granada (Spain), related to computers and education [44]; University of Valencia (Spain), related to ecomonics [45]; Consejo Superior de Investigaciones Científicas (CSIC) (Spain), related to bibliometrics [46]; Chinese Academy of Sciences (China), related to biodiversity and conservation [47] and Leiden University (Netherlands), related to bibliometry, the one already reported as the most cited bibliometric article [39].

Leiden University is a benchmark in research evaluation and bibliometric studies through the Centre for Science and Technology Studies (CWTS). It works closely with Clarivate Analytics, which bases its analyses on Web of Science and *is continuously expanding its data system to include other sources, such as Scopus, PubMed, Crossref, PATSTAT, Mendeley and ORCID [48].*

International collaborations (IC) were analyzed for both Scopus publications using SciVal and WoS publications using InCites, see Table 1. For Scopus data, the minimum international collaboration for the top 20 is 15.8% for the Consiglio Nazionale delle Ricerche (CNR), while the maximum is 81% for the Universidad de Chile. For WoS data, the minimum of international collaboration in this top 20 is 10% from Istituto di Analisi dei Sistemi ed Informatica Antonio Ruberti (IASI-CNR); while the maximum is 79.5% from Georgia Institute of Technology. But both databases, for the average scientific collaboration of this top 20 offer the same result, 41.4 % according to Scopus, and 41 % according to WoS. The first five institutions have relatively low international scientific collaboration in this field, between 21 and 38%. But if we analyze the average of these five institutions, 29.8% according to Scopus, and 29.9% according to WoS. Therefore, it is possible to establish that the main institutions dedicated to bibliometrics collaborate less than the average of the other 15, which without them have an average of 45% of international collaboration in both databases.

Table 2-1. Main affiliations according to Scopus and WoS

Rank	Scopus				WoS			
	Affiliation	N_{TOT}	N_{IC} SciVal	IC (%)	Affiliation	N_{TOT}	N_{IC} InCites	IC (%)
1	Universidad de Granada	259	55	21.2	Consejo Superior de Investigaciones Científicas (CSIC)	198	47	23.7
2	University of Valencia	211	74	35.1	University of Granada	198	49	24.7
3	Consejo Superior de Investigaciones Científicas (CSIC)	196	61	31.1	Leiden University	154	59	38.3
4	Chinese Academy of Sciences	188	50	26.6	Chinese Academy of Sciences	138	46	33.3
5	Leiden University	177	62	35.0	University of Valencia	133	39	29.3
6	Universidade de São Paulo	136	22	16.2	Asia University Taiwan	129	83	64.3
7	Asia University Taiwan	133	91	68.4	Max Planck Society	120	57	47.5
8	Wuhan University	118	39	33.1	University of London	115	67	58.3
9	Consiglio Nazionale delle Ricerche (CNR)	114	18	15.8	Consiglio Nazionale delle Ricerche (CNR)	112	20	17.9
10	Peking University	111	61	55.0	University of Rome Tor Vergata	109	18	16.5

11	University of Rome Tor Vergata	109	18	16.5	Peking University	101	53	52.5
12	Administrative Headquarters of the Max Planck Society	106	52	49.1	Wuhan University	101	34	33.7
13	Universitat Politècnica de València	104	35	33.7	University System of Georgia	90	67	74.4
14	Universidad de Chile	100	81	81.0	KU Leuven	80	59	73.8
15	KU Leuven	92	62	67.4	Universitat Politecnica de Valencia	80	30	37.5
16	Sichuan University	85	36	42.4	Harvard University	78	35	44.9
17	Georgia Institute of Technology	85	65	76.5	Istituto di Analisi dei Sistemi ed Informatica Antonio Ruberti (IASI-CNR)	78	8	10.3
18	An-Najah National University	85	26	30.6	Georgia Institute of Technology	73	58	79.5
19	Universidade Federal de Santa Catarina	82	19	23.2	University of Barcelona	73	34	46.6
20	Universitat de Barcelona	80	56	70.0	Universidade de São Paulo	72	9	12.5

N_{TOT} = Total number of publications

N_{IC} = publications with international collaboration

2.3.4 Scientific areas of indexing

2.3.4.1 Scopus. Subject Area

Figure 5 shows the indexation by subject area in Scopus. The Social Sciences category leads the published documents with slightly more than 38% of the publications, which was to be expected since this is where bibliometrics is classified. In second place is the Computer Science category with 26.5%, showing that there is an increasingly important volume of data management and that therefore advanced computer techniques must be applied. The third category in order of number of documents is the field of Medicine with more than 23%, this is worth a reflection on the importance of bibliometrics. The next three categories are close to 10 % and are: Business, Management and Accounting (12 %), Engineering (9 %) and Environmental Science (8 %).

Figure 5 shows the temporal evolution by years of the first 6 categories from 2000 to 2020 according to Scopus. Since 2008, bibliometric publications have been led by the Social Sciences category. The Computer Science category has occupied the second place from 2009 to 2019, and already in the last year it is surpassed by the Medicine category which was in third place since 2009. The next three categories have had a quite similar behavior, exceeding 100 publications *per year the Business, Management and Accounting category in 2016, Engineering in 2017 and Environmental Science in 2018, to finish all of them with 300 or more papers per year in the last year studied, 2020.*

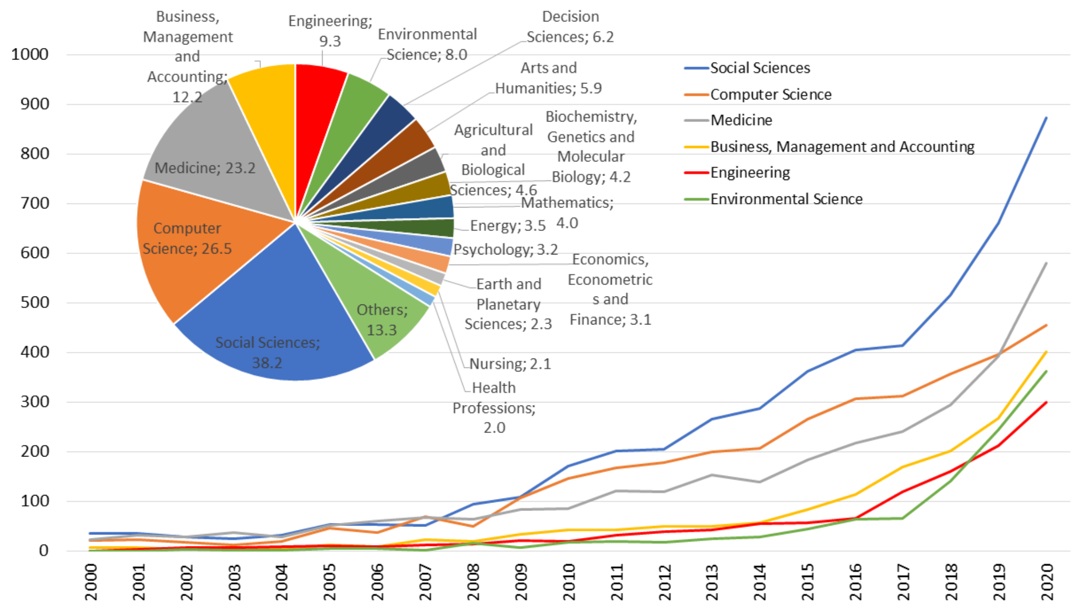

Figure 2-5. Subject area in Scopus and its trend from 2000 to 2020.

2.3.4.2 SciVal

According to SciVal, the average number of citations per document was 12.4. This section starts to discuss the Topic Name extracted from Scival, see table 2. It is observed that the main topic name is Hirsch Index, Self-Citation, Journal Impact Factor; followed closely by: Intellectual Structure, Co-citation Analysis, Scientometrics. In third place is: Co-Authorship, Scientific Collaboration, Scientometrics.

Since the Hirsch Index or H index was proposed in 2005 [49], many evaluation agencies and even journals make use of it to measure the quality of an individual author's impact. This has also given rise to the misconduct by some authors of self-citation to artificially raise their own H index [50]. There are studies that propose eliminating self-citation for the calculation or correction of the H index [51]. Self-citations do not only occur in individual authors, but some journals have been able to encourage this practice in citing articles from their own journal to raise its Journal Impact Factor [52], this is named journal self-citation. These facts have inspired many studies that make this Topic Name the most prominent one to date.

In the second topic name, these studies are based on describing the intellectual structure of a particular scientific field from the point of view of frequently occurring keywords and phrases, using Co-citation Analysis, co-word analysis, hierarchical clustering, and link analysis [53]. The third of the main topic name focuses on the analysis of the structure of scientific collaboration networks [54]. These scientific collaboration networks are analyzed by scientific fields [55], countries [56-57] or even institutions [58-60].

Table 2-2. Topic Name (Scival) for bibliometrics publications

Topic Name	***N***	***C***	***C/D***
Hirsch Index, Self-Citation, Journal Impact Factor	*1005*	*16417*	*16.34*
Intellectual Structure, Co-citation Analysis, Scientometrics	*980*	*17639*	*18.00*

Co-Authorship, Scientific Collaboration, Scientometrics	*743*	*11159*	*15.02*
Citation Counts, Bibliometric Analysis, Journal Impact Factor	*438*	*4897*	*11.18*
Scientometrics, Research Productivity, Bibliometric Analysis	*319*	*1580*	*4.95*
European Regional Development Fund, Bibliometric Indicators, ERDF	*283*	*2186*	*7.72*
Beauties, Citations, Sleeping Beauty	*220*	*2295*	*10.43*
Social Science and Humanities, Research Evaluation, Book Publishers	*198*	*8895*	*44.92*
Bibliometric Analysis, Citation Index, Document Type	*188*	*3472*	*18.47*
Readership, Citation Counts, Journal Impact Factor	*186*	*2863*	*15.39*
Scientific Journals, Doctoral Thesis, Spanish Universities	*146*	*1078*	*7.38*
Technology Roadmapping, Patent Analysis, Technological Competitiveness	*145*	*3306*	*22.80*
Female Scientist, Research Productivity, Women in Science	*120*	*1596*	*13.30*
Research Productivity, Bibliometric Analysis, Arab Countries	*114*	*1213*	*10.64*
Scientific Publications, Research Productivity, Bibliometric Analysis	*101*	*1090*	*10.79*
Tourism Research, Tourism and Hospitality, Hospitality Management	*85*	*1517*	*17.85*
Citations, Summarization, Scholarly Publication	*68*	*647*	*9.51*
Open Access Publishing, Scholarly Communication, Preprints	*67*	*586*	*8.75*
Economists, Co-Authorship, Economic Journals	*61*	*596*	*9.77*
Library Science, Tenure, Land Information System	*57*	*495*	*8.68*

N= Total number of publications; C = total number of citations; C/D = cites per document

Table 2 lists each topic name according to the average number of citations received per document. According to this index, the leading topic name is Social Science and Humanities, Research Evaluation, Book Publishers with almost 45 citations per document, followed in second place by Technology Roadmapping, Patent Analysis, Technological Competitiveness with almost 23, and in third place by Bibliometric Analysis, Citation Index, Document Type with almost 19.

Table 3 shows the main topic clusters related to bibliometric studies. The main topic cluster is the one focused on: Publications, Periodicals as Topic, Research. This cluster stands out from the rest as it is 11 times larger than the next cluster, which is focused on: Industry, Innovation, Entrepreneurship; and 30 times larger than the third: Library, Librarian, Information. In relation to the citations of each topic cluster name. Leads this ranking: Decision Making, *Fuzzy Sets, Models with 23 Cites per Document. E.g the manuscript "Fuzzy decision making: A bibliometric-based review" [61] has 163 cites according to Scopus. In second place is: Industry, Innovation, Entrepreneurship with 18 Cites per Document. In third place is Electricity, Energy, Economics with 16 Cites per Document. E.g "Power quality: Scientific collaboration networks and research trends" [62].*

Table 2-3. Topic Cluster Name (Scival) for bibliometrics publications

Topic Cluster Name	***N***	***C***	***C/D***
Publications, Periodicals as Topic, Research	*6020*	*84217*	*13.99*
Industry, Innovation, Entrepreneurship	*536*	*9593*	*17.90*
Library, Librarian, Information	*196*	*1560*	*7.96*
Research, Meta-Analysis as Topic, Guidelines as Topic	*163*	*1530*	*9.39*
Periodicals as Topic, Open Access, Library	*146*	*1560*	*10.68*
Tourism, Tourists, Destination	*133*	*1987*	*14.94*
Industry, Research, Marketing	*130*	*1429*	*10.99*
Supply Chains, Supply Chain Management, Industry	*129*	*1907*	*14.78*
Semantics, Models, Recommender Systems	*114*	*1171*	*10.27*
Corporate Social Responsibility, Corporate Governance, Firms	*110*	*1277*	*11.61*
Schools, Brazil, Education	*108*	*382*	*3.54*
Electricity, Energy, Economics	*101*	*1605*	*15.89*
Brazil, Health, Nursing	*95*	*363*	*3.82*
Libraries, Metadata, Ontology	*81*	*246*	*3.04*
Work, Personality, Psychology	*78*	*911*	*11.68*
Students, Medical Students, Education	*77*	*563*	*7.31*
Construction, Construction Industry, Project Management	*74*	*971*	*13.12*
Research, Data, Information Dissemination	*60*	*676*	*11.27*
Rotavirus, Norovirus, Coronavirus	*56*	*369*	*6.59*

Decision Making, Fuzzy Sets, Models	51	1184	23.22

N= Total number of publications; C = total number of citations; C/D = cites per document

2.3.4.3 WoS. Categories

The classification by WoS categories is shown in Table 4. As is well known, the categories do not match those of Scopus. On the other hand, in both databases the same document can be indexed in more than one category if the journal in which it was published is indexed in more than one category. For the documents analyzed, the great discrepancy between scientific fields between the two databases is observed in the field of Medicine in Scopus, which does not correspond to the first positions ranked by WoS. Although there are comparable categories in WoS such as: MEDICINE, RESEARCH & EXPERIMENTAL, or MEDICINE, GENERAL & INTERNAL, there are many other categories specific to the medical field that are independent for indexing. In our case, for example, the categories of: ONCOLOGY, PSYCHIATRY, PEDIATRICS, ANESTHESIOLOGY, RESPIRATORY SYSTEM, OPHTHALMOLOGY, DERMATOLOGY, or TROPICAL MEDICINE, but all of them with values below 1%, which does not make it possible to reach the 23.2% that appeared in Scopus. Therefore, the indexing field of medicine is very different between the two databases.

In the last column of Table 4, the average number of citations of these bibliometric documents has been calculated according to WoS data. For the whole documents analyzed the average number of citations per document was 11.7. Only three categories are below 5 citations per document: Engineering, Electrical & Electronic, Computer Science, Theory & Methods, and Social Sciences, Interdisciplinary. In general, these documents are highly cited within their scientific categories, especially in Management and Engineering, Industrial, both with more than 18 citations per document (C/D).

Table 2-4. Indexing by category according to WoS

Category	N	%	C/D
Information Science & Library Science	2508	16.3	15.8
Computer Science, Interdisciplinary Applications	1552	10.1	17.7
Computer Science, Information Systems	666	4.3	14.3
Environmental Sciences	616	4.0	9.5
Management	521	3.4	18.2
Business	379	2.5	16.8
Public, Environmental & Occupational Health	373	2.4	7.7
Green & Sustainable Science & Technology	331	2.1	12.0
Surgery	299	1.9	8.5
Environmental Studies	289	1.9	8.7
Education & Educational Research	270	1.8	5.0
Economics	225	1.5	5.4
Clinical Neurology	204	1.3	9.2
Computer Science, Theory & Methods	195	1.3	2.6

Computer Science, Artificial Intelligence	*194*	*1.3*	*9.9*
Engineering, Electrical & Electronic	*174*	*1.1*	*4.4*
Operations Research & Management Science	*171*	*1.1*	*17.1*
Health Care Sciences & Services	*165*	*1.1*	*11.0*
Social Sciences, Interdisciplinary	*162*	*1.1*	*3.5*
Engineering, Industrial	*145*	*0.9*	*18.1*

N= Total number of publications; C/D = cites per document

2.3.4.4 InCites

In this section the macro, meso and micro topics in which WoS classifies all bibliometric publications will be discussed. The macro topics are listed in the table 5. Leading this classification are the social sciences which has 5 times more documents than the following one. Followed by Clinical & Life Sciences, and in third place is Electrical Engineering, Electronics & Computer Science, with far fewer documents.

In terms of cites per document, social sciences remain the main one with 14. But now the second place in this other ranking is for Electrical Engineering, Electronics & Computer Science with 12 cites per document. With 10 cites per document there are already several categories: Chemistry, and Engineering & Materials Science. The average number of citations per document (C/D) is 8.5.

Table 2-5. Macro topic (InCites)

Macro Topic	***Code***	***N***	***C***	***C/D***
Social Sciences	*6*	*5614*	*80783*	*14.39*
Clinical & Life Sciences	*1*	*1047*	*7771*	*7.42*
Electrical Engineering, Electronics & Computer Science	*4*	*387*	*4732*	*12.23*
Agriculture, Environment & Ecology	*3*	*278*	*2587*	*9.31*
Chemistry	*2*	*105*	*1068*	*10.17*
Earth Sciences	*8*	*62*	*522*	*8.42*
Engineering & Materials Science	*7*	*46*	*500*	*10.87*
Arts & Humanities	*10*	*44*	*199*	*4.52*
Physics	*5*	*29*	*83*	*2.86*
Mathematics	*9*	*14*	*68*	*4.86*

N= Total number of publications; C = total number of citations; C/D = cites per document

The 20 main meso topics are listed in Table 6, highlighting Bibliometrics, Scientometrics & Research Integrity, with 11 times more publications than the second meso topic, Management. These two meso topics can be included within the main macro topic of Social Science, mentioned above. As can be seen in column 2 of table 6, the first number indicates the macro topic. It can be observed that in this top 20 are not present the macro topics of: Chemistry (2), Earth Sciences (8), Engineering & Materials Science (7), Arts & Humanities (10), Physics (5), or Mathematics (9).

The two meso topics with the most citations per document are Artificial Intelligence & Machine Learning (19 C/D), Operations Research & Management Science (17 C/D), both from the macro topic 4, Electrical Engineering, Electronics & Computer Science. The average number of citations per document for this top 20 meso topic is 11.7 C/D.

Table 2-6. Meso topics (InCites)

Meso Topic	**Code**	**N**	**C**	**C/D**
Bibliometrics, Scientometrics & Research Integrity	6.238	4489	67420	15.02
Management	6.3	397	6049	15.24
Medical Ethics	1.155	144	1477	10.26
Sustainability Science	6.115	114	1633	14.32
Nursing	1.14	101	808	8.00
Knowledge Engineering & Representation	4.48	90	484	5.38
Education & Educational Research	6.11	86	716	8.33
Hospitality, Leisure, Sport & Tourism	6.223	70	1053	15.04
Forestry	3.40	69	853	12.36
Healthcare Policy	1.156	58	569	9.81
Economics	6.10	57	595	10.44
Climate Change	6.153	56	511	9.13
Artificial Intelligence & Machine Learning	4.61	51	1012	19.84
Human Geography	6.86	48	559	11.65
Design & Manufacturing	4.224	47	715	15.21
Social Psychology	6.73	41	247	6.02

Operations Research & Management Science	*6.294*	*40*	*691*	*17.28*
Supply Chain & Logistics	*4.84*	*37*	*581*	*15.70*
Marine Biology	*3.2*	*35*	*215*	*6.14*
Psychiatry	*1.21*	*34*	*332*	*9.76*

N= Total number of publications; C = total number of citations; C/D = cites per document

Finally, the micro topics, as expected, the first one, Bibliometrics, belongs to the Bibliometrics, Scientometrics & Research Integrity meso topic, see table 7. And the second, Knowledge Management, and the fourth, Corporate Social Responsibility, belong to the Management meso topic. The third, Systematic Reviews, is included in the Medical Ethics meso topic. In the first 20 micro topics there is an average of 15 C/D. Fuzzy Sets stands out above all with more than 30 C/D and belongs to the meso topic with the highest average number of citations per document, Artificial Intelligence & Machine Learning.

Table 2-7. Micro topics (InCites)

Micro Topic	***Code***	***N***	***C***	***C/D***
Bibliometrics	*6.238.166*	*4460*	*66782*	*14.97*
Knowledge Management	*6.3.2*	*134*	*2199*	*16.41*
Systematic Reviews	*1.155.611*	*87*	*718*	*8.25*
Corporate Social Responsibility	*6.3.385*	*66*	*1113*	*16.86*
Tourism	*6.223.247*	*61*	*1014*	*16.62*
Foresight	*6.294.1807*	*39*	*689*	*17.67*
Entrepreneurship	*6.3.726*	*38*	*743*	*19.55*
Environmental Kuznets Curve	*6.115.234*	*31*	*471*	*15.19*
Academic Entrepreneurship	*6.3.1467*	*31*	*569*	*18.35*
Information Literacy	*4.48.228*	*30*	*153*	*5.10*
Customer Satisfaction	*6.3.65*	*29*	*369*	*12.72*

Project Scheduling	*4.224.599*	*28*	*495*	*17.68*
Fuzzy Sets	*4.61.56*	*28*	*857*	*30.61*
Agglomeration Economies	*6.86.280*	*27*	*356*	*13.19*
Internationalization	*6.3.1229*	*23*	*226*	*9.83*
Internet of Things	*4.13.807*	*22*	*481*	*21.86*
Sentiment Analysis	*4.48.672*	*21*	*149*	*7.10*
Unified Health System	*1.156.1509*	*20*	*106*	*5.30*
Corporate Governance	*6.10.63*	*20*	*379*	*18.95*
Life Cycle Assessment	*6.115.1181*	*20*	*258*	*12.90*

N= Total number of publications; C = total number of citations; C/D = cites per document

2.3.5 Source (Journal)

Table 8 shows the top 20 journals indexed in both WoS and Scopus, and where the bibliometric articles are published. The table shows both the ranking of the journal by total number of publications in the subject studied and by citations received for these articles. In addition, the different impact indicators according to JCR, SJR and Scopus and the relative position of the journal within its category according to JCR and SJR, e.g. the quartile, are also shown.

The first consideration for journals is that they should have not the same number of articles published in the same period in both databases. What probably happens is that editorial articles or short communications are considered differently in both databases.

It is noted that apart from the journals indexed in the category of Information Science & Library Science, there are many of them in the categories of Environmental Sciences Environmental Studies such as: Sustainability, Journal of Cleaner Production, Environmental Science and Pollution Research. Or Even Journals in The Field of Medicine Such as Medicine or World Neurosurgery.

Considering the quartile of the journals, it can be found that according to JCR: 6 are Q1, 6 are Q2, 5 are Q3, 2 are Q4 and one does not have a JCR impact factor. That is to say that most are Q1 and Q2. According to Scopus: 7 are Q1, 9 are Q2, 1 Q3, and 3 have no SJR. Of all these journals, the one with the highest impact both IF JCR and SJR is Journal of Informetrics.

Table 2-8. Main indexes of WoS-JCR and Scopus-SJR bibliometric sources

Rank	WoS - JCR						Scopus - SJR					
	Journal	**N_1**	**Cit_1**	**Q_1**	**IF_2**	**IF_5**	**Journal**	**N_2**	**Cit_2**	**Q_2**	**IF_3**	**CS**

1	*Scientometrics*	*1051*	*20447*	*Q1*	*2.87*	*3.07*	*Scientometrics*	*1036*	*26087*	*Q1*	*1.210*	*5.6*
2	*Journal of Informetrics*	*203*	*5691*	*Q1*	*4.61*	*4.41*	*Library Philosophy and Practice*	*307*	*406*	*Q2*	*0.220*	*0.3*
3	*Sustainability*	*180*	*852*	*Q2*	*2.58*	*2.8*	*Journal of Informetrics*	*204*	*7542*	*Q1*	*2.079*	*8.4*
4	*Journal of the American Society for Information Science and Technology*	*83*	*3178*	*n/a*	*n/a*	*n/a*	*Sustainability*	*185*	*1483*	*Q2*	*0.581*	*3.2*
5	*Journal of the Association for Information Science and Technology*	*81*	*1609*	*Q2*	*2.41*	*3.17*	*Journal of the American Society for Information Science and Technology*	*83*	*4018*	*N/A*	*N/A*	*N/A*
6	*Revista Española de Documentación Científica*	*74*	*252*	*Q3*	*1.3*	*1.12*	*Revista Española de Documentación Científica*	*81*	*552*	*Q2*	*0.497*	*1.7*
6	*Journal of Cleaner Production*	*74*	*1287*	*Q1*	*7.25*	*7.49*	*Malaysian Journal of Library and Information Science*	*81*	*732*	*Q2*	*0.414*	*1.3*
8	*Current Science*	*71*	*292*	*Q4*	*0.73*	*0.88*	*Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*	*78*	*244*	*Q2*	*0.427*	*1.9*
9	*Research Evaluation*	*64*	*914*	*Q2*	*2.57*	*3.41*	*Espacios*	*78*	*57*	*Q3*	*0.215*	*0.5*
10	*Technological Forecasting and Social Change*	*61*	*1934*	*Q1*	*5.85*	*5.18*	*Journal of Cleaner Production*	*75*	*1867*	*Q1*	*1.886*	*10.9*

11	*Profesional de la Información*	*60*	*351*	*Q3*	*1.58*	*1.42*	*Journal of the Association for Information Science and Technology*	*74*	*2317*	*Q1*	*1.270*	*7.9*
12	*Environmental Science and Pollution Research*	*59*	*352*	*Q2*	*3.06*	*3.31*	*Current Science*	*69*	*427*	*Q2*	*0.238*	*1.2*
13	*International Journal of Environmental Research and Public Health*	*52*	*167*	*Q1*	*2.85*	*3.13*	*Research Evaluation*	*67*	*1165*	*Q1*	*1.792*	*5.6*
14	*PLOS ONE*	*51*	*912*	*Q2*	*2.74*	*3.23*	*ACM International Conference Proceeding Series*	*64*	*114*	*N/A*	*0.200*	*0.8*
15	*World Neurosurgery*	*50*	*306*	*Q3*	*1.83*	*2.07*	*Profesional de la Información*	*62*	*615*	*Q1*	*0.480*	*2.1*
16	*Malaysian Journal of Library and Information Science*	*49*	*215*	*Q3*	*1.55*	*0.96*	*Technological Forecasting and Social Change*	*62*	*2662*	*Q1*	*1.815*	*8.7*
16	*Investigación Bibliotecologica*	*49*	*42*	*Q4*	*0.35*	*0.48*	*CEUR Workshop Proceedings*	*62*	*123*	*N/A*	*0.177*	*0.6*
16	*Medicine*	*49*	*245*	*Q3*	*1.55*	*2*	*DESIDOC Journal of Library and Information Technology*	*57*	*280*	*Q2*	*0.281*	*1.0*
19	*Research Policy*	*41*	*2541*	*Q1*	*5.35*	*7.93*	*World Neurosurgery*	*55*	*463*	*Q2*	*0.727*	*2.4*
20	*Journal of Information Science*	*35*	*645*	*Q2*	*2.41*	*2.34*	*Environmental Science and Pollution Research*	*55*	*403*	*Q2*	*0.788*	*4.9*

N_1= Number of publications (WoS)

Cit_1= Number of citations (WoS)

Q_1 = Quartile JCR (data 2019)

IF_2= Journal Impact Factor JCR (data 2019)

IF_5= 5-year Journal Impact Factor JCR (data 2019)

N_2= Number of publications (Scopus)

Cit_2= Number of citations (Scopus)

Q_2= Quartile SJR (data 2019)

IF_3= Impact SJR (data 2019)

CS= Cite Score (data 2019)

A comparative study of the top 10 countries and affiliations publishing in the leading bibliometrics journal, Scientometrics, is shown in table 9. If the results obtained in table 9 are compared with the global results of scientific production by country, it can be seen that the first 3 countries are the same and in the same ranking order: China, United States, and Spain. Another 4 countries that appear in the top 10 of both rankings, although in a different order, are: United Kingdom, Germany, India and Italy. In summary there is an overlap of 7 of the 10 countries in both rankings. Although China and the USA are the two countries with the most publications, the Netherlands dominates in citations per document with 22 followed by Hungary with 19.

With regard to affiliations, something similar happens, since of the top 10 that publish the most in Scientometrics, 6 are in the top 20 worldwide. These are: Universidad de Granada, Consejo Superior de Investigaciones Científicas (CSIC), Chinese Academy of Sciences, Leiden University, Wuhan University, and KU Leuven. In the case of the affiliations, i.e. the most productive ones are also the most cited in Scientometric journal: KU Leuven (18 C/D), Magyar Tudomanyos Akademia (21 C/D), and Leiden University (35 C/D).

Table 2-9. Top 10 countries and affiliations publishing in Scientometrics

RANK	***Country***	***N***	***C***	***C/D***	***Affiliation***	***N***	***C***	***C/D***
1	China	1174	7881	6.7	KU Leuven	271	4986	18.4
2	United States	1125	14841	13.2	Magyar Tudomanyos Akademia	268	5660	21.1
3	Spain	693	7538	10.9	Leiden University	248	8665	34.9
4	United Kingdom	579	10206	17.6	Consejo Superior de Investigaciones Científicas	210	2924	13.9
5	Netherlands	572	12720	22.2	Universiteit Antwerpen	157	2642	16.8
6	Germany	558	7890	14.1	Wuhan University	152	1191	7.8
7	Belgium	469	7681	16.4	Universidad de Granada	132	1969	14.9
8	India	340	2787	8.2	Chinese Academy of Sciences	126	950	7.5
9	Hungary	315	5974	19.0	Dalian University of Technology	123	1375	11.2
10	Italy	314	3197	10.2	Indiana University Bloomington	122	1770	14.5

N= Number of publications (1978-2021); C= Number of citations (1978-2021); C/D = cites per document

2.3.6 CNCI vs FWCI

Table 10 shows the CNCI and FWCI. Both the CNCI and the FWCI measure the actual citation impact on the expected citation for the articles studied. As long as it is equal to or greater than 1 they have achieved the expected citation. There are only three journals that in both indicators, CNCI and FWCI, are below one: Current Science, Malaysian Journal of Library, and Information Science, and Revista Española de Documentación Científica. Then there are two that have a CNCI < 1, although the FWCI is above 1: Sustainability, and Environmental Science and Pollution Research. All the other journals, 15 out of 20, are above 1 in both indicators, so in general the bibliometric articles achieve a higher number of citations than expected based on the journal and category.

Considering the number of citations per document, for Incites the average is 15.5, and for Scival it is 14.8, so that for this select group of journals the average is about 15. The three journals with the most citations per document according to Incites are: Research Policy (62 C/D), Technological Forecasting and Social Change (31.7 C/D) and Journal of Informetrics (28 C/D). The lowest one for Incites is Investigación Bibliotecológica (0.9 C/D). The three journals with the most citations per document according to Scival are: Journal of the American Society for Information Science and Technology (48.4 C/D), Technological Forecasting and Social Change (42.9 C/D) and Journal of Informetrics (37 C/D). The lowest one for Scival is Espacios (0.7 C/D).

Table 2-10. CNCI (Category Normalized Citation Impact) from InCites and FWCI (Field-Weighted Citation Impact) from SciVal

	InCites					***SciVal***				
Rank	***WoS Journal name***	***N***	***C***	***C/D***	***CNCI***	***Scopus Journal name***	***N***	***C***	***C/D***	***FWCI***
1	Scientometrics	1051	20447	19.5	1.37	Scientometrics	1036	26087	25.2	2.51
2	Journal of Informetrics	203	5691	28.0	2.02	Library Philosophy and Practice	307	406	1.3	0.61
3	Sustainability	180	852	4.7	0.89	Journal of Informetrics	204	7542	37.0	3.23
4	Journal of the American Society for Information Science and Technology	83	3178	38.3	5.14	Sustainability	185	1483	8.0	1.54
5	Journal of the Association for Information Science and Technology	81	1609	19.9	7.27	Journal of the American Society for Information Science and Technology	83	4018	48.4	2.19
6	Revista Española de Documentación Científica	74	252	3.4	0.3	Revista Española de Documentación Científica	81	552	6.8	0.94
6	Journal of Cleaner Production	74	1287	17.4	1.27	Malaysian Journal of Library and Information Science	81	732	9.0	0.72
8	Current Science	71	292	4.1	0.42	Lecture Notes in Computer Science	78	244	3.1	0.91
9	Research Evaluation	64	914	14.3	3.4	Espacios	78	57	0.7	0.11
10	Technological Forecasting and Social Change	61	1934	31.7	2.39	Journal of Cleaner Production	75	1867	24.9	2.35

11	*Profesional de la Información*	*60*	*351*	*5.9*	*1.67*	*Journal of the Association for Information Science and Technology*	*74*	*2317*	*31.3*	*2.83*
12	*Environmental Science and Pollution Research*	*59*	*352*	*6.0*	*0.99*	*Current Science*	*69*	*427*	*6.2*	*0.25*
13	*International Journal of Environmental Research and Public Health*	*52*	*167*	*3.2*	*1.44*	*Research Evaluation*	*67*	*1165*	*17.4*	*1.75*
14	*PLOS ONE*	*51*	*912*	*17.9*	*1.61*	*ACM International Conference Proceeding Series*	*64*	*114*	*1.8*	*0.39*
15	*World Neurosurgery*	*50*	*306*	*6.1*	*1.43*	*Profesional de la Información*	*62*	*615*	*9.9*	*2.90*
16	*Malaysian Journal of Library and Information Science*	*49*	*215*	*4.4*	*0.35*	*Technological Forecasting and Social Change*	*62*	*2662*	*42.9*	*3.95*
16	*Investigación Bibliotecológica*	*49*	*42*	*0.9*	*0.11*	*CEUR Workshop Proceedings*	*62*	*123*	*2.0*	*0.71*
16	*Medicine*	*49*	*245*	*5.0*	*0.78*	*DESIDOC Journal of Library and Information Technology*	*57*	*280*	*4.9*	*0.76*
19	*Research Policy*	*41*	*2541*	*62.0*	*2.73*	*World Neurosurgery*	*55*	*463*	*8.4*	*1.25*
20	*Journal of Information Science*	*35*	*645*	*18.4*	*1.13*	*Environmental Science and Pollution Research*	*55*	*403*		*1.38*

Figure 6 shows the journals studied in Table 11, where the size of the dot is the number of articles studied. Both indicators, FCWI and CNCI, have been plotted, here two trends have been observed. The first one involving the largest number of journals is slightly favored by the FWCI. The second trend, which favors CNCI over FWCI, occurs in the journals: Journal of the American Society for Information Science and Technology, Research Evaluation, Journal of the Association for Information Science and Technology, World Neurosurgery, and Revista Española de Documentación Científica.

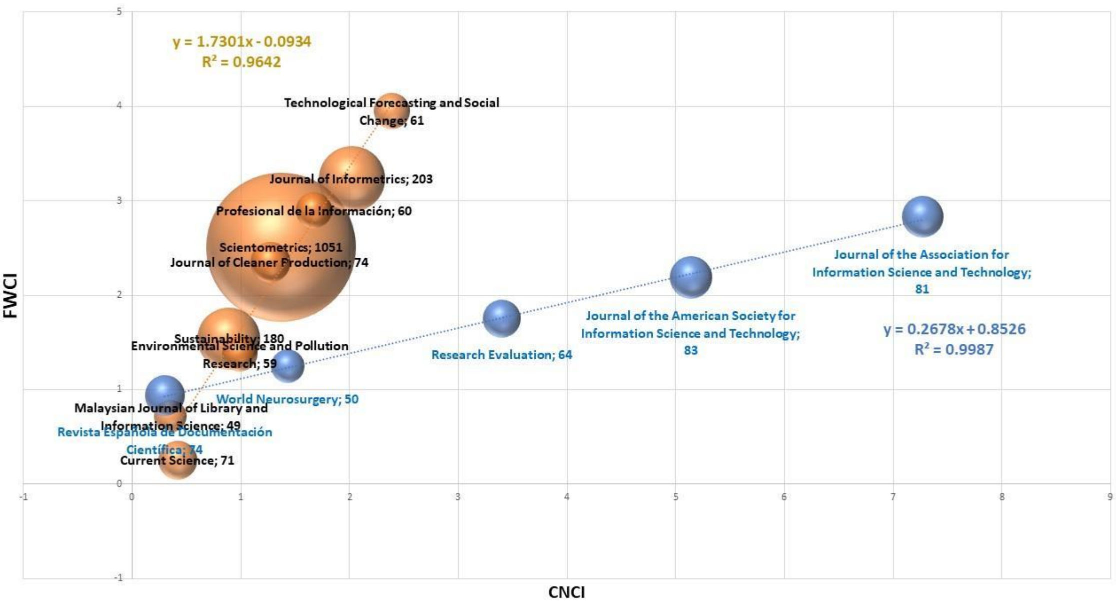

Figure 2-6. CNCI vs FWCI for the top 20

2.4 The medicine and environmental sciences categories as case of study.

Once all the bibliometric manuscripts have been analyzed, it has been observed that the two main categories are those that could be classified as natural for bibliometrics, the social sciences and computer sciences. After these, the third category has been found to be medicine, and the other emerging category is environmental sciences. These two categories are therefore worth studying as a case study, which is the second objective of this manuscript.

2.4.1 The medicine category

2.4.1.1 Countries and affiliations

Figure 7 shows a worldwide map with the distribution by country of bibliometric publications in the medicine category. Publications from 136 different countries have been found. It can be seen that it covers geographically all the countries of the world.

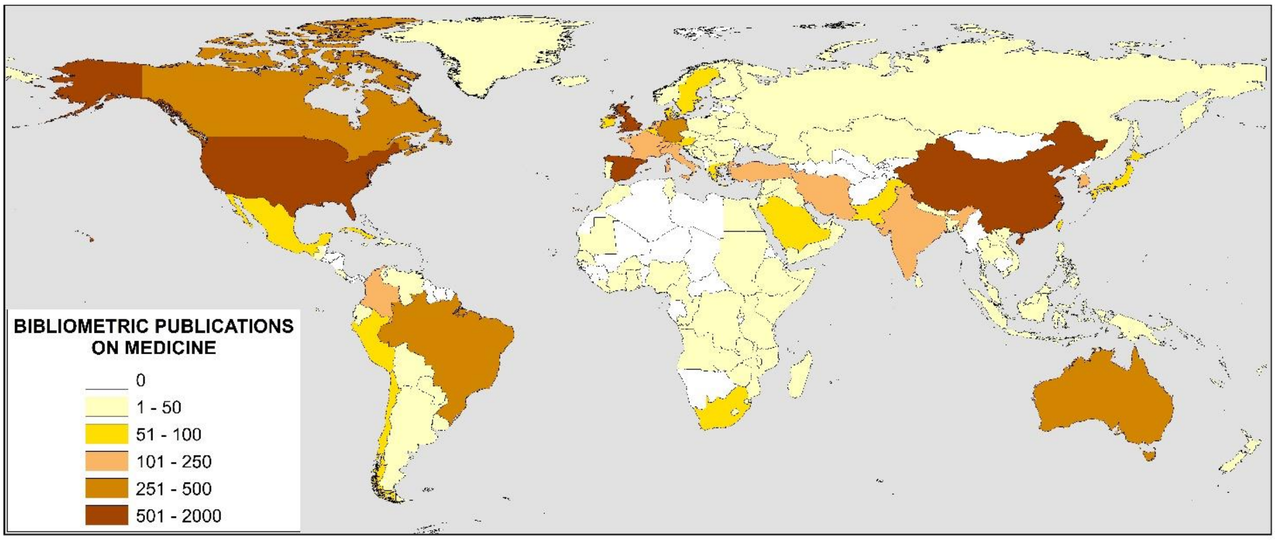

Figure 2-7. Global distribution of bibliometric publications by country in the medicine category

Table 11 shows the top 10 countries and affiliations publishing on bibliometrics in the category of medicine. They have been analysed from 2000 to 2020 and based on the Scopus database.

In terms of countries, this ranking is led by the USA with more than twice more publications than the next country, China. It should be noted that the most cited article from the USA in this category is on the history and meaning of the impact factor, even though it is published in a medical journal, the Journal of the American Medical Association (jama) [63]. Although the second most cited manuscript from this country is on the effectiveness of interventions, whose results are subsequently contradicted [64].

In third place is the UK where its most cited manuscript is related to a taxonomy of behavior change techniques used in interventions [65]. For the fourth country, Spain, the most cited manuscript can also be considered a bibliometric research paper related exclusively to medicine, the Spanish version of the Short Form 36 Health Survey [66].

Among the top 10 affiliations that have published bibliometric manuscripts in the category of medicine, there are three from Spain, University of Valencia, Consejo Superior de Investigaciones Científicas, Universidad Miguel Hernandez de Elche; and other three from Canada: University of Toronto, McMaster University, and The University of British Columbia. The two most cited manuscripts from the University of Valencia focus on bibliometric aspects of scientific collaborations [67], or the impact factors of medical journals [68], and the third most cited manuscript focuses on a purely medical topic with the leishmaniasis [69]. The most cited manuscript from the University of Toronto is a purely medical one, such as the propensity-score methods that are increasingly being used to reduce the impact of treatment-selection bias in the estimation of treatment effects using observational data [70].

Table 2-11. Top 10 countries and affiliations publishing in Medicine category

RANK	Country	N	Affiliation (Country)	N
1	United States	1919	University of Valencia (Spain)	110
2	China	834	University of Toronto (Canada)	110
3	United Kingdom	688	Harvard Medical School (USA)	102
4	Spain	597	Universidade de Sao Paulo – USP (Brasil)	93

5	Canada	458	McMaster University (Canada)	86
6	Brazil	359	Consejo Superior de Investigaciones Cientificas (Spain)	80
7	Australia	336	Universidad Miguel Hernandez de Elche (Spain)	73
8	Germany	303	The University of Sydney (Australia)	67
9	France	226	An-Najah National University (Palestine)	61
10	Italy	223	The University of British Columbia (Canada)	56

N= Number of publications (1978-2021); C= Number of citations (1978-2021); C/D = cites per document

2.4.1.2 Keywords

In this section the most frequent keywords in the fields of medicine that appear in the bibliometric publications in this category have been identified. Among the scientific fields of medicine, Epidemiology and Pediatrics stand out above the rest. The main affiliations in these two fields are Universidad Tecnológica de Pereira (Colombia) and University of Valencia (Spain) respectively.

Table 2-12. Top 10 medical keywords in bibliometric publications in this category and the main affiliations using them

Medicine topic	***N***	***Main Affiliation (Country)***
Epidemiology	194	Universidad Tecnológica de Pereira (Colombia)
Pediatrics	194	University of Valencia (Spain)
Orthopedics	186	Centre Hospitalier Universitaire de Clermont-Ferrand (France) CNRS Centre National de la Recherche Scientifique (France) Second Military Medical University (China) McMaster University (Canada)
Cardiology	166	Universidade de Sao Paulo – USP (Brasil)
Neurosurgery	164	University of Tennessee Health Science Center (USA)
Radiology	152	Hallym University, College of Medicine (South Korea)
Ophthalmology	134	China Medical University Shenyang (China)
Oncology	131	University of Texas MD Anderson Cancer Center (USA) University of Michigan, Ann Arbor (USA)

Plastic Surgery	*121*	*Harvard Medical School (USA)* *Massachusetts General Hospital (USA)*
Psychiatry	*119*	*King's College London (UK)* *Universidad de Alcalá (Spain)*

2.4.1.3 Journals

Table 13 shows the top 10 journals publishing articles in bibliometrics in the category of medicine and their main WoS-JCR and Scopus-SJR bibliometric source indices. It can be seen that the top three journals are above 80 manuscripts, and stand out from the rest. Of these 10 JCR journals, 3 are Q1, 3 Q2, 3 Q3 and one has no impact factor. However for SJR, 5 are Q1, 4 Q2, and 1 Q3.

Table 2-13. Top 10 journals publishing articles on bibliometrics in the category of medicine and their main bibliometric source indices

Rank			WoS - JCR			Scopus - SJR		
	Journal	N_1	Q_1	IF_2	IF_5	Q_2	IF_3	CS
1	Journal Of The Medical Library Association	87	Q2	2.042	2.299	Q1	0.894	2.8
2	International Journal Of Environmental Research And Public Health	83	Q1	2.849	3.127	Q2	0.739	3.0
3	World Neurosurgery	82	Q3	1.829	2.074	Q2	0.727	2.4
4	Journal Of Clinical Epidemiology	55	Q1	4.952	6.234	Q1	2.702	9.0
5	BMJ Open	42	Q2	2.496	2.992	Q1	1.247	3.5
6	Health Research Policy And Systems	40	Q2	2.365	2.762	Q1	0.987	3.8
7	Medicine United States	40	Q3	1.552	1.998	Q2	0.639	2.7
8	Plastic And Reconstructive Surgery	37	Q1	4.235	4.387	Q1	1.916	5.3
9	Revista Cubana De Informacion En Ciencias De La Salud	36	n/a	n/a	n/a	Q3	0.172	0.5
10	Health Information And Libraries Journal	35	Q3	1.356	1.280	Q2	0.521	2.6

N_1= Number of publications (Scopus)

Q_1 = Quartile JCR (data 2019)

IF_2= Journal Impact Factor JCR (data 2019)

IF_5= 5-year Journal Impact Factor JCR (data 2019)

Q_2= Quartile SJR (data 2019)

IF_3= Impact SJR (data 2019)

CS= Cite Score (data 2019)

2.4.2 The environmental sciences category

2.4.2.1 Countries and affiliations

Figure 8 shows a world map with the country distribution of bibliometric publications in the environmental sciences category. Publications from 83 different countries have been found. It can be seen that it covers geographically a large part of the world and that Africa is the continent with the fewest publications in this regard.

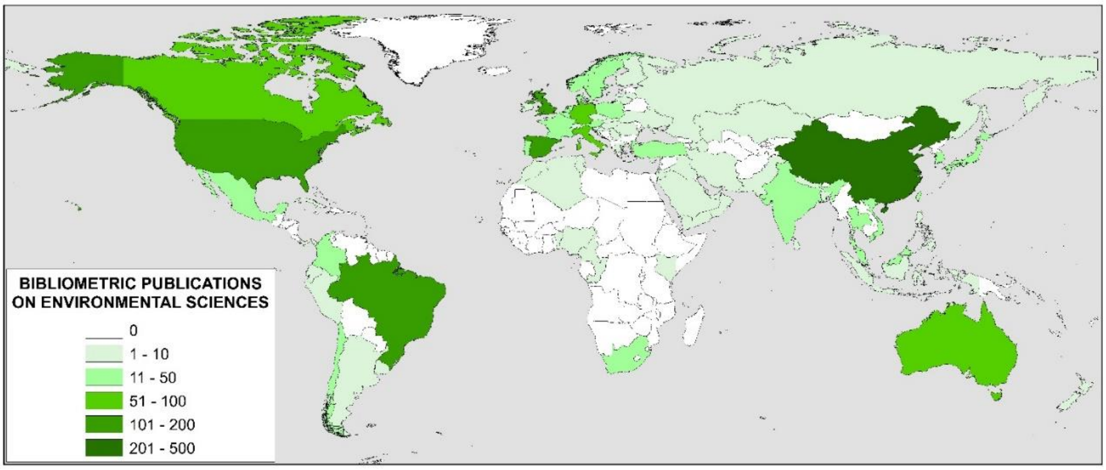

Figure 2-8. Global distribution of bibliometric publications by country in the environmental sciences category

Table 14 shows the top 10 countries and affiliations publishing on bibliometrics in the category of Environmental Sciences. They have been analysed from 2000 to 2020 and based on the Scopus database. By country, this ranking is led by China, with more than twice as many publications as the next country, Spain. Notably, the most cited article from China in this category is on sustainable, smart, resilient and low-carbon cities [71]. The second most cited manuscript from this country is on anaerobic digestion of food waste [72].

The top 2 in this category, Spain, has its most cited article on sensitivity analysis in chemical modelling [73]. The following is on green innovation [74]. The top 3 in this category, USA, has its most cited article on urban resilience [75]. The following are on Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change [76]. Impacts of anthropogenic noise on marine life [77].

Among the top 12 affiliations that have published bibliometric manuscripts in the environmental sciences category, there are 10 from China and 2 from Spain. The top two affiliations are the Chinese Academy of Sciences and the University of Almeria. The two most cited manuscripts from the Chinese Academy of Sciences are related to global biodiversity [78] and, the other on ecological engineering and ecosystem restoration [79]. For the University of Almeria the most cited manuscript are related to and nitrate leaching [80] and energy efficiency in public buildings [81].

Table 2-14. Top 10 countries and affiliations publishing in Environmental Sciences category

RANK	***Country/region***	***N***	***Affiliation (Country)***	***N***
1	*China*	*485*	*Chinese Academy of Sciences (China)*	*94*
2	*Spain*	*191*	*Universidad de Almeria (Spain)*	*47*

3	United States	177	Asia University Taiwan (China)	38
4	Brazil	122	University of Chinese Academy of Sciences (China)	30
5	United Kingdom	113	Beijing Institute of Technology (China)	29
6	Australia	81	Peking University (China)	27
7	Italy	75	Ministry of Education China (China)	25
8	Germany	56	Research Center for Eco-Environmental Sciences Chinese Academy of Sciences (China)	19
9	Canada	54	University of Valencia (Spain)	18
10	Taiwan	50	Tianjin University (China) Beijing Normal University (China) Wuhan University (China)	18

N= Number of publications (1978-2021); C= Number of citations (1978-2021); C/D = cites per document

2.4.2.2 Keywords

In this section the most frequent keywords in the fields of environmental sciences that appear in the bibliometric publications in this category have been identified, table 15. Among the scientific fields of environmental sciences, sustainability and sustainable development keywords stand out above the rest. The main affiliations for these top 10 keywords, are the University of Almeria (Spain) and the Chinese Academy of Sciences (China).

fields are Universidad Tecnológica de Pereira (Colombia) and University of Valencia (Spain) respectively. The third afiliation is the Goethe-Universität Frankfurt am Main (Germany) and the environmental topic is related to public health.

Table 2-15. Top 10 environmental sciences keywords in bibliometric publications in this category and the main affiliations using them

Environmental sciences topic	***N***	***Main Affiliation (Country)***
Sustainability	214	Universidad de Almeria (Spain)
Sustainable Development	207	Universidad de Almeria (Spain)
Climate Change	144	Chinese Academy of Sciences (China)
Ecology	66	Chinese Academy of Sciences (China)
Environmental Impact	58	Universidad de Almeria (Spain)
Biodiversity	57	Chinese Academy of Sciences (China)
Environmental Protection	45	Chinese Academy of Sciences (China)
Environmental Management	44	Chinese Academy of Sciences (China)

Public Health	43	Goethe-Universität Frankfurt am Main (Germany)
Environmental Monitoring	37	Chinese Academy of Sciences (China)

2.4.2.3 Journals

Table 16 shows the top 10 journals publishing articles in bibliometrics in the category of envoronmental science and their main WoS-JCR and Scopus-SJR bibliometric source indices. It can be seen that the top journal is Sustainability with a large number of bibliometric manuscripts. The second and third journals are Journal Of Cleaner Production and International Journal Of Environmental Research And Public Health respectively.Among these 10 JCR journals, 4 are Q1, 3 Q2, 1 Q3 and 2 has no impact factor. However for SJR, 5 are Q1, 3 Q2, and 2 Q3.

Table 2-16. Top 10 journals publishing articles on bibliometrics in the category of environmental sciences and their main bibliometric source indices

Rank			WoS - JCR			Scopus - SJR		
	Journal	N_1	Q_1	IF_2	IF_5	Q_2	IF_3	CS
1	Sustainability Switzerland	239	Q2	2.576	2.798	Q2	0.581	3.2
2	Journal Of Cleaner Production	108	Q1	7.246	7.491	Q1	1.886	10.9
3	International Journal Of Environmental Research And Public Health	83	Q1	2.849	3.127	Q2	0.739	3.0
4	Environmental Science And Pollution Research	60	Q2	3.056	3.306	Q2	0.788	4.9
5	Science Of The Total Environment	30	Q1	6.551	6.419	Q1	1.661	8.6
6	Acta Ecologica Sinica	30	n/a	n/a	n/a	Q3	0.229	1.1
7	Science And Public Policy	26	Q3	1.730	2.114	Q1	0.771	3.3
8	Water Switzerland	22	Q2	2.544	2.709	Q1	0.657	3.0
9	IOP Conference Series Earth And Environmental Science	19	n/a	n/a	n/a	Q3	0.175	0.4
10	Ecological Indicators	15	Q1	4.229	4.968	Q1	1.331	7.6

N_1= Number of publications (Scopus)

Q_1 = Quartile JCR (data 2019)

IF_2= Journal Impact Factor JCR (data 2019)

IF_5= 5-year Journal Impact Factor JCR (data 2019)

Q_2= Quartile SJR (data 2019)

IF_3= Impact SJR (data 2019)

CS= Cite Score (data 2019)

2.5 Independent cluster analysis of bibliometric publications.

In this section, all the papers have been classified by analysis of scientific communities or clusters, and their links between them, by means of the citations they make to each other. Afterwards, the most frequent keywords have been extracted from each of these scientific communities to name them, see Table 17. Bibliometrics and Bibliometric Analysis are the search terms and excluded.

Figure 9 shows the graph generated with all the articles, where in the outer circle are documents not related to any other, or in other words, documents that do not cite any other bibliometric work, and therefore are in a certain way isolated from the core of the bibliometric publications. On the other hand, the central core are papers related by references, since they cite each other and thus establish a relationship. From this core of publications, seven communities or clusters have been detected, which are represented by colors in Figure 9. In this figure, a particular paper has also been marked in red, which is the most cited article by all the bibliometric papers (Van Eck & Waltman, 2010).

The clusters have been outlined in Table 8, where the 20 main keywords have also been collected. These clusters have been: Science Mapping (28.72%), Research Productivity (23.29%), Medical research (19.65%), Environment (11.84%), Psychology (7.02%), Nursing (5.66%), and Engineering (3.82%).

Table 18 shows, for each cluster, the use of WoS or Scopus, being mainly highlighted in the Environment cluster. The only exception to this is in the Nursing cluster, where Scopus is preferred.

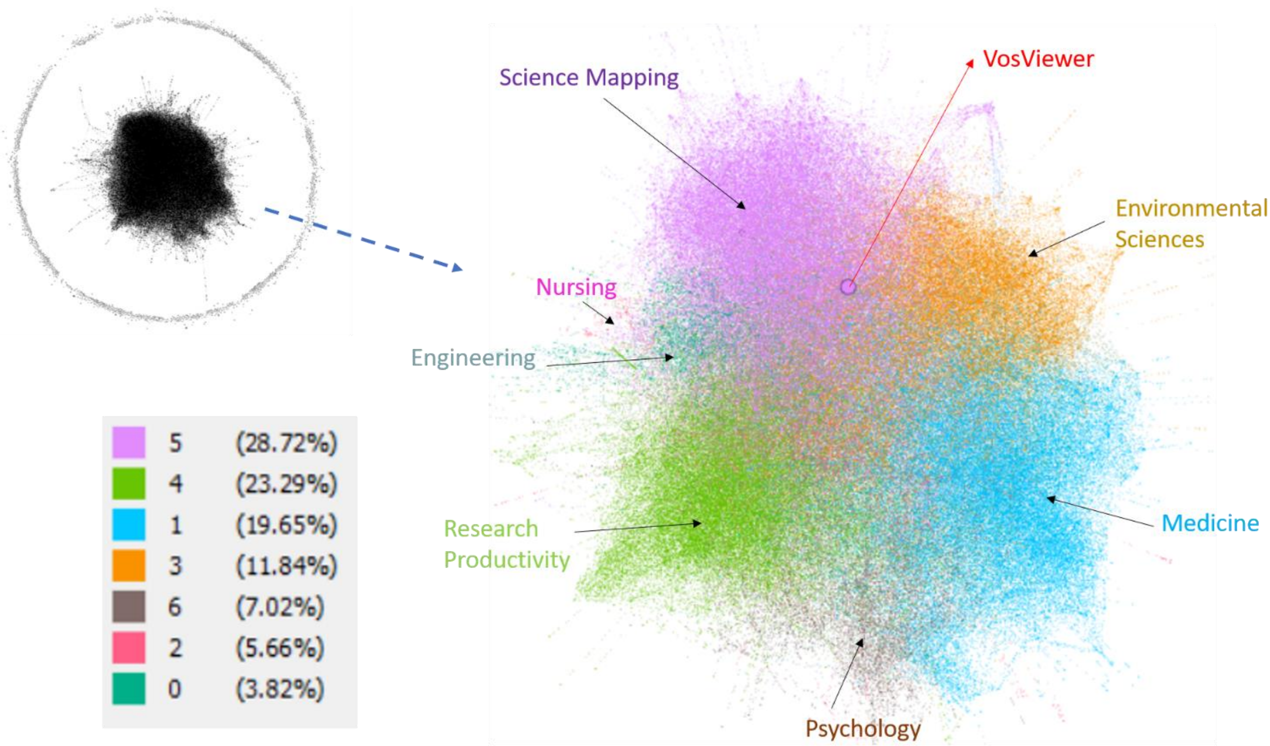

Figure 2-9. Scientific communities of bibliometric publications

Table 2-17. Main keywords of each cluster

Cluster 5	***Cluster 4***	***Cluster 1***	***Cluster 3***	***Cluster 6***	***Cluster 2***	***Cluster 0***
Science Mapping	***Research Productivity***	***Medicine***	***Environmental sciences***	***Psychology***	***Nursing***	***Engineering***
28.72 %	*23.29 %*	*19.65 %*	*11.84 %*	*7.02 %*	*5.66 %*	*3.82 %*
Vosviewer	*Citation Analysis*	*Citation Analysis*	*Research Trends*	*Bibliometric Indicators*	*Citation Analysis*	*Nanotechnology*
Citation Analysis	*H-index*	*Citations*	*Web Of Science*	*Impact Factor*	*Authorship Pattern*	*Scientometrics*
Web Of Science	*Citations*	*Publications*	*Scientometrics*	*Bibliometry*	*Scientometrics*	*Citation Analysis*
Literature Review	*Research Evaluation*	*Scientometrics*	*Citespace*	*Spain*	*Nursing*	*Text Mining*
Scopus	*Scientometrics*	*H-index*	*Sci-expanded*	*Research*	*Research Productivity*	*Information Retrieval*
Scientometrics	*Impact Factor*	*Impact Factor*	*Social Network Analysis*	*Scientific Journals*	*Bibliometric Study*	*Patent Analysis*
Bibliometric Study	*Altmetrics*	*Research*	*Scopus*	*Scientometrics*	*Scopus*	*Digital Libraries*
Co-word Analysis	*Web Of Science*	*Web Of Science*	*Citations*	*Journals*	*India*	*Citations*
Sustainability	*Scopus*	*Scopus*	*Citation Analysis*	*Bibliometric Study*	*Author Productivity*	*Nanoscience*
Co-citation Analysis	*Peer Review*	*Journal Impact Factor*	*Climate Change*	*Publications*	*Nursing Research*	*China*
Network Analysis	*Journal Impact Factor*	*Pubmed*	*Publications*	*Citations*	*Citations*	*Citation Network*
Science Mapping	*Italy*	*Bibliometric Study*	*Impact Factor*	*Web Of Science*	*Impact Factor*	*Technology Forecasting*
Social Network Analysis	*Research Assessment*	*Vosviewer*	*Sci*	*Psychology*	*Library And Information Science*	*Computational Linguistics*
Citations	*Publications*	*Covid-19*	*Research*	*Databases*	*Lotka's Law*	*Emerging Technologies*
Content Analysis	*Research*	*Research Productivity*	*Vosviewer*	*Periodicals*	*Research Output*	*Research Evaluation*
Citespace	*Google Scholar*	*Biomedical Research*	*Sustainability*	*Scopus*	*Degree Of Collaboration*	*Document Clustering*
Co-citation	*Universities*	*Latin America*	*H-index*	*Citation Analysis*	*Bibliometric Indicators*	*Bibliometric Study*
Research Trends	*Research Productivity*	*Citespace*	*Scientific Production*	*Journal Article*	*Scientific Production*	*Publications*
Bibliometric Review	*Evaluation*	*Bibliometric Indicators*	*Research Hotspots*	*Impact*	*Research*	*Network Analysis*

Table 2-18. Main database used for each cluster

Cluster	***Name***	***WoS***	***Scopus***	***Main Country keyword***
Cluster 5	*Science Mapping*	*192*	*133*	*China*
Cluster 4	*Research Productivity*	*73*	*61*	*Italy*
Cluster 1	*Medical Research*	*81*	*75*	*China/India*
Cluster 3	*Environment*	*102*	*37*	*China*

Cluster 6	*Psychology*	*22*	*17*	*Spain*
Cluster 2	*Nursing*	*12*	*20*	*India*
Cluster 0	*Engineering*	*2*	*1*	*China*

2.6 Conclusions

This study has analyzed the bibliometric documents produced between 1996 and 2020. It has been observed how bibliometrics were applied to research in all scientific fields during these years. To evaluate these documents, a methodology has been used that has proven to be valid to relate scientific production in Scopus and WoS and link it to bibliometric indicators through SciVal and InCites.

The first conclusion drawn from this work is that there is an exponential growth in publications between 2000 and 2020 and that most of the documents are indexed as articles (72% in Scopus and 68% in WoS), as opposed to reviews (13% in Scopus and 14% in WoS). Three countries have led the number of documents published: China with 16 %, USA with 15 %, and in third place Spain with 12.5 %. In this sense, it is worth highlighting the role of Spain in third place compared to the two large countries with the highest scientific production in absolute terms.

From the point of view of the institutions, there are differences between the two databases analyzed. However, the top five positions in the ranking are shared by the same institutions: University of Granada, University of Valencia, Consejo Superior de Investigaciones Científicas (CSIC), Chinese Academy of Sciences, and Leiden University. Once again, the predominance of Spanish institutions in this ranking stands out. International collaboration is undoubtedly a parameter that allows us to know the synergies in scientific production. In this case it has been shown that the institutions located in the top five positions of the ranking do not have a parallelism between quantity of production and international collaboration, they have 30% of international collaboration, that is to say, they have collaboration below the average, which without these institutions is 45%.

Regarding the topics where bibliometrics is applied, the publications have been categorized, and despite the differences between Scopus and WoS when classifying the publications, the results show that this type of studies have been classified mainly in the areas most related to Bibliometrics. According to Scopus in order of importance: Social Science and Computer Sciences, Medicine, Business, Management and Accounting, Engineering and Environmental Science. According to WoS: Information Science & Library Science, Computer Science, Environmental Sciences, and Management. There is a high degree of interest in the application of Bibliometrics to other disciplines as an element of analysis of their own progress.

Completing the review of the topics, the topics for Scopus indexing have been considered as an indicator of where the publications on bibliometrics are standing out. In this sense, the trend also shows the predominance of topics related to the discipline addressed in this research. Hirsch Index, Self-Citation, Journal Impact Factor as predominant Topic Name in SciVal. Publications, Periodicals as Topic, Research as predominant Topic Cluster Name. Interestingly, the ones with the most citations per document are for the Topic Name, Social Science and Humanities, Research Evaluation, Book Publishers has 45 citations per document as average; and for the Topic Cluster Name, Decision Making, Fuzzy Sets, Models with 23 Cites per Document.

In InCites they are mostly included in the Macro Topic of Social Sciences with an average of 14 citations per document, in the Meso Topic of Bibliometrics, Scientometrics & Research Integrity, but with respect to citations per document the meso topic of Artificial Intelligence & Machine Learning stands out (19 C/D). In the Micro Topic, the main one by number of documents is Bibliometrics, but regarding citations per document Fuzzy Sets stands out above all with more than 30 C/D. That is to say that in the citations per document the computer science topics stand out.

The analysis of the sources shows that, despite the different indexing criteria of JCR and SJR, there is variety in the categories in which they have been indexed. The first positions, according to the number of publications, are occupied by journals specialized in Bibliometrics, but journals specialized in Medicine or Environment also appear among the first 20 journals. In terms of quartile ranking, a greater number of SJR journals are positioned in Q1 and Q2 compared to JCR, undoubtedly due to the different indexing criteria applied by the two databases. To complete the quartile ranking, impact factors and citation level, two metrics have been used that allow the performance of the sources based on the *citations received and those expected to be received. The InCites CNCI shows that 7 of the 20 are below 1 and the SciVal FWCI shows that 9 of the 20 are also below this threshold.*

In the analysis of the Medicine category alone, it has been observed that 136 countries have contributions in this field. The main countries are United States, China and United Kingdom. In the field of medicine, the main research areas studied were: Epidemiology, Pediatrics, Orthopedics, Cardiology, Neurosurgery, Radiology, Ophthalmology, Oncology, Plastic Surgery, and Psychiatry.

With respect to Environmental Sciences category, less international dissemination has been found, with only 83 countries having worked in this field. The main ones are China, Spain and United States. Regarding the top 10 institutions, it can be stated that only Spain and China are relevant. Spain focuses on sustainability and China on the environment. In the field of Environmental Science, the main research areas studied were: Sustainability, Sustainable Development, Climate Change, Ecology, Environmental Impact, Biodiversity, Environmental Protection, Environmental Management, Public Health, and Environmental Monitoring.

The relationships between the citations of the publications have allowed, with an independent analysis, to establish clusters by key words based on the level of citation. These 7 clusters were: Science Mapping, Research Productivity, Medicine, Environmental Sciences, Psychology, Nursing, and Engineering. In the 7 communities in which the 20 main keywords were collected, a predominance of terms related to Bibliometrics applied to the different clusters was again observed. The main country keyword data has also been extracted, highlighting the relevance of China as the predominant country in 4 of the 7 clusters analyzed. The independent analysis of the indexing category of the journals highlights that Medicine and Environmental Sciences are the most relevant areas in the field of bibliometrics, after Social Sciences and Computer Science.

In conclusion, there are many parameters that can be used to see the evolution of Bibliometric studies in the period under analysis. In this case, bibliometric data and indicators have been used to study the evolution of this discipline over the years and the performance of publications. In any analysis it is important to start from the objectives of the study to be able to apply the appropriate metric values. In this sense, the recommendations established in the Leiden Manifesto and the San Francisco Declaration should not be forgotten to make proper use of the metrics that allow scientific production to be correctly assessed.

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Capítulo 3.

The Contribution of Spanish Science to Patents: Medicine as Case of Study

3 Capítulo 3. The Contribution of Spanish Science to Patents: Medicine as Case of Study

3.0 Abstract

Investments in research and development (R&D) and innovation are expensive, and one wishes to be assured that there is positive feedback and to receive guidance on how to direct investments in the future. The social or economic benefits of investments in R&D are of particular interest to policymakers. In this regard, public expense in research, especially through universities, is sometimes being questioned. This paper establishes a measure of how research in Spain, and specifically in its universities, is involved. In this study, we have analyzed all the literature cited in the period 1998–2018 produced by Spanish institutions and which has been cited in at least one international patent, obtaining more than 40,000 publications from more than 160,000 different authors. The data have been surprisingly positive, showing that practically all public universities contribute to this subject and that there is a great deal of international collaboration, both in terms of the number of countries with which they collaborate and the prestige of the institutions involved. Regarding the specific scientific fields in which this collaboration is most relevant, biochemistry, genetics and molecular biology, and medicine together account for almost 40% of the total works. The topics most used by these publications were those of diseases or medical problems such as: Neoplams, Carcinoma, Alzheimer Disease, or human immunodeficiency virus (HIV-1). Oncology was according to the All Science Journal Classification (ASJC) the leading and central issue. Therefore, although the result of basic research is difficult to quantify, when it is observed that there is a return in fields such as medicine or global health, it can be said that it is well employed. In terms of journals from a purely bibliometric point of view, it has been observed that some journals do not have a great impact or relative position within their categories, but they do have a great relevance in this area of patent support. Therefore, it would be worthwhile to set up a rank for scientific journals based on the citations of patents, so the percentage of articles cited in patents with Field-Weighted Citation Impact (FWCI) >1, and as an indicator of scientific transfer from universities or research centres, the transference index in patents (TIP) is also proposed.

3.1 Introduction

Basic needs are all those vital necessities that contribute directly or indirectly to a person's survival, and among the most basic or subsistence necessities could be considered those of health and food. Science must respond to the needs of society and to global challenges [1]. Scientific progress enables us to have a better quality of life [2,3], for example the field of health [4] provides us with new medication to treat diseases and, if not possible [5], at least to mitigate pain [6].

Patents protect inventions that consist of products and processes that can be reproduced and replicated for industrial purposes [7]. Companies, laboratories, and individuals can apply for a patent to protect a new technology, sometimes even simply to establish technological boundaries [8]. Whatever the strategic reasons, a patent can be applied for, only if it is for industrial use [9,10]. They are extremely relevant to companies, as they are resources that serve the long-term business. The idea is to keep them in the company for a long period of time. In this way it is possible to develop or invest in a certain line of business, maintaining a certain advantage or protection against the competence. As a major source of new technology generation in developing and transition countries, universities and R&D institutions have played an increasingly active role in the technological innovation, technology transfer and commercialization of intellectual property resulting from research efforts, that finally contribute to the economic, social and cultural development of countries.

Although it is clear that patents are the engine of the industry, in the case of the biotechnology industry that has an impact on the manufacture of drugs such as vaccines [11] or some other medicines, they have a short-term impact on our health or well-being. The transfer of knowledge from research carried out in universities or research centres to the industrial sector is very complex and generally not immediate, but an important indicator is its impact on the number of patents.

Reviewing the research on the properties of the academic literature cited in the patents, it is fair to mention that one of the first works in this regard is the paper of Francisc Narin and Elliot Noma in 1985 [12]. They focused their analysis *on 275 biomedical journals and the biotechnology patents in the US Patent Office classification system. As interesting data, they use as reference time for the citations the first eight years after the documents are published. The main conclusion was that science and technology were converging in key high-tech areas. Another very interesting line of research is the study of the patents that are cited by the patents [13,14], highlighting that scientometric assessments, especially of industrial activity, should include patent statistics.*

Peter Collins and Suzanne Wyatt [15] studied genetics patents in the U.S. patent system granted during 1980–1985. Although the data are old, they showed that the average citations per patent to papers in basic research journals depending of the applicant country varies between 1 to 10. Another interesting data was that the age distribution of journal citations in patents granted can reach 25 years. Despite the fact that the literature in this field is extensive, focusing on the field of medicine, it is worth mentioning that it has been analyzed in specific fields since 1998 in Gastroenterology research in the United Kingdom [16] till more lately in 2019 in Cardiovascular disease research in Brazil [17].

Scientific innovation is determined by science and technology which together determine the way forward, thus, research documents and patent literature can be used to characterize scientific and technological research in a quantitative, automatic and visual way [18]. Recent studies suggest the need to improve collaboration among private and public sectors and health care organizations in research and patent activities [19]. This sort of analysis, from scientific literature and patent search data, has shown as an example that bioinformatics technology is a valuable strategy to modify, synthesize, or recombine existing antimicrobial peptides to obtain drugs against tumors with high activity and low toxicity [20].

There are some works that highlight this issue by analyzing the patents in the field of biotechnology in Spain but in a very short period of time, from 2000 to 2007 [21], or in Brazil in a longer period of time, from 1975 to 2010 [22]. In both studies, they are analyzed from the point of view of patents and not from the point of view of the science that supports them in the form of scientific publications. In any case, this work focuses on the patents obtained by these countries. In the case of the study of Brazil, only 163 patents were international, that is, from the online at World Intellectual Property Organization (WIPO) for the period from 1997 to 2010 [22]. The study of Spain shows a scarce production of patents in biotechnology, compared with European countries with similar scientific and economic capacity, which indicates a deficit in the capacity to absorb the production of new technologies generated in the public scientific sector [21]. In Spain, some recent studies in the field of medicine propose the inclusion of patent databases such as Lens.org for the assessment of the quality criteria of scientific publications [23].

The University must contribute to social and scientific progress and therefore must respond to the demands and needs of the society in which it is embedded [24,25]. Spain accounts for 87 universities of which 50 are public [26]. With respect to public universities, there is a long tradition, as the first public Spanish university that still exists was founded in 1218, the University of Salamanca (although, the first university was that of Palencia in 1209), and the last one was founded in 1998, the Polytechnic University of Cartagena. As for private universities, the first was founded in 1886, the University of Deusto, and the last three were founded in 2019. In this context, the statistics for Spain are satisfactory, with a population of almost 47 million inhabitants, there's a public university for every million inhabitants. Thus, if the age group is between 18 and 24 years, that's four million people of university age, and the rate increases to more than 12.5 public universities per million inhabitants. If private universities are also considered, the data amounts to almost 21.75 universities per million people of university age. Regarding the research funding in Spain, this was 15,000 million euros (€15 billion) in 2018.

On the other hand, the analysis of innovation systems often occurs at a national, aggregated scale, frequently based on surveys or bibliometric data derived from scientific publications such as academic papers and patents [27]. University patenting has grown most rapidly, especially in fast-growing technologies, in which university-business co-patenting is most prevalent. This suggests that rising public investment in university research is paying off, and that university research is industry-relevant [28]. In this sense, if the patents applied for by Spanish universities since they have been registered are analyzed, it can be seen that in the period from 2007 to 2018 there have been 6322, of which 327 were in 2018, the lowest amount in the whole historical period [29].

The objective of this research is twofold. On the one hand, to offer a global perspective of the knowledge transfer carried out by Spanish universities, understood as the influence that their scientific publications have on patents, that is, on those publications that are cited by the patents, and within these, the impact that this transfer has on the field of medicine, since it is one of the most important research activities in Spain. Secondly, a proposal was made to provide an index to classify universities according to their transfer, and in particular the publications cited in patents.

3.2 Materials and Methods

The data have been acquired using scientific databases through the different tools that these databases make available to us. Currently, access to these databases is restricted to the organizations that have subscribed to them, which limits the use of these sources. There are free access sources to access scientific publications, but the quality of the data is not the same as in the sources that are mentioned below. Logically, access to science is limited for some researchers, but the reality is that the dominance of these resources has made them indispensable for the world of research, becoming official data sources at the institutional and governmental level.

Scopus is the database developed by Elsevier that indexes the content of more than 24,600 active journal titles and more than 194,000 books from more than 5000 publishers. Its historical content dates back to 1788, and currently contains over 75 million articles, 1.4 billion references cited since 1970, over 9.5 million conference proceedings, 437 million patents from the five largest patent offices worldwide, 16 million author profiles, and around 70,000 membership profiles. Therefore, this database has been used in considerable bibliometric work in every field of knowledge [30], including medicine [31,32].

Based on the data from Scopus, Elsevier has developed its own research performance analysis tool: SciVal, offering access to the scientific output of more than 230 countries and 14,000 institutions from 1996 to the present. It should be noted that this database has also been used for studies related to the field of medicine [33]. Therefore, the main source of data for this study has been Scopus, obtained through SciVal.

In order to complete data on the ranking of scientific journals has been used:

- *SCImago Journal Rank (SJR) indicator. Developed by SCImago from the widely known algorithm Google PageRank™, this indicator shows the visibility of the journals contained in the Scopus® database from 1996 [34].*

- *CiteScore (Scopus). This recent metric, launched in 2016 by Elsevier, is a way of measuring the citation impact of serial titles. It is an alternative to the JCR impact factor (IF) [35].*

- *JCR (journal citation reports), is a quality indicator of journals that measures the impact of the journals according to the citations received in the Web of Science in the SCIE (Science Citation Index Expanded) and SSCI (Social Science Citation Index) collections. JCR (Journal Citation Reports) provides a quality indicator of journals that measures the impact of the journals according to the citations received in the Web of Science in the SCIE (Science Citation Index Expanded) and SSCI (Social Science Citation Index) collections [36].*

To obtain data under analysis, the following search in SciVal has been used as a starting point: "scientific publications in Spain between 1998 and 2018 filtered by ASJC categories". Journal classification approaches perform an essential function in bibliometric analysis [37]. ASJC (All Science Journal Classification) categories is the classification of subjects used by SciVal to categorise Scopus sources and the publications of each of those sources (e.g., journals). Each Scopus source can be assigned to one or more categories in the selected subject classification. Initially there are the four major subject areas: physical sciences, health sciences, social sciences, and life sciences. The ASJC classification has 27 categories (see Table 1) which are further subdivided into various subcategories. Note that multidisciplinary belongs to the four subject areas.

Table 3-1. ASJC (All Science Journal Classification) categories

Subject Area	***Subject Area Classifications***
Physical Sciences	*Chemical Engineering*
	Chemistry
	Computer Science
	Earth and Planetary Sciences
	Energy
	Engineering

	Environmental Science
	Material Science
	Mathematics
	Physics and Astronomy
	Multidisciplinary
Health Sciences	*Medicine*
	Nursing
	Veterinary
	Dentistry
	Health Professions
	Multidisciplinary
Social Sciences	*Arts and Humanities*
	Business, Management and Accounting
	Decision Sciences
	Economics, Econometrics and Finance
	Psychology
	Social Sciences
	Multidisciplinary
Life Sciences	*Agricultural and Biological Sciences*
	Biochemistry, Genetics and Molecular Biology
	Immunology and Microbiology
	Neuroscience
	Pharmacology, Toxicology and Pharmaceutics
	Multidisciplinary

Figure 1 summarizes the methodology. Once the search was performed, it was filtered by the bibliometric marker "Patent-Cited Scholarly Output" for all publication types and for all patent offices. The result provides all publications that have been cited in at least one patent. The coverage of these patents reaches the five largest patent offices: EPO (European patent office), USPTO (U.S. patent office), UK IPO (UK intellectual property office), JPO (Japan patent office), and WIPO (World Intellectual Property Organization).

On the basis of these data, the evolution over time from 1998 to 2018 of the publications that have been cited in patents, the contribution of the authors of these publications to the development of patents, as well as the international collaboration between these authors have been analysed.

In the analysis of affiliations, the source data of the analysis has been completed with data from global publications of each affiliation between 1998 and 2018 based on Scopus. The search has been carried out by affiliation, considering the publications that as an institution have been published in each of the universities or R&D centers under study in this date range.

When analyzing the impact of the journal, it has been chosen to analyze the impact of the journal on JCR, based on data from 2018, obtaining the following metric values:

- *SJR category and position within the category (rank SJR). SJR thematic categories corresponds to the classification assigned to each journal indexed in the Scopus database [34].*

• *Indicator SJR. It expresses the average number of weighted citations received in the selected year by the documents published in the selected journal in the three previous years*

• *CiteScore. Calculating CiteScore is based on the average citations received per document. CiteScore is the number of citations received by a journal in one year to documents published in the three previous years, divided by the number of documents indexed in Scopus published in those same three years [35].*

• *JCR category and position within the category. The JCR Category is the thematic category assigned to the journal in the Web of Science and within each category the ranking of the journal is shown, calculated according to the position of the journal in relation to the total of each category. Each journal in JCR is assigned to at least one category and may be classified in more than one category.*

• *Five-year journal impact factor. This indicator shows the average number of times articles from the journal have been cited in the JCR year over the past five years. It is calculated by dividing the number of citations in the JCR year by the total number of articles published in the previous five years.*

When analyzing research topics, SciVal uses so-called Topics. A Topic is a set of documents with a common interest. Topics are based on the grouping of the citation network of 95% of the Scopus content (all documents published since 1996) and are grouped within SciVal based on direct citation analysis using document reference lists, so that a document can belong to only one Topic but as newly published documents are indexed, they are added to the Topics using their reference lists. This makes the Topics dynamic and most of them increase in size over time.

They are obtained from more than one billion citation links between more than 48 million documents indexed by Scopus from 1996 onwards and more than 20 million other non-indexed documents that are cited at least twice. There are approximately 96,000 Topics. Once a year SciVal re-runs the SciVal Topics algorithm to identify newly emerging topics. A combination of the potential for emergence (recent numbers of publications vs. previous years), size of the topic, citations, and funding is considered to rank a new topic. As an example, in 2019, 37 new topics were identified and added to SciVal.

The Topics name is part of the topics cluster name. A topic cluster name is created by adding topics with similar research interests to form a broader, higher-level research area. These topic clusters can be used to gain a broader understanding of the research being carried out by a country, institution (or group) or researcher (or group). Each of the 96,000 topics has been paired with one of the 1500 cluster topics. As with topics, a researcher or institution can contribute to multiple topics, but a topic can only belong to one topic and a publication can only belong to one topic (and therefore to one cluster topic). Clusters topics are formed using the same direct citation algorithm that creates the topics. When the strength of the citation links between the topics reaches a threshold, a cluster topic is formed.

Among all the other possible metrics to evaluate the quality of the journals, it has been chosen the field-weighted citation impact, this is the average number of citations received in relation to the expected ones. Recent studies prove that the FWCI is consistent in different areas of research [38]. Expected citations are calculated for the same year of publication, same type of publication, and same discipline. The benchmark is 1, above which, the expected, and below, it has not reached what was expected.

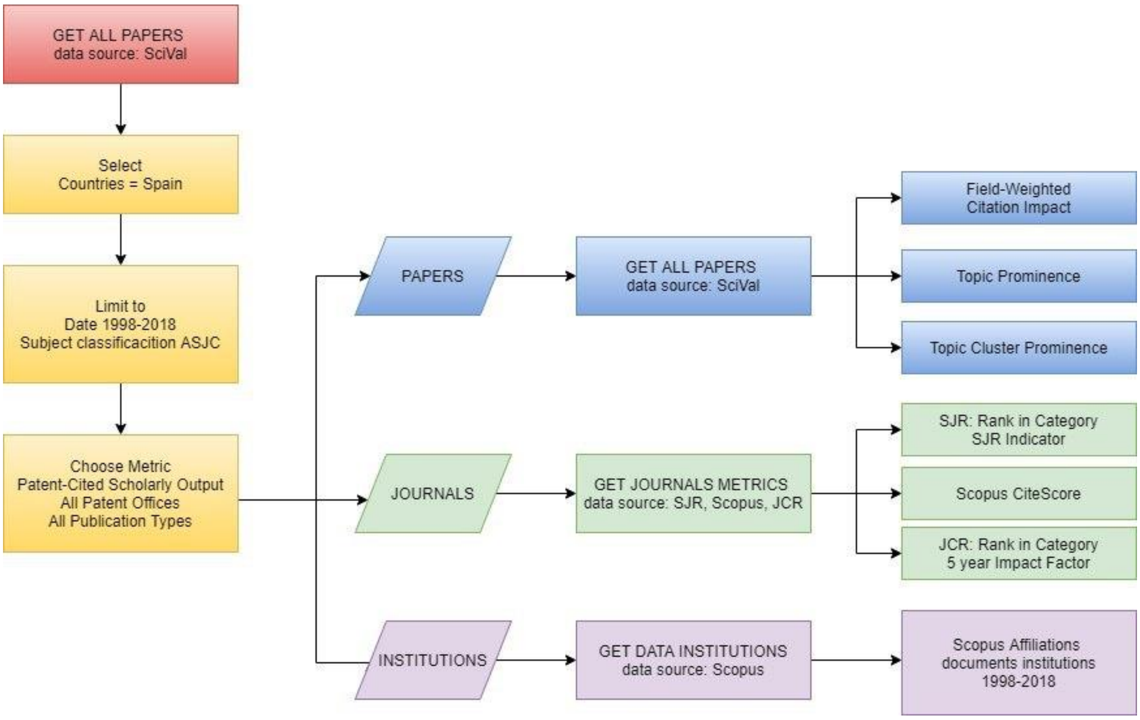

Figure 3-1. Methodology flowchart. Note: SJR (SCImago Journal Rank); JCR (Journal Citation Reports)

3.3 Results

The results achieved from this search, of Spanish scientific papers cited by international patents from 1998 to 2018, have yielded a value of 41,068 cited publications. As expected, almost all these publications are journal articles, more than 96%, being anecdotic the case of the books (Book and Book series) with just over 1% and the conference proceedings with just over 2%. These works have been written by 313,458 co-authors, of which there are 161,046 different authors, identified by their Scopus ID. Most frequently, authors contribute to only one publication, which is the case for 35.5%, those with two are 7.5%, those with three are 3%, those with four are 1.5%, and those with five are less than 1%. By way of exception, there are 50 authors with more than 50 contributions cited by patents. This case study would be particularly interesting to study.

3.3.1 Global Temporal Trend

Figure 2 shows the evolution of the articles cited by patents in the period studied. The trend from 1998 to 2008 is very similar, i.e., it seems clear that the greater the research funding, the greater the number of works cited by patents. From this date the trends are different, but it must be clarified that the research does not have an immediate impact on the industry, this trend can be evaluated in the long term, so we can consider that the data up to 10 years ago, should they be representative.

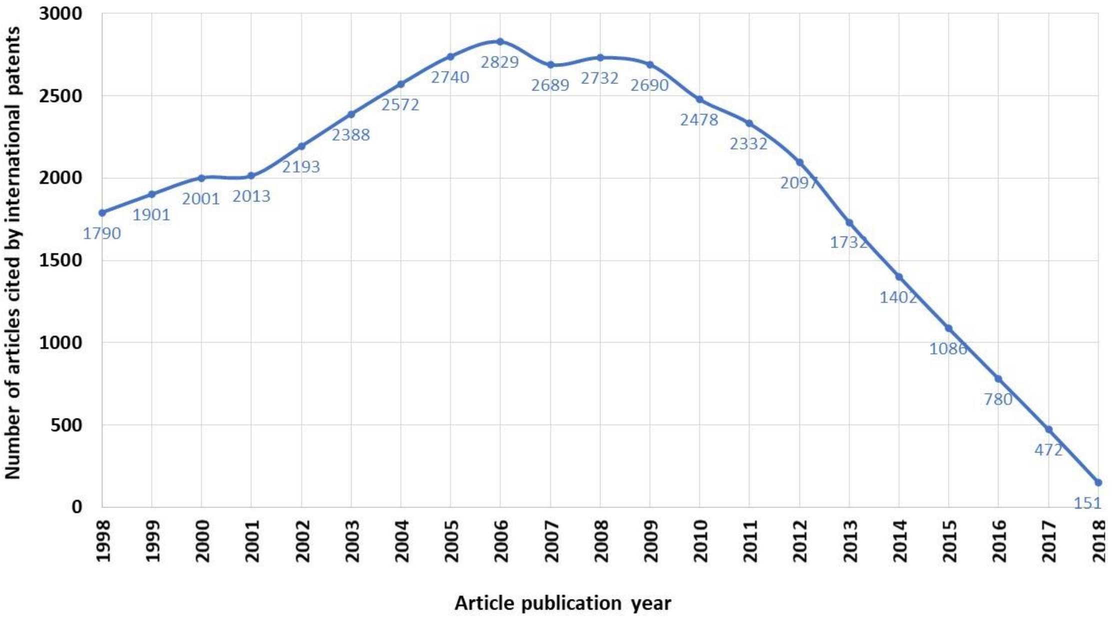

Figure 3-2. Publications cited by international patents and R&D funding in Spain

3.3.2 Countries, Affiliations and Collaborations

The authors of these publications cited in patents belong to just over 5000 institutions around the world, proving a great collaboration with the rest of the world by the Spanish institutions. A total of 165 different countries have been involved, with the USA being the most important with almost 7500 contributions, followed by the UK with around 4200 and Germany with just over 3700. Figure 3 shows a map of Spain's international collaboration. There is scarce, or almost no, collaboration with African countries, despite the fact that, as will be seen later, the pharmaceutical industry and the area of medicine are very prominent in the domain of patents, and there are very widespread diseases in these areas, such as malaria [39], AIDS, or tuberculosis [40].

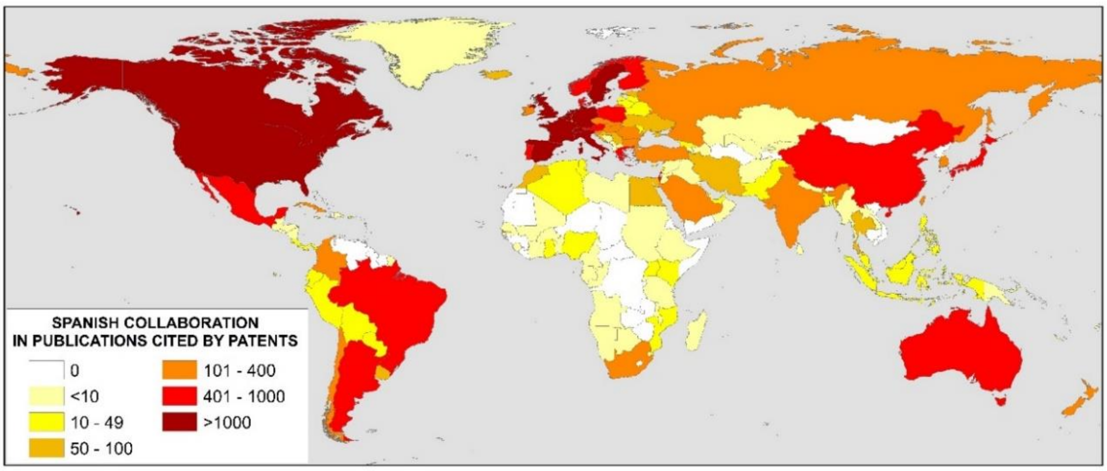

Figure 3-3. Worldwide collaboration with Spanish publications cited in patents

The top 20 Spanish institutions that have contributed mostly with their publications to international patents are shown in Figure 4. It can be observed as expected that the CSIC, Consejo Superior de Investigaciones Científicas, as the Spanish state agency dedicated to scientific research and technological development, leads this ranking. An example of these studies, which is also widely cited, is a collaboration between University of Valencia, Consejo Superior de

Investigaciones Científicas, Beth Israel Deaconess Medical Center, and Harvard Medical School related to the Transcranial magnetic stimulation [41].

Figure 4 highlights the non-university institutions, which include, apart from a specific section of the CSIC, the National Center for Biotechnology, two other autonomous health institutions, the CIBER—Center for Biomedical Research Network and the Instituto de Salud Carlos III. With respect to the universities, two of the first four stand out: The University of Barcelona and the Autonomous University of Barcelona; and two in Madrid, the Autonomous University of Madrid, and the Complutense University. In fifth place is the University of Valencia, but already distant in the number of publications. In this ranking it is remarkable that there are no other research agencies such as CIEMAT (Energy, Environmental and Technological Research Center) that in this period only appear with 251 publications cited, almost as small universities, as the University of Almeria with 210 publications cited in patents. Interestingly, these two institutions cooperate extensively in research, perhaps due to the proximity of one of the CIEMAT centres, Plataforma Solar de Almeria, to the aforementioned university, e.g., they have investigate solar reflector materials degradation due to the sand deposited on backside protective paints [42].

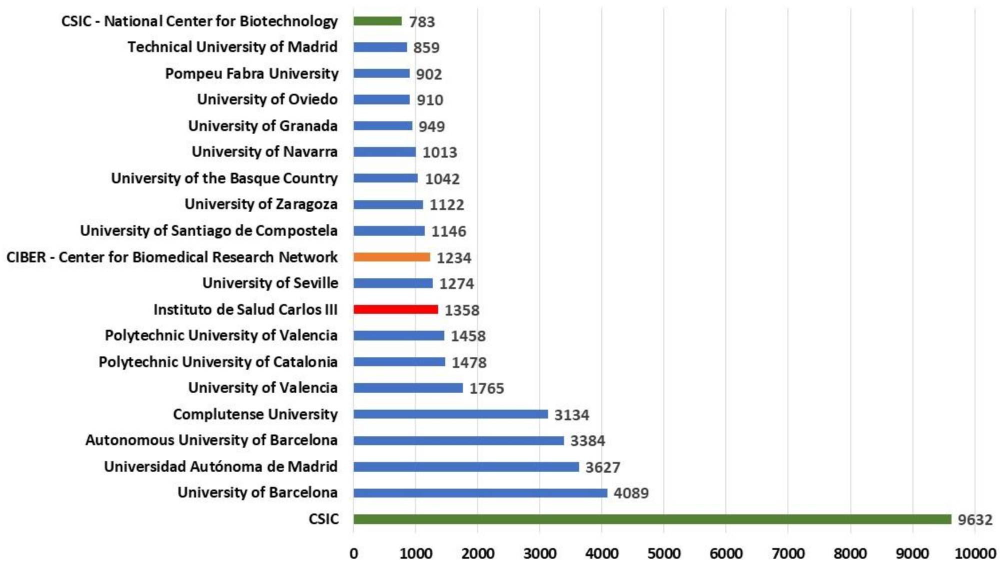

Figure 3-4. Top 20 Spanish institutions by publications cited in patents. Note: CSIC (Consejo Superior de Investigaciones Científicas)

With the aim of having a metric of the impact of the scientific production of the universities in its transference with respect to the patents. The transference index in patents (TIP) is proposed, and this is calculated as a percentage of publications cited in patents over the total number of publications indexed. Table 2 shows this index calculated for the Top 20 Spanish universities. Those that are above 5% are considered outstanding, excellent between 4% and 5%, very good between 3% and 4%, good between 2% and 3%, average < 2%.

This TIP index shows that among this top 20, 4 universities are in the range of outstanding, apart from the three most productive, now included in this category is the University of Navarra (5.24), which is a private university. In the range of excellent there are two universities: Complutense University (4.74) and Pompeu Fabra University (4.66). Further, in the rank of very good, we find eight universities.

What is surprising at first glance is that the most technological universities are not necessarily the best at this transfer rate: Polytechnic University of Valencia (3.77), Polytechnic University of Catalonia (2.85), and Technical University of Madrid (2.31).

In Figure 5, the top 20 non-Spanish institutions that participate in these works have been represented the ones with which most collaboration takes place. The collaboration of Spanish institutions is especially remarkable with the CNRS (Centre national de la recherche scientifique) in France with more than 1000 works. In addition, there are three other institutions in this country in the top 20: Institut national de la santé et de la recherche médicale (773), Université Paris-Saclay (498) and Sorbonne Université (416). This fact is striking since France was in fourth place in Spanish collaboration.

Spanish institutions collaboration with foreign countries is significant, as 21,136 of the total number of contributions analysed are of Spanish authorship only, representing 51% of the works. Therefore, in broad terms, this means that half of the contributions cited in patents are in collaboration with foreign institutions. However, when it concerns universities, the percentage is significantly lower Table 2 shows the contributions of each university without collaboration. If the data are analyzed in relative terms, in terms of percentages, the University of Murcia has the highest percentage without collaboration with 41% and the lowest, with 5%, is the Pompeu Fabra University. But the important data is the average, which is 25%. So, only one of each four contributions cited in patents is authored by a Spanish university without collaboration.

Concerning the collaboration with the USA, the first place is taken by Harvard University (864), followed by the National Institutes of Health (539). With the UK, the institutions are universities, University College London (510), Imperial College London (455), and the University of Oxford (411). It is striking that in this top 20 of international collaboration no German institution exists, even though Germany is the third country in terms of international collaboration for Spain. Finally, it should be noted that, apart from the CNRS, the only two non-university institutions carrying out research in the field of health are the aforementioned Institut national de la santé et de la recherche médicale (France) and the Karolinska Institutet (Sweden).

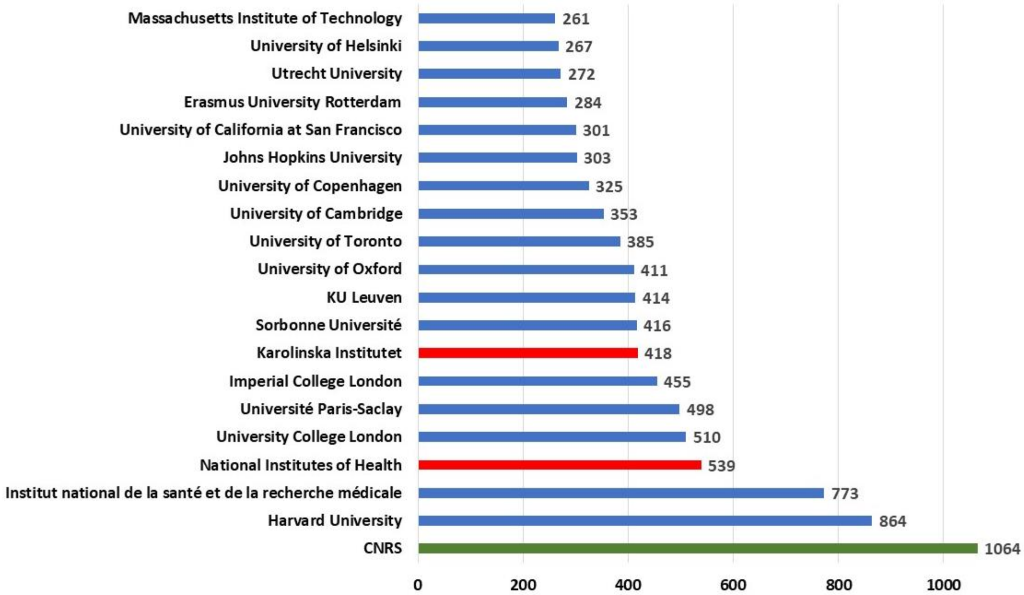

Figure 3-5. Top 20 Foreign institutions that collaborates with Spanish institutions

Table 3-2. Proposed Transference Index in Patents (TIP)

University	N Cited in Patents (NCP)	NCP without Collaboration	N (1998–2018)	TIP (TIP = NCP × 100/N)
University of Barcelona	4089	781	68,392	5.98
Autonomous University of Madrid	3627	314	63,288	5.73
Autonomous University of Barcelona	3384	551	65,910	5.13
Complutense University of Madrid	3134	587	66,136	4.74
University of Valencia	1765	376	52,037	3.39
Technical University of Catalonia	1478	415	51,882	2.85
Polytechnic University of Valencia	1458	339	38,660	3.77
University of Seville	1274	268	37,233	3.42
University of Santiago De Compostela	1146	412	32,766	3.77
University of Zaragoza	1122	273	32,863	3.49

University of The Basque Country	*1042*	*311*	*40,071*	*2.80*
University of Navarra	*1013*	*315*	*19,324*	*5.39*
University of Granada	*949*	*316*	*43,755*	*2.32*
University of Oviedo	*910*	*365*	*25,656*	*3.70*
Pompeu Fabra University	*902*	*50*	*19,366*	*4.70*
Technical University of Madrid	*859*	*197*	*37,155*	*2.43*
Universidad Rovira i Virgili	*751*	*190*	*19,691*	*3.81*
Universidad de Salamanca	*650*	*114*	*19,411*	*3.35*
University of Murcia	*595*	*270*	*20,699*	*2.87*
University of Málaga	*539*	*178*	*19,589*	*2.75*

3.3.3 Top Journals Used for the Spanish Publications Cited in Patents

The Spanish scientific studies that have been cited in patents have been published in 4579 different journals. In Table 3, the top 20 of these journals are reported, together with some of their bibliometric indicators. It can be seen that these journals are mainly in the chemical or medical field, with the clear exception of the highly recognized multidisciplinary journals such as Proceedings of the National Academy of Sciences of the United States of America (PNAS), PLoS ONE, or Nature. As an anecdote, there is only one article from the journal Science in this list of journals.

About the metrics of the Top 20 journals obtained, most of them belong to the first quartile (Q1), 17 of the 20 analyzed, but only four are the first of their category. Of the many metrics that can be used to analyze the journals, the field-weighted citation impact has been used, as mentioned, if the publications are above the value of 1, it is more than expected. In our case, the average of all the publications analysed is almost 4 (3.97), and 27,888 of the 41,068 papers analysed are above 1, i.e., 68%.

Table 3-3. Top 20 Journals and their metrics (Data 2018)

Journal	***N***	***SJR category***	***Rank SJR***	***SJR Indicator***	***CiteScore Scopus***	***JCR category***	***Rank JCR***	***Impact Factor (5 years) JCR***
Journal of Biological Chemistry	*507*	*Biochemistry*	*37/446-Q1*	*2.403*	*3.92*	*Biology & Biochemistry*	*1/434-Q1*	*4.279*
		Cell Biology	*45/288-Q1*					
		Molecular Biology	*69/409-Q1*					
Journal of Agricultural and Food Chemistry	*350*	*Agricultural and Biological Sciences (miscellaneous)*	*32/272-Q1*	*1.111*	*3.8*	*Agriculture, Multidisciplinary*	*3/57-Q1*	*3.911*
						Chemistry, Applied	*14/71-Q1*	
		Chemistry (miscellaneous)	*56/437-Q1*			*Food Science &Technology*	*28/135-Q1*	
Proceedings of the National Academy of Sciences of the United States of America (PNAS)	*321*	*Multidisciplinary*	*4/120-Q1*	*5.601*	*8.58*	*Multidisciplinary Sciences*	*7/69-Q1*	*10.600*
PLoS ONE	*292*	*Agricultural and Biological Sciences (miscellaneous)*	*32/272-Q1*	*1.100*	*2.97*	*Multidisciplinary Sciences*	*24/69-Q2*	*3.337*
		Biochemistry, Genetics and Molecular Biology (miscellaneous)	*53/242-Q1*					
		Medicine (miscellaneous)	*474/2836-Q1*					

Journal of the American Chemical Society	*253*	*Biochemistry* *Catalysis* *Colloid and Surface Chemistry* *Chemistry (miscellaneous)*	*5/446-Q1* *1/58-Q1* *1/16-Q1* *7/437-Q1*	*7.468*	*14.75*	*Chemistry Multidisciplinary*	*12/172-Q1*	*14.491*
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	*253*	*Computer Science (miscellaneous)* *Theoretical Computer Science*	*131/449-Q2* *96/160-Q3*	*0.283*	*1.06*	*Computer Science, Theory & Methods* *(2005 is last year available)*	*62/71-Q4*	*n/a*
Nature	*236*	*Multidisciplinary*	*1/120-Q1*	*16.345*	*15.21*	*Multidisciplinary Sciences*	*1/69-Q1*	*45.819*
Journal of Organic Chemistry	*233*	*Organic Chemistry*	*15/177-Q1*	*1.607*	*4.57*	*Chemistry, Organic*	*7/57-Q1*	*4.224*
Journal of Medicinal Chemistry	*232*	*Molecular Medicine* *Drug Discovery*	*18/173-Q1* *7/167-Q1*	*2.287*	*1.05*	*Chemistry, Medicinal*	*3/61-Q1*	*6.060*
Blood	*221*	*Biochemistry* *Cell Biology* *Immunology* *Hematology*	*9/446-Q1* *19/288-Q1* *10/216-Q1* *2/133-Q1*	*6.065*	*7.27*	*Hematology*	*1/73-Q1*	*13.206*
Applied and Environmental Microbiology	*196*	*Food Science* *Biotechnology* *Ecology* *Applied Microbiology and Biotechnology*	*11/301-Q1* *30/328-Q1* *27/357-Q1* *11/111-Q1*	*1.663*	*4.18*	*Biotechnology & Applied Microbiology* *Microbiology*	*33/162-Q1* *38/133-Q2*	*4.701*
Tetrahedron	*196*	*Biochemistry* *Organic Chemistry* *Drug Discovery*	*228/446-Q3* *60/177-Q2* *56/167-Q2*	*0.709*	*2.39*	*Chemistry, Organic*	*26/57-Q2*	*2.193*
Journal of Virology	*190*	*Insect Science* *Immunology* *Microbiology* *Virology*	*2/146-Q1* *25/216-Q1* *15/149-Q1* *8/70-Q1*	*2.590*	*4.02*	*Virology*	*8/36-Q1*	*4.259*
Cancer Research	*181*	*Cancer Research* *Oncology*	*11/216-Q1* *14/368-Q1*	*4.047*	*6.94*	*Oncology*	*21/230-Q1*	*9.062*
Journal of Chromatography A	*180*	*Biochemistry* *Analytical Chemistry* *Organic Chemistry* *Medicine (miscellaneous)*	*122/446-Q2* *14/117-Q1* *27/177-Q1* *417/2836-Q1*	*1.188*	*3.78*	*Biochemical Research Methods* *Chemistry, Analytical*	*13/79-Q1* *15/84-Q1*	*3.741*

New England Journal of Medicine	*177*	*Medicine (miscellaneous)*	*3/2836-Q1*	*19.524*	*16.1*	*Medicine, General & Internal*	*1/160-Q1*	*70.331*
Applied Physics Letters	*167*	*Physics and Astronomy (miscellaneous)*	*29/267-Q1*	*1.331*	*3.58*	*Physics, Applied*	*31/148-Q1*	*3.352*
Clinical Cancer Research	*165*	*Cancer Research* *Oncology*	*7/216-Q1* *10/368-Q1*	*4.965*	*8.32*	*Oncology*	*16/230-Q1*	*9.174*
Chemistry - A European Journal	*164*	*Catalysis* *Chemistry (miscellaneous)* *Organic Chemistry*	*8/58-Q1* *31/437-Q1* *8/177-Q1*	*1.842*	*4.77*	*Chemistry, Multidisciplinary*	*37/172-Q1*	*4.843*
Angewandte Chemie - International Edition	*159*	*Catalysis* *Chemistry (miscellaneous)*	*2/58-Q1* *12/437-Q1*	*5.478*	*11.68*	*Chemistry, Multidisciplinary*	*17/172-Q1*	*12.359*
FEBS Letters	*159*	*Biochemistry* *Biophysics* *Cell Biology* *Genetics* *Molecular Biology* *Structural Biology*	*63/446-Q1* *10/133-Q1* *76/288-Q2* *60/338-Q1* *101/409-Q1* *14/53-Q2*	*1.849*	*3.01*	*Biochemistry & Molecular Biology* *Biophysics* *Cell Biology*	*160/299-Q3* *30/73-Q2* *129/193-Q3*	*3.386*

Three indices have been chosen to assess the articles published in the top 20 journals: field-weighted citation impact, top 10% topic, and top 10% topic cluster. The Field-Weighted Citation Impact, a Scopus-specific metric value, allows users to measure whether publications have exceeded the percentage of citations expected from them, considering the year of publication, the type of publication and the discipline. The benchmark is 1, so that higher values meet the publication's expectations and lower values below 1 do not.

Figure 6 shows the percentage of publications in each of the journals that were above 1. The data show the different percentages achieved, with the New England Journal of Medicine standing out as all the articles published exceeded the value of 1. Between 90% and 100% there are two other journals Nature and Blood, followed by the rest of the journals that are above 50%, only two titles (Lecture Notes in Computer Science, including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics and Tetrahedron) do not exceed 50%. Based on these data, the majority of publications not only contribute to the development and advancement of science, but also have a direct application in knowledge transfer by being cited in patents. They have surpassed the perspectives expected from them and have had a practical application in research transfer.

The second index considered was the percentage of publications within each journal that contributed to the top 10% of topic and topic cluster. Being in the Top 10% of these values is indicative of the momentum of the Topics that have been assigned to these publications, thus promoting the visibility of these fields of research. Journals such as the New England Journal of Medicine or Nature place more than 75% of their publications in the top 10% of topics, as well as Angewandte Chemie—International Edition, Chemistry—A European Journal or Journal of the American Chemical Society and Angewandte Chemie—International Edition, which place more than 60% of their publications in the top 10% of topic clusters.

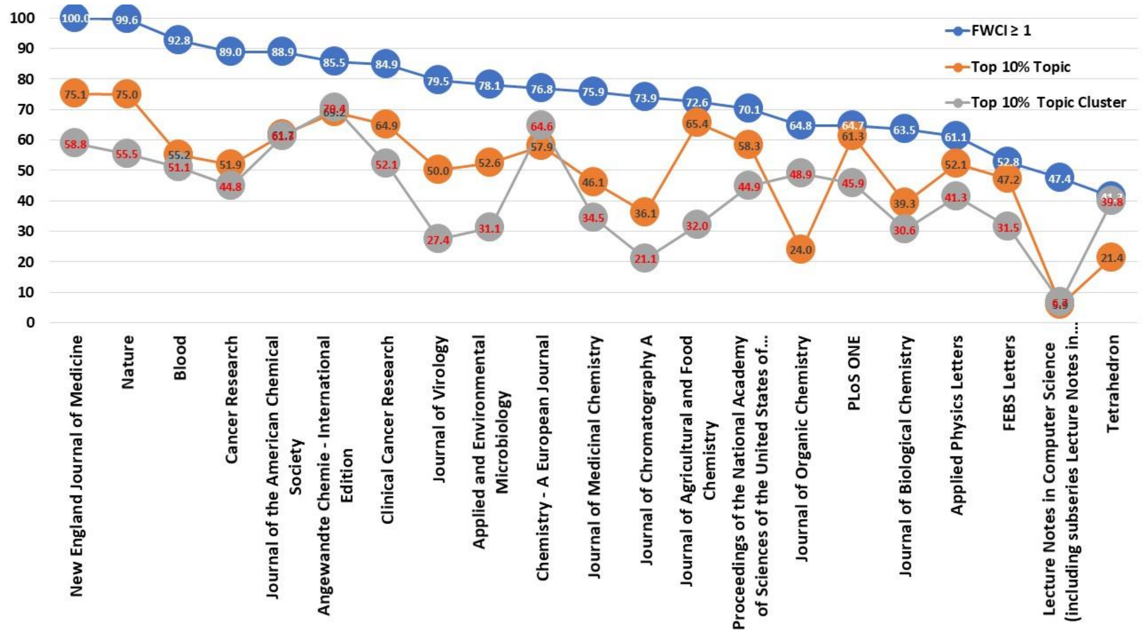

Figure 3-6. Percentage of articles Field-Weighted Citation Impact (FWCI) ≥ 1, Top 10% Topic y Topic Cluster

3.3.4 Subject Area Classifications of the Publications Cited in Patents

Although the journals are an early indicator of the topics covered, if one uses the classification of the database itself, namely the all science journal classification (ASJC) field name, these contributions appear in four subject areas, which in turn are divided into the 30 categories indicated in Table 1, and this classification allows a third level. This is done by in-house experts when of the serial title is set up for Scopus coverage; the classification is based on the aims and scope of the title, and on the content it publishes. If the distribution of the scientific output by the All Science Journal Classification (ASJC) are analysed regarding the distribution in the four subject areas, the one that contributes most is physical sciences with 44%, followed closely by life sciences with 38%, in third place health sciences with 16%, in fourth place social sciences with less than 1% as expected. The works in the multidisciplinary category have not been attributed to any subject area, being overall 1%. Note that this scientific production refers to the whole, i.e., it includes articles, books, and proceedings.

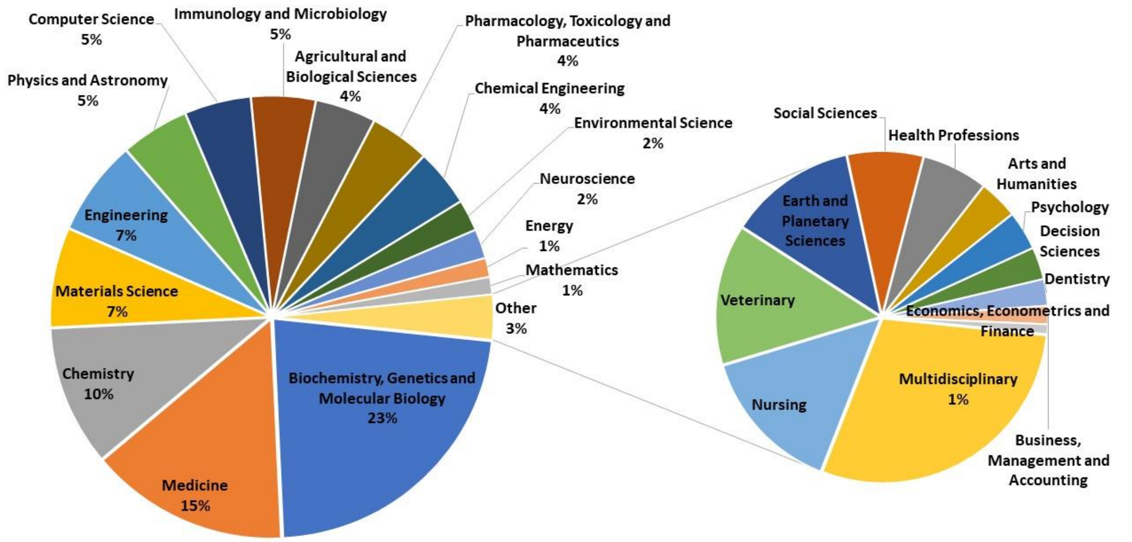

Figure 3-7. Distribution of the scientific output by ASJC (articles, books, and proceedings)

If the studies are analyzed by subject area classifications, Figure 7 is obtained. The highest percentage of studies is biochemistry, genetics and molecular with 23%, followed by medicine with 15%, and then chemistry with 10%. This means, for example, that of the total number of Spanish scientific output cited in patents, 15% are classified in the field of medicine. The other categories are already below 10%. Figure 8 shows a cloud of words made with the subcategories of the ASJC in order to establish a visual comparison.

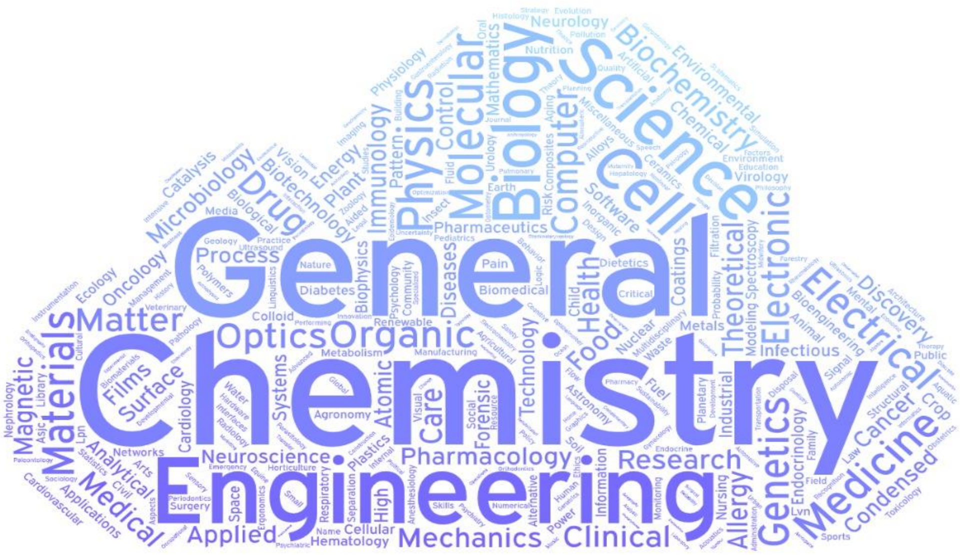

Figure 3-8. Cloud Word of Topic cluster names

3.3.5 Topics of the Publications Cited in Patents

The topics covered in all these papers could be summarized by two indexing fields: topic cluster name, and topic name. Table 4 lists the first 20 Topic Cluster names and Topic names. In the Topic names, the topics of medicine and biochemistry are more present, but some of other areas such as algorithms, plants, or solar cells are present. On the other hand, in the Topic names no longer appears anything of these other areas, and they do appear diseases apart from neoplasms, appear terms like carcinoma, Alzheimer Disease, or HIV-1. To establish a visual comparison, the topic names have also been represented in a cloud of words in Figure 9.

Table 3-4. Top 20 Topic Cluster names and Topic names

Topic Cluster Name	***N***	***Topic Name***	***N***
Neoplasms	*3062*	*Neoplasms*	*1180*
Patients	*2743*	*Receptors*	*828*
Catalysts	*1614*	*Proteins*	*464*
Synthesis (Chemical)	*956*	*Cells*	*463*
Models	*883*	*Patients*	*374*
Algorithms	*842*	*Synthesis (chemical)*	*348*
Genes	*821*	*DNA*	*339*
Hydrogenation	*795*	*Carcinoma*	*336*
Zeolites	*795*	*Genes*	*312*

Pharmaceutical Preparations	*686*	*Mutation*	*304*
Proteins	*656*	*Pharmaceutical Preparations*	*294*
Cells	*641*	*Receptor*	*288*
Catalysis	*617*	*Peptides*	*284*
T-Lymphocytes	*596*	*T-Lymphocytes*	*276*
Plants	*586*	*Ligands*	*269*
Bacteria	*555*	*Breast Neoplasms*	*263*
Solar Cells	*551*	*Nanoparticles*	*258*
Immunotherapy	*535*	*Alzheimer Disease*	*236*
Ligands	*495*	*RNA*	*232*
Breast Neoplasms	*489*	*HIV-1*	*228*

Figure 3-9. Cloud Word of Topic names

3.4 The Contribution of Spanish Science to Patents: The Medicine Area

3.4.1 Temporal Trend in the Medicine Area

Although civil society is sometimes critical of medical patents, as universal access to medicines is understood from a human point of view. However, the WHO (World Health Organization) itself is in favor of this system, since it is clear that, after basic research, they have to be manufactured, and in order for them to be affordable, investment has to be made in their manufacture, which is determined by exclusivity or patents. Furthermore, the WHO itself makes it clear that it is possible to develop many medicines that are patentable (i.e., that meet the requirement of novelty and inventive step), but this does not mean that they add value to existing medicines. According to the data of the IQWiG (Institute for Quality and Efficiency in Health Care—Institut für Qualität und Wirtschaftlichkeit im Gesundheitswesen), of all the medicines that are patented annually, only 10% add great value to what already exists, and only 17% add considerable value, i.e., only 27% of these medicines should be incorporated into the health system.

In the previous sections, a ranking of universities has been established according to their transfer, but, although the Spanish university is not singularly specialized, except as mentioned for certain technical universities. It is necessary to establish a ranking by areas of knowledge. In this way it will be possible to know the transference and the relevance of a university in a specific area.

In this study, the publications classified within the category of medicine only are 11,287, but there are about 4100 that are also indexed in other categories. If we compare the field of medicine with the total, we can see that it has been very stable over the years. In Figure 10, it can be seen how scientific works classified in the category of medicine have always been at least 20% of the works cited by patents.

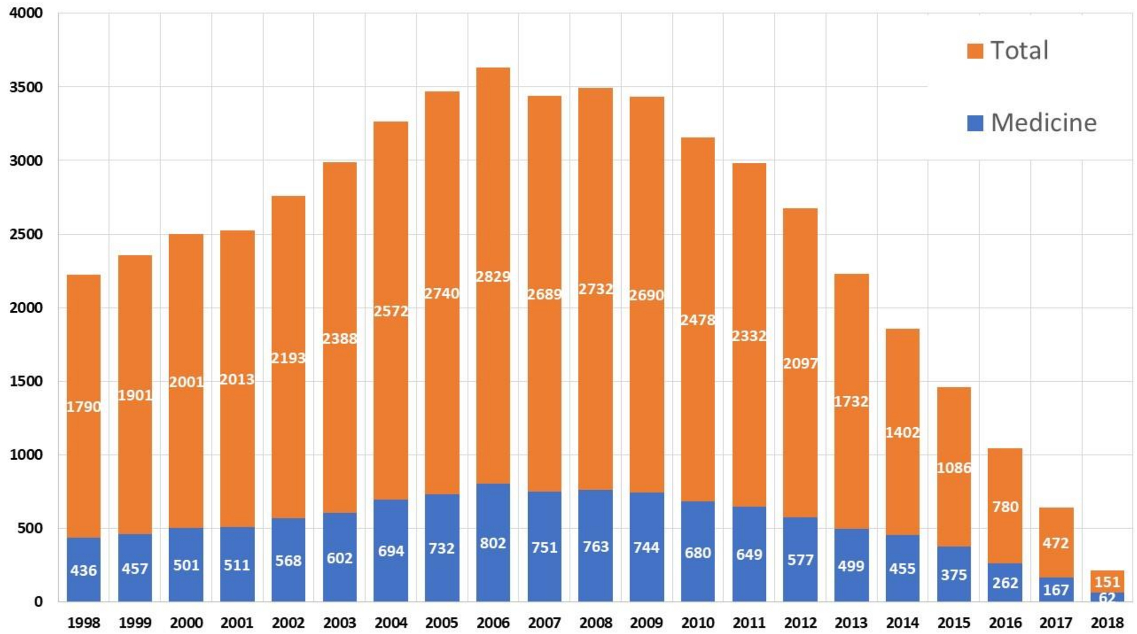

Figure 3-10. Medicine category display in relation to the total number of publications cited in patents

3.4.2 Medicine Transference Index in Patents for Spanish Universities

The Spanish scientific output developed by the institutions in the field of medicine cited in patents is reflected in Table 5. Broadly speaking, it can be seen that they are basically the same institutions as the general transfer, with some exceptions of universities, which do not have medical faculties and do not appear in this ranking. If one observes the last column of the table, the explanation is easy: medical research accounts for a very high percentage of the publications cited in patents. The table has been ordered according to this percentage, with the University of Navarra reaching more than 50%. It can be seen that this percentage decreases in accordance with the vocation of each university, so that the last ones in this ranking are technical universities that do not have a medical faculty, and this scientific output is due to collaboration with other institutions.

Table 3-5. Medicine Transference Index in Patents (MED-TIP)

University	N-MED [1]	NCP [2]	N [3]	TIP [4]	TIP-MED [5]	% MED-TOT [6]
University of Navarra	566	1013	19,324	5.24	2.93	55.87
Autonomous University of Barcelona	1690	3384	65,910	5.13	2.56	49.94
University of Barcelona	2001	4089	68,392	5.98	2.93	48.94
Pompeu Fabra University	372	902	19,366	4.66	1.92	41.24
Complutense University	1223	3134	66,136	4.74	1.85	39.02
Polytechnic University of Valencia	568	1458	38,660	3.77	1.47	38.96

Universidad de Salamanca	*223*	*650*	*19,411*	*3.35*	*1.15*	*34.31*
Universidad Autónoma de Madrid	*1207*	*3627*	*63,288*	*5.73*	*1.91*	*33.28*
University of Valencia	*568*	*1765*	*52,037*	*3.39*	*1.09*	*32.18*
University of Santiago de Compostela	*312*	*1146*	*32,766*	*3.50*	*0.95*	*27.23*
University of Granada	*235*	*949*	*43,755*	*2.17*	*0.54*	*24.76*
University of Zaragoza	*268*	*1122*	*32,863*	*3.41*	*0.82*	*23.89*
University of Murcia	*133*	*595*	*20,699*	*2.87*	*0.64*	*22.35*
University of Valladolid	*89*	*426*	*17,007*	*2.50*	*0.52*	*20.89*
University of Oviedo	*189*	*910*	*25,656*	*3.55*	*0.74*	*20.77*
Universidad Rovira i Virgili	*124*	*751*	*19,691*	*3.81*	*0.63*	*16.51*
University of the Basque Country	*159*	*1042*	*40,071*	*2.60*	*0.40*	*15.26*
University of Seville	*143*	*1274*	*37,233*	*3.42*	*0.38*	*11.22*
Technical University of Madrid	*52*	*859*	*37,155*	*2.31*	*0.14*	*6.05*
Polytechnic University of Catalonia	*69*	*1478*	*51,882*	*2.85*	*0.13*	*4.67*

[1] N-MED Total number of publications classifies as Medicine category (ASJC) cited in patents; [2] NCP Total number of publications cited in patents; [3] N Total number of publications published by the institution in period 1998–2018; [4] TIP = NCP × 100/N; [5] TIP-MED = N-MED × 100/N; [6] % MED-TOT = N-MED × 100/NCP.

3.4.3 ASJC Clusters and Relationship Network

So, to this point, the above information is that which can be extracted more or less directly from the databases analysed. In this section, the aim is to detect in an independent way, and from the published studies, if the scientific fields of medicine described in previous sections, have any relation between them, that is to say, if they can be grouped in scientific communities or clusters. For this purpose, the bibliometric information of all these works have been downloaded with the Scopus API. If an analysis of data is made with the Gephi software of the network of relationships between the publications that are being analyzed on medicine. Figure 11 shows the relationship found between all the contributions, where each dot is a publication, and the line that joins two dots is the relationship it has for having been cited by that publication, the thickness of the dot indicates the number of times that publication is cited by the others. There is an outer circle of publications, which have no relationship with the others, that is, they would be publication that have been used in the references of some patents in the field of medicine, but which have no relationship with any other publication of this analysis. However, those that are linked to others, are publications that in addition to having been cited by patents, are related to others of this selection of publication. This means that these are more central publication that have been cited by patents, but they have also contributed to opening a line of work in this particular field for research itself since it is related to the other publication. In figure 11, the publications have been colored according to the ASJR category assigned by Scopus. One can appreciate that they dominate oncology (11,78 %), immunology and allergy (9.48 %), infectious diseases (7.1 %), cardiology and cardiovascular (6.63 %), hematology (6.44 %), neurology (clinical) (5.34 %), and general medicine (4.74 %). The oncology category has a central role in this relationship. On the other hand, it is seen that general medicine is widely spread throughout the network, as expected, since it has a direct relationship with all other medical disciplines. This is also the case, although to a lesser extent, with cardiology and cardiovascular.

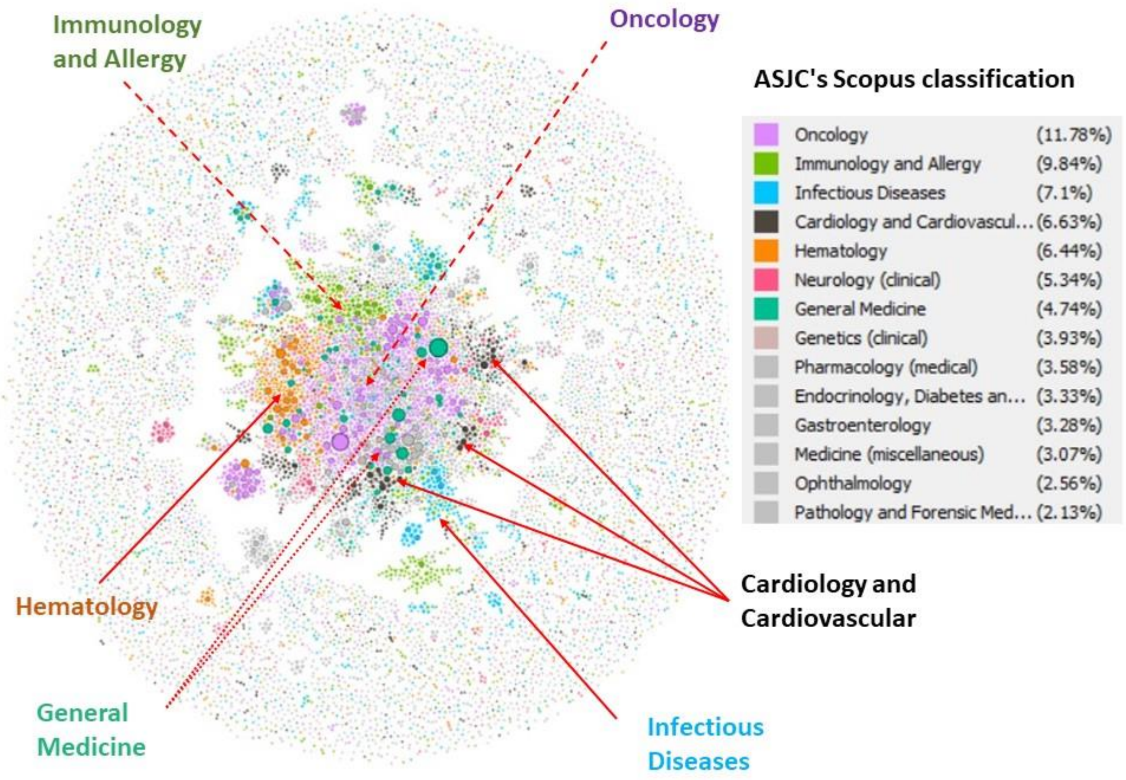

Figure 3-11. Relationship between publications that are cited in patents in the field of medicine according to the subcategories of medicine of the ASJC

3.4.4 Cluster Detection Indenpent Analysis

In a second analysis, the relationships between the publications analysed will be detected. This analysis is independent of the ASJC's Scopus classification done in previous section. In this case the analysis was done with a cluster detection algorithm that contains the software Gephi. Thus, the clusters have been obtained according to the relationships that exist between the publications. Figure 12 shows a color-coded according to the twenty-two clusters cluster obtained. The weight of the cluster reflects in ratio the significance of this set of publications in the whole network of relations. Once the clusters are established, all the keywords are extracted from all the publications in that cluster. Then, the frequency of each keyword that is found in each cluster is calculated as an index of its importance within that cluster. Tables 6–11 show a list of the main keywords for the leading clusters found, up to 5% of weight. The proposed name for each cluster was made according to the keywords of this cluster.

The advantage of this second analysis is that it allows to detect which specific medical topics are being transferred to patents. Thus, the leading topics obtained were: neoplasms, leukemia, DNA repair, human leukocyte antigen, Alzheimer disease, and carcinoma.

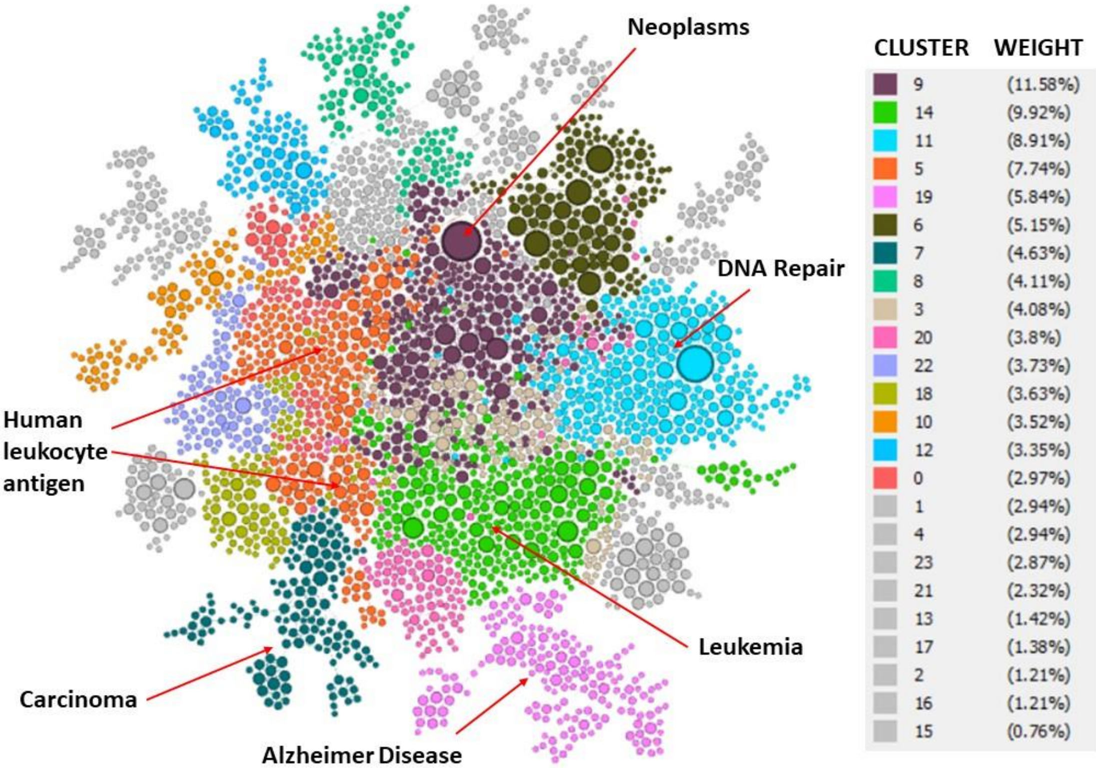

Figure 3-12. Network of the relationship between publications that are cited in patents in the field of medicine according to the subcategories of medicine of the ASJC

Table 3-6. Neoplasms. Cluster (9), weigh 11.58 %

Topic Names	*N = 335*
Breast Neoplasms, Receptor, Epidermal Growth Factor, Adjuvant trastuzumab	*27*
Receptor, Epidermal Growth Factor, Neoplasms, Antibodies, Monoclonal	*21*
Multiple Myeloma, Patients, Diagnosed multiple	*13*
Activated-Leukocyte Cell Adhesion Molecule, T-Lymphocytes, Activated leukocyte	*12*
Colorectal Neoplasms, Drug Therapy, Colorectal cancer	*11*
Colorectal Neoplasms, Mutation, Anti-epidermal growth	*10*
Breast Neoplasms, Receptor, Epidermal Growth Factor, Immunohistochemistry (IHC)	*9*
Sirolimus, Neoplasms, Mammalian target	*9*
Breast Neoplasms, Neoplasms, HER3 expression	*8*

Table 3-7. Leukemia. Cluster (14), weigh 9.92 %

Topic Names	*N = 287*
Leukemia, Lymphocytic, Chronic, B-Cell, Patients, Lymphocytic leukemia	*19*
Lymphoma, Large B-Cell, Diffuse, Lymphoma, Rituximab cyclophosphamide	*18*
Lymphoma, Mantle-Cell, Patients, MCL patients	*16*
Tetraspanins, Cells, Cell migration	*10*

T-Lymphocytes, B-Lymphocytes, XIAP (X-linked inhibitor of apoptosis protein) deficiency	*8*
Multiple Myeloma, Plasma Cells, Cytogenetic abnormalities	*7*
Leukemia, Precursor Cell Lymphoblastic Leukemia-Lymphoma, Phenotype acute	*7*
Lymphoma, Follicular, Lymphoma, Mantle cell	*7*
Precursor Cell Lymphoblastic Leukemia-Lymphoma, Neoplasm, Residual, Disease MRD (Minimal residual disease)	*7*
Liver Transplantation, Liver, Liver allograft	*6*

Table 3-8. DNA Repair. Cluster (11), weigh 8.91 %

Topic Names	***N= 258***
DNA, Neoplasms, Liquid biopsies	*19*
DNA Repair, Carcinoma, Non-Small-Cell Lung, Repair cross-complementation	*18*
Carcinoma, Non-Small-Cell Lung, Receptor, Epidermal Growth Factor, Lung cancers	*16*
Epithelial-Mesenchymal Transition, Neoplasms, Epithelial-to-mesenchymal transition	*10*
Breast Neoplasms, Methylation, Suppressor genes	*8*
Breast Neoplasms, Neoplasms, Cancer subtypes	*7*
DNA Methylation, Methylation, Whole-genome bisulfite	*7*
Methyltransferases, DNA, Temozolomide (TMZ)	*7*
Precursor Cell Lymphoblastic Leukemia-Lymphoma, DNA Methylation, Methylation	*7*
Urinary Bladder Neoplasms, Carcinoma, Bladder cancers	*6*

Table 3-9. Human leukocyte antigen (HLA). Cluster (5), weigh 7.74 %

Topic Names	***N= 224***
Neoplasms, HLA Antigens, HLA class	*19*
Fetal Blood, Transplantation, Blood UCB (Umbilical Cord Blood)	*10*
T-Lymphocytes, Neoplasms, Cancer immunotherapy	*9*
HLA-G Antigens, HLA Antigens, SHLA-G levels	*8*
Lectins, C-Type, T-Lymphocytes, T cells	*8*
Killer Cells, Natural, Receptors, Natural Killer Cell, Ly49 receptors	*7*
Receptors, Antigen, T-Cell, T-Lymphocytes, Antigen receptor	*7*
Dendritic Cells,T-Lymphocytes, Plasmacytoid DCs	*5*
Interleukin-12, Neoplasms, Gene therapy	*5*
Receptors, KIR (Killer Immunoglobulin-like Receptor), Killer Cells, Natural, Killer immunoglobulin-like	*5*

Table 3-10. Alzheimer Disease. Cluster (19), weigh 5.84 %

Topic Names	***N= 169***
Restless Legs Syndrome, Sleep, Patients	*15*
Tauopathies, Alzheimer Disease, Tau oligomers	*12*
Platelet-Rich Plasma, Blood Platelets, Intercellular Signaling Peptides and Proteins	*10*
Deep Brain Stimulation, Parkinson Disease, Microelectrode recording	*8*

Alpha-Synuclein, Parkinson Disease, Protein α-synuclein	*7*
Lipids, Lipolysis, Adipose triglyceride	*6*
Adrenoleukodystrophy, Fatty Acids, Acids VLCFA (Very Long Chain Fatty Acids)	*5*
Lewy Body Disease, Dementia, Probable DLB (Dementia with Lewy bodies)	*5*
Phenylketonurias, Phenylalanine, Phenylalanine levels	*5*
Alzheimer Disease, Amyloid, Amyloid plaques	*4*

Table 3-11. Carcinoma. Cluster (6), weigh 5.15 %

Topic Names	***N= 149***
Carcinoma, Hepatocellular, Survival, Sorafenib treatment	*20*
Hepatitis C, Chronic, Ribavirin, Hepacivirus	*13*
Carcinoma, Hepatocellular, Neoplasms, HCC (HepatoCellular Carcinoma) patients	*10*
HIV, Hepacivirus, HIV (Human Immunodeficiency Virus) /HCV (Hepatitis C Virus) co-infected	*10*
Hepatitis C, Liver Transplantation, Recurrent hepatitis	*8*
Elasticity Imaging Techniques, Fibrosis, Spleen stiffness	*7*
Hypertension, Portal, Fibrosis, Cirrhotic rats	*6*
Hemorrhage, Esophageal and Gastric Varices, Acute variceal	*4*
Hepacivirus, Ribavirin, Direct-acting antiviral	*4*
Carcinoma, Hepatocellular, Liver Transplantation, Microvascular invasion	*3*

3.4.5 Top Journals Used for the Spanish Medicine Publications Cited in Patents

Finally, these works have been published in specialized medical journals, and it is worth highlighting which have been the most used by patents in the field of medicine. Table 12 shows the most used journals, where the JCR categories and their ranking in 2018 and their five-year impact factor are also shown. The journals are mostly in the category of oncology (six of them) and Hematology (three of them). These journals mostly occupy relevant positions in their category, being 17 of them Q1, 2 of them Q3, and one Q4 (Drugs of the Future). This last journal is noteworthy because it is an atypical case, journals that are little valued by the scientific community, since the impact and position are based on the number of citations received for other scientific work, while here, they appear in a ranking of publications used in patents. Of course, the title of the journal itself has a strong emphasis on technology transfer. A bibliometric reflection on this work would be whether a ranking of journals cited in patents would be worthwhile, that is, as an indicator of scientific transfer fed by the sector itself and in which the university and research centres can also be involved.

Table 3-12. Top 20 journal in medicine category. Data 2018

Journal	***N***	***SJR category***	***Rank SJR***	***SJR Indicator***	***CiteScore Scopus***	***JCR Category***	***Rank JCR***	***Impact Factor (5 years) JCR***
Blood	*221*	*Biochemistry*	*9/446-Q1*	*6.065*	*7.27*	*Hematology*	*1/73-Q1*	*13.206*
		Cell Biology	*19/288-Q1*					
		Immunology	*10/216-Q1*					
		Hematology	*2/133-Q1*					
Cancer Research	*181*	*Cancer Research*	*11/216-Q1*	*4.047*	*6.94*	*Oncology*	*21/230-Q1*	*9.062*
		Oncology	*14/368-Q1*					
New England Journal of Medicine	*177*	*Medicine (miscellaneous)*	*3/2836-Q1*	*19.524*	*16.1*	*Medicine, General & Internal*	*1/160-Q1*	*70.331*
	165	*Cancer Research*	*7/216-Q1*	*4.965*	*8.32*	*Oncology*	*16/230-Q1*	*9.174*

Clinical Cancer Research		*Oncology*	*10/368-Q1*					
Drugs of the Future	*155*	*Pharmacology (medical)*	*221/261-Q4*	*0.123*	*0.08*	*Pharmacology & Pharmacy*	*267/267-Q4*	*0.109*
		Pharmacology	*283/330-Q4*					
Journal of Immunology	*147*	*Immunology*	*28/216-Q1*	*2.521*	*4.41*	*Immunology*	*43/158-Q2*	*5.066*
		Immunology and Allergy	*21/203-Q1*					
Vaccine	*130*	*Molecular Medicine*	*28/173-Q1*	*1.759*	*3.18*	*Immunology* *Medicine, Research & Experimental*	*78/158-Q2* *57/136-Q2*	*3.293*
		Immunology and Microbiology (miscellaneous)	*13/49-Q2*					
		Infectious Diseases	*41/286-Q1*					
		Public Health, Environmental and Occupational Health	*38/530-Q1*					
		Veterinary (miscellaneous)	*2/182-Q1*					
Journal of Clinical Microbiology	*108*	*Microbiology (medical)*	*11/123-Q1*	*2.314*	*3.65*	*Microbiology*	*24/133-Q1*	*4.183*
The Lancet	*108*	*Medicine (miscellaneous)*	*5/2836-Q1*	*15.871*	*10.28*	*Medicine, General & Internal*	*2/160-Q1*	*54.664*
Antimicrobial Agents and Chemotherapy	*99*	*Infectious Diseases*	*29/286-Q1*	*2.096*	*4.34*	*Microbiology* *Pharmacology & Pharmacy*	*28/133-Q1* *27/267-Q1*	*4.719*
		Pharmacology (medical)	*11/261-Q1*					
		Pharmacology	*21/330-Q1*					
Hepatology	*94*	*Hepatology*	*3/67-Q1*	*5.096*	*6.87*	*Gastroenterology & Hepatology*	*5/84-Q1*	*12.795*
		Medicine (miscellaneous)	*39/2836-Q1*					
Journal of Clinical Oncology	*91*	*Cancer Research*	*2/216-Q1*	*11.754*	*11.08*	*Oncology*	*5/230-Q1*	*22.565*
		Medicine (miscellaneous)	*9/2836-Q1*					
		Oncology	*4/368-Q1*					
Human Molecular Genetics	*84*	*Genetics*	*27/338-Q1*	*3.097*	*4.88*	*Biochemistry & Molecular Biology* *Genetics & Heredity*	*62/299-Q1* *32/174-Q1*	*5.281*
		Molecular Biology	*47/409-Q1*					
		Genetics (clinical)	*8/100-Q1*					
		Medicine (miscellaneous)	*75/2836-Q1*					
Annals of Oncology	*78*	*Hematology*	*3/133-Q1*	*6.047*	*8.44*	*Oncology*	*9/230-Q1*	*11.791*
		Medicine (miscellaneous)	*35/2836-Q1*					
		Oncology	*8/368-Q1*					
Leukemia	*78*	*Cancer Research Anesthesiology and Pain*	*8/216-Q1*	*4.518*	*6.08*	*Oncology* *Hematology*	*14/230-Q1* *4/73-Q1*	*9.679*
		Medicine	*1/122-Q1*					
		Hematology	*5/133-Q1*					
		Oncology	*11/368-Q1*					
Annals of the Rheumatic Diseases	*72*	*Biochemistry, Genetics and Molecular Biology (miscellaneous)*	*6/242-Q1*	*7.081*	*9.18*	*Rheumatology*	*2/31-Q1*	*12.692*
		Immunology	*8/216-Q1*					
		Immunology and Allergy	*6/203-Q1*					

		Rheumatology	*1/60-Q1*					
Journal of Hepatology	*72*	*Hepatology*	*2/67-Q1*	*6.274*	*9.32*	*Gastroenterology & Hepatology*	*3/84-Q1*	*14.265*
Gastroenterology	*71*	*Gastroenterology*	*1/145-Q1*	*7.384*	*7.07*	*Gastroenterology & Hepatology*	*2/84-Q1*	*19.066*
		Hepatology	*1/67-Q1*					
Haematologica	*66*	*Hematology*	*6/133-Q1*	*3.077*	*4.07*	*Hematology*	*7/73-Q1*	*6.931*
International Journal of Cancer	*65*	*Cancer Research*	*18/216-Q1*	*3.276*	*6.93*	*Oncology*	*51/230-Q1*	*6.210*
		Oncology	*24/368-Q1*					

The analysis made to assess the articles published in the Top 20 journals cited in patents is now made in the case study of the category of medicine for Percentage of articles at Top 20 medicine journals: FWCI ≥ 1, top 10% topic and topic cluster. Figure 13 shows that the New England Journal of Medicine and the Lancet have all their articles above the expected citation value (100 % of FWCI ≥ 1). Four other journals also reach values between 90% and 100%, these are Gastroenterology, Journal of Clinical Oncology, Blood, and Annals of Oncology. Another eight journals are above 80% and all are above 50%, except Drugs of the Future with a very low percentage (4.52%).

According to the percentage of articles that are in the top 10% in topic, it is observed that there is a gradual increase among the journals, and that this ranking is led by journals with more than 75%, which are in order: The Lancet, Annals of Oncology, New England Journal of Medicine, and Annals of the Rheumatic Diseases. Then there are 13 journals with more than 50% and only two below 50%: Journal of Immunology, and Drugs of the Future. The topic cluster has an even lower grading, and there is no journal above 75 %. However, above 50% would be nine journals, where the first four are now: Leukemia, Journal of Clinical Oncology, Annals of the Rheumatic Diseases, and Annals of Oncology. This last journal is the only one that is among the first four in the three rankings analyzed FWCI ≥ 1, top 10% topic and topic cluster.

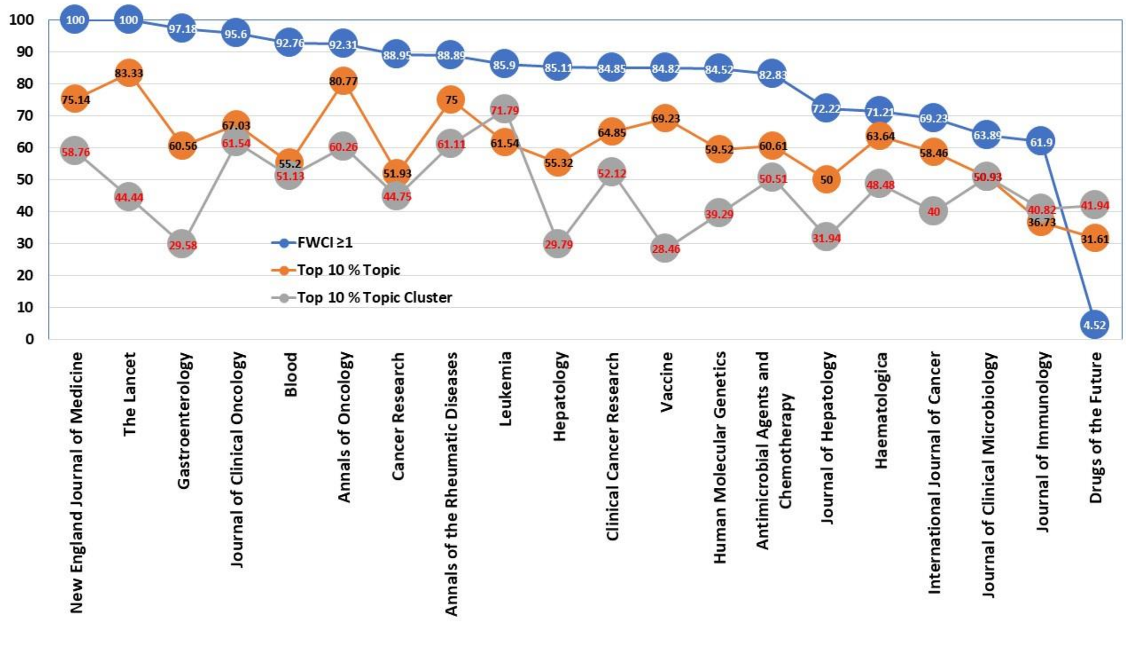

Figure 3-13. Percentage of articles at Topo 20 medicine journals: FWCI ≥ 1, Top 10% Topic and Topic Cluster

3.5 Conclusions

Universities and, by extension research centers or agencies, have the duty of producing knowledge, which is generally measured by their scientific production in the form of publications, which, if they are of good quality, are included in international databases that serve as a basis for future research or technological development. Today, this mission is intended to be extended to the solving of society's problems in general and specifically to the demands of the industrial segment. This new purpose has to date not been easily measured except in the form of patents that universities themselves have developed or applied for. However, this last aspect remains the most important aspect of basic research, which is probably the one that involves the greatest amount of funding. This study has been motivated by the need to understand the role of public research in the development of industry, which is reflected in the contribution to the number of patents. The aim is to address an important gap in the research system by proposing the dilemma of applied research versus basic research carried out in universities and research centres.

This study sets out a methodology to assess the impact of university research on the patent system by analysing the global impact of universities on international patents. In order to evaluate this parallelism, a methodology is established to relate the contribution of Spanish scientific production to international patents based on their citation in these patents. The study was carried out at a global level, but it has been reduced to the field of medicine since the high percentage (20%) of studies cited in patents related to this scientific field.

It has been observed that overall investment in research means an increase in the number of publications that have been cited in patents. Therefore, a direct relationship between funding and transfer is shown. At the same time, international collaboration amongst Spanish authors of these publications is a constant, as shown by the high level of collaboration with countries such as the USA. UK, or Germany at a global level and with France in the field of medicine. Apart from the leading role of the public research body (CSIC), the universities are the institutions that produce applied research and are cited in the patents. A method has been presented that allows the classification of universities based on the relationship between their overall scientific production and the production applied to patents. The results obtained allow to observe that the universities with a TIP (transference index in patents) higher than 5% (outstanding) are not those that have a mainly technological profile, as it would be reasonable to think. However, in the medicine transference index in patents (MED-TIP), it is the universities with medical schools that are positioned at the top of the table.

As an index of where Spanish science is standing out at the transfer level, the Topics and Topic Clusters have been considered. In addition, the highlighted Topics can be used for decision-making in future allocations to research funding. However, the fact that prominence (the topics) represents demand and general visibility should not be lost sight of. It is therefore necessary to support the top 10% topic and top 10% topic cluster indicators. The analysis of the topic and cluster topic has determined networks relating the publications cited in patents both at a general level and from the medical point of view. The clustering of outstanding topics translates directly into the visibility of these publications for the industry sector.

This study shows that public research is fundamental to industrial R&D, as reflected by the number of patents that are based on this knowledge and significantly to R&D in the field of medicine. The leading topics according the ASJC classification were oncology (11.78%), immunology and allergy (9.48%), infectious diseases (7.1%), cardiology and cardiovascular (6.63%), hematology (6.44%), neurology (Clinical) (5.34%), and general medicine (4.74%). In a more detailed and independent analysis, it allowed to determine the leading topics, which were: neoplasms, leukemia, DNA repair, human leukocyte antigen, Alzheimer disease, and carcinoma.

Contrary to the idea that university research generates abstract knowledge that is of poor use to society in general, this study reveals that public research and above all that carried out in universities suggests new products in the form of patents and therefore helps society to advance. Since patents are the basis for industries to develop a product, such research thus reaches society to improve our quality of life.

In short, from the bibliometric point of view, both databases such as Scopus or Web of Science, which provide quality indicators at the publication level, and databases such as JCR or SJR, which quantify the quality of the journals, lack specific indicators that measure the impact of both the publications and their sources in their R&D transfer aspect. Therefore, a ranking of journals cited in patents has been proposed as an indicator of scientific transfer, since it is fed by the industrial sector itself and in which the university and research centres can also be involved. Thus, for universities, the TIP (transference index in patents) has been proposed as a long-term indicator of scientific transfer in patents. In spite of the revealed complexity of the problem about the rates of return to R&D, this work opens new perspectives in the field of transfer of both basic and applied science by proposing a ranking for both journals and research centres, all based on the work cited in patents.

3.6 Referencias. Capítulo 3

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Capítulo 4.

Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27

4 Capítulo 4. Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27

4.0 Abstract

Agriculture as an economic activity and agronomy as a science must provide food for a constantly growing population. Research in this field is therefore becoming increasingly essential. Much of the research is carried out in academic institutions and then developed in the private sector. Patents can be issued not only by scientific institutions. Patents from scientific institutions are intended to have a certain economic return on the investment made in research when the patent is transferred to industry. A bibliometric analysis was carried out using the Scopus and SciVal databases. This study analyses all the research carried out in the field of agronomy and related sciences (Agricultural and Biological Sciences category of Scopus database) by the EU-27 countries, which has been cited in at least one international patent. The data show that out of about 1 million published works only about 28,000 have been used as a source of patents. This study highlights the main countries and institutions in terms of this transfer. Among which Germany, France and Spain stand out in absolute terms, but considering the degree of specialization. Regarding their specialization the institution rank is led by Swedish University of Agricultural Sciences (58%), AgroParisTech (52%), Wageningen University & Research (48%), and INRAE (38%). It also analyses which are the most important journals used for this transfer. For these publications more than 90% of the articles have had a higher-than-expected citation level for the year of publication, the type of publication and the discipline in which they are categorized. The main research fields obtained fields can be distinguished those related to genetics or molecular biology, those related to specific foods such as Cheeses, Milk, Breads or Oils, and thirdly the group covering food related constituents such as Caseins, Probiotics, Glutens, or Starch.

4.1 Introduction

Agronomy is based on scientific and technological principles, and must study the physical, chemical, biological, economic, and social factors that, in one way or another, influence crop production [1]. Its fundamental basis is focused on studying human intervention in nature from an agro-productive point of view, or in other words, studying the agro-ecosystem as a specific model of human intervention in nature, with the aim of producing food and raw materials [2]. In short agronomy may be defined as the science of soil management and crop production [3].

The essential issue in agronomy is the study of the relationship between soil, plant, and environment, with the aim of maximizing yields, reducing production costs, but doing so with responsibility and not at any price [4]. To do this, it is necessary to plan the processes, as well as to implement different measures to obtain the maximum use of natural resources, in order to produce more and better [5]. All this must be done but always paying special attention to non-renewable natural resources, which are in danger due to the negligent and uncontrolled use of man [6]. At this point, it is the agronomy, which must be in charge of developing sustainable plans, for the efficient use of these resources, in order not to aggravate this situation, as the case of water re-use in agriculture [7].

On the other hand, it also deals with the selection of suitable crop varieties, i.e., those best suited to the particular conditions of the environment [8,9], the adoption of the most effective production system [10], the choice of the most suitable growing techniques [11], the selection of the appropriate plant protection measures [12,13], the adoption of the most efficient harvesting methods both in terms of quantity and quality [14,15], and the choice of the most appropriate post-harvest technologies [16,17]. This is done by considering the management of inputs, such as labor, seeds, fertilizers, facilities, and machinery [18].

Agronomy is certainly the fundamental basis of human nutrition [19]. The demographic pressure is increasing but the cultivation area remains static, therefore in order to feed the growing population it is necessary to exploit to the maximum the yields of the production systems and it is here where Agronomy plays a fundamental role. Agronomy is a dynamic discipline, in continuous advance, which makes the knowledge of plants and their environment greater every day [20]. This leads to the development and implementation of new agricultural practices focused on exploiting the potential of the different production systems to the full [21], as well as improving the production and processing processes of food from both a quantitative and qualitative point of view. In addition, agronomy must develop plans that enable integrated *agricultural systems to be implemented, to achieve sustainable agricultural growth, that is to say without compromising the environment [22].*

All these challenges are not possible without high-quality R&D that is broad and multidisciplinary, and above all geographically distributed [23]. It is well known that public research usually allocates its large resources to basic research, while companies focus on applied research, which they can market either directly or by selling the knowledge they have developed [24]. On this last point, the key is the protection of these rights, generally via patents [25].

It is a consensus in all industrialized countries that patent law has a decisive influence on the organization of the economy, as it is a key element in promoting technological innovation [26]. This last aspect is of the utmost importance, as it largely regulates business investment in R&D. It should suffice to mention that one of the points to be reformed in the legislation of the applicant countries is the law governing patents when a country becomes a member of the European Union. For example, Spain's admission to the EU in 1986 led to the revocation of the 1929 patent law. European patent legislation is based on the Munich Convention of 5 October 1973 on the European Patent [27] and the Luxembourg Convention on the Community Patent of 15 December 1975 [28]. This European patent directive has been incorporated into almost all European patent legislation [29].

Without going into detail on European patent law, it should be noted that there are two categories of industrial property rights: patents for invention and utility models [30]. Patents give their holders a territorial right to prevent the commercial exploitation of the patented object without their consent for 20 years from the priority date, while for utility models this is limited to 10 years [31].

In short, patent laws must aim to promote the technological development of countries, starting from their industrial situation [32]. Particular attention has therefore been paid to the protection of national interests [33], especially by strengthening the obligations of patent holders so that the exploitation of patents takes place within their territory and a real transfer of technology takes place, but always in accordance with the Paris Union Convention of 20 May 1883, the text of which was revised in Stockholm on 14 July 1967 [34].

The issue of plant variety protection is particularly interesting. However, it is specified that a patent cannot be awarded for a particular variety of a plant or for essentially biological processes for obtaining plants such as crossing and selection. Some authors suggest that the right to patent agricultural innovations is increasingly placed in a political context [35].

Plant varieties can be protected by obtaining Plant Variety Protection (PVP) or Plant Variety Rights (PVR) provided that these varieties are new, distinct, uniform, and stable and have a name which is not liable to be confused with the names of other plants or with trademarks for Class 31 according to the Nice Classification [36].

In Spain, for example, the right obtained by entering the plant variety in the national register of commercial varieties does not correspond to this plant variety right but is distinct and complementary. To establish novelty there is a useful period of grace during which commercial acceptance can be verified. Plant variety titles grant their holder a territorial right to prevent the commercial exploitation of the variety without his consent for 30 years for vine, and potatoes varieties and tree species and 25 years for all other plant varieties, from the date the title is awarded [37].

In the plant breeding sector, patent protection of innovations is the prevalent strategy in the United States and China [38]. In Europe, however, plant breeders are choosing to protect new plant varieties [39]. According to the latest data provided by the International Union for the Protection of New Varieties of Plants (UPOV), the registration of plant varieties at the Community Office is the most widely used method worldwide, because it makes it possible to obtain protection in all EU Member States at a proportionately more attractive cost compared with the domestic route. The mission of UPOV is to provide and promote an effective system of plant variety protection, to encourage the development of new varieties of plants, for the benefit of society (https://www.upov.int/portal/index.html.en).

This article is organized as follows, first a background section related to patentometrics and Triple Helix concept is introduced, then the data used, and the methodology followed are described in Materials and Methods section. The results are then analyzed and then discussed with other papers. This last section is organized as: Global temporal trend; Countries, Affiliations, and collaborations; Top Journals used for the publications cited in patents; The quality of the articles; The Open Access and European funding agencies; and Topics of the publications cited in patents. Finally, the main conclusions of this research are drawn.

4.2 Background: Patentometrics and Triple Helix

Since the 2000s university patenting in the most advanced economies has been on the decline both as a percentage and in absolute terms [39]. We suggest that the institutional incentives for university patenting have disappeared with the new regime of university ranking, since patents or spin-offs are not counted in university rankings.

Patent statistics have long been of interest to innovation-conscious economists. The central question left open is whether or not patent statistics represent the real state of innovation [40]. The statistical analysis of patents can be named Patentometrics [41]. The first articles on this issue are quite recent, dating back to 2001 [40]. On the one hand there are the statistics of the patents themselves, such as defining rankings for them based on citations [42], as patent h-index indicator to assess patenting quality [43]. Patent h-index have been introduced to evaluate the patenting activities of research organizations [44]. However, the h-index has mostly been questioned for being insensitive to some exceptionally widely cited items, as can be seen from the large number of so-called h-indexes proposed to address this issue and to replace the original h-index, a review of these h-type indexes can be found in several studies as [45]. Patentometric indicators make possible to quantify and qualify the performance of technological output on the basis of granted patents, e.g., in Brazil [46].

There is increasing interest in technology-based enterprises, for their capacity to contribute to economic and social development. To this end, patent-based indices have been developed with the aim of monitoring the impact of specific patents, or the state of technology in a given field, or comparing technology between countries. The comparative study between countries of patent production in a given field shows, according to some researchers, how advanced a technology is in the countries that are leaders in this field, and they call it the specialisation index [47]. So, the information contained in patent documentation has become one of the principal techniques for modeling technology scenarios for government, business and industry, research institutes or projects, [48]. Most of this work is based on patent databases such as USPTO (United States Patent and Trademark Office) [17] or EPO (European Patent Office), but one alternative that has proved to be valid and open access is Google Patents (www.google.com/patents) that includes over 8 million full-text patents [49,50].

Patenting is not only a significant method of university knowledge transfer, but also an important indicator for measuring academic R&D strength and knowledge utilization [43]. Because patents are a direct output of innovative activities, cross-border patents are used to analyze the trend of global collaborative creativity [51]. Usually two sets of documents, impact articles and patents have been used as approximation measures to analyze the research of the institutions, and in this way both the trajectories of the scientific and technical front are analyzed, and then the research of these can be categorized as basic science or applied technology [52]. e.g., Brazil, scientometric and patentometric indicators have been studied to assess non-financial criteria associated with technology for the purposes of financial funding, as there is a growing interest in technology-based companies for their ability to contribute to economic and social development [53]. Another issue of great relevance is the assessment of scientific publications and patent analysis production. It enables the definition of the growth rate of scientific and technological output in terms of the top countries, institutions and journals producing knowledge within the field as well as the identification of main areas of research and development [41].

A modern and competitive economic model needs science, it needs a strong public R&D system, funded in a stable way, and aligned with economic development. Science is gradually advancing towards a technological orientation rather than a theoretical orientation [54]. Triple Helix, is an academic theory that argues that the potential for development of the knowledge economy in regions or countries lies in the close collaboration of companies, universities and governments based on new institutional formulas designed for the production, transfer and application of knowledge. The theory of the triple helix introduced and developed by Etzkowitz and Leydesdorff [55] follows the same line, highlighting the role of government along with the other two helixes: universities and industry [56]. This is because innovation processes, as well as research and innovation policy decision-making processes, tend to increasingly involve the variety of components of the innovation system, i.e., academia, industry and stakeholders who are the end-users.

A triple helix model to study university-industry-government relationships is based on indicators such as: webometric, scientometric and technometric [55]. Patent-based metrics could be utilized in a Triple Helix context, and how hybrid indicators could be developed by combining patent with other data [55]. Most of the patented academic inventions are related to scientific research and are financed by public funds. These tend to be used in large companies rather than in start-ups founded by academic entrepreneurs [56]. Moreover, some studies show that scientific excellence and technology transfer activities are mutually reinforcing [57], so it is important to understand their relationship.

The first step in this context is to define the indicators and then to establish a benchmarking framework. The European Commission has elaborated an evaluation report in this regard to benchmark the five aspects: Human resources in RTD; Public and private investment in RTD; Scientific and technological productivity; Impact of RTD on economic competitiveness and employment; Promotion of RTD culture and public understanding of science. These indicators are based on % of GDP or per million population.

In relation to agriculture, the Triple Helix model is not well studied, but it is worth noting the work in this field done in Korea and China, where they used bibliometric indicators. The raw inputs were the numbers (or %) of manuscripts with only academic authors, only industry authors, only government authors, only authors who are from academia or industry, etc. [58].

Previous studies have focused only on the evolution of new technologies through the study of patents and have rarely explored the context of prior knowledge, i.e., the research on which these patents are based. The aim of this paper is therefore to analyze the potential contribution of research in the EU-27 countries as a driving force for technological innovation in the field of agricultural and biological sciences. To this end, bibliometric indicators will be used to analyze all the works published in this scientific field by the EU-27 countries that are cited in at least one patent. The Europe of 27 (EU27) is made up of the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. Finally, the aim is to launch a visualized model that can be applied, as a tool for analyzing any scientific field in any country or group of countries, where the degree of transfer of the research carried out can be measured by means of patent citation. The Europe of 27 (EU27) is made up of the following countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

4.3 Materials and Methods

Science can be considered as what is published in scientific journals [59]. Scientific databases therefore play a key role in the progress of science since what has been published previously is the basis for new research. Within the existing scientific databases, WOS (Web Of Science) and Scopus can be considered to have leading positions in most branches of knowledge. There are many research studies that indicated that Scopus covers at least 80% of the content of the WOS database. Scopus has been used in considerable bibliometric studies in many branches of knowledge, such as those of Engineering [60], Environmental Science [61] or Agricultural and Biological Sciences [62,63].

To carry out this study, the publications in the scientific field of Agricultural and Biological Sciences indexed in Scopus in the period 1999–2019 in the geographical area of the European Union (the current 27 EU countries) have been analyzed. Of the data obtained, the study focuses on those publications that have been cited at least once in patents. This limitation has been made with SciVal; a tool closely linked to Scopus.

As one of the most important reference databases in the field of research, Scopus indexes around 25,000 journal titles from more than 5000 publishers. Although its contents date back to 1788, it was not until 1996 that these contents became the basis of SciVal, Elsevier's tool for metric analysis. SciVal provides access to the scientific output of more than 230 countries and 14,000 institutions. SciVal therefore makes it possible to visualize research performance, make comparisons, analyze trends, and evaluate collaborations [64]. As an analysis tool, SciVal has been employed in several publications, applying the metrics provided by this tool. e.g., studies on the progress of thermal spraying research were carried out between 1985 and 2015 [65,66] and supplemented by SciVal. Also, in 2016 Yu et al. [67] used SciVal in a comparison metric analysis with ResearchGate. In the domain of research in medical radiation science, Ekpo, Hogg and McEntee [68] analyzed international collaboration and institutional activity with metrics obtained from SciVal. Or as last example, the analysis of research results from Russian universities was also based on SciVal conducted in 2018 [69], and also recently in 2019, a bibliometric analysis of big data was carried out using SciVal [70].

To achieve the direct download of data from Scopus and SciVal, the Scopus API Key has been used, by means of this API it is possible to obtain more data than from a direct download (https://dev.elsevier.com/sc_apis.html). To visualize the results, Microsoft Excel has been used as an analysis tool by means of the use of dynamic tables and ArcGIS for the representation of the map.

Using these two tools, the data have been obtained by carrying out two searches. See Figure 1 for an outline of the methodology. The first in Scopus: publications between 1999–2019, in the scientific field of Agricultural and Biological Sciences, in the EU-27. The second in SciVal: publications between 1999–2019, in the scientific field of Agricultural and Biological Sciences, in the EU-27 and which have been cited in patents. To obtain data on publications cited in patents, the bibliometric indicator "Patent-Cited Scholarly Output" has been selected for all publication types and for all patent offices. SciVal offers coverage of five of the largest patent offices: EPO (European patent office), USPTO (US Patent Office), UK IPO (UK Intellectual Property Office), JPO (Japan Patent Office) and WIPO (World Intellectual Property Organization) [71].

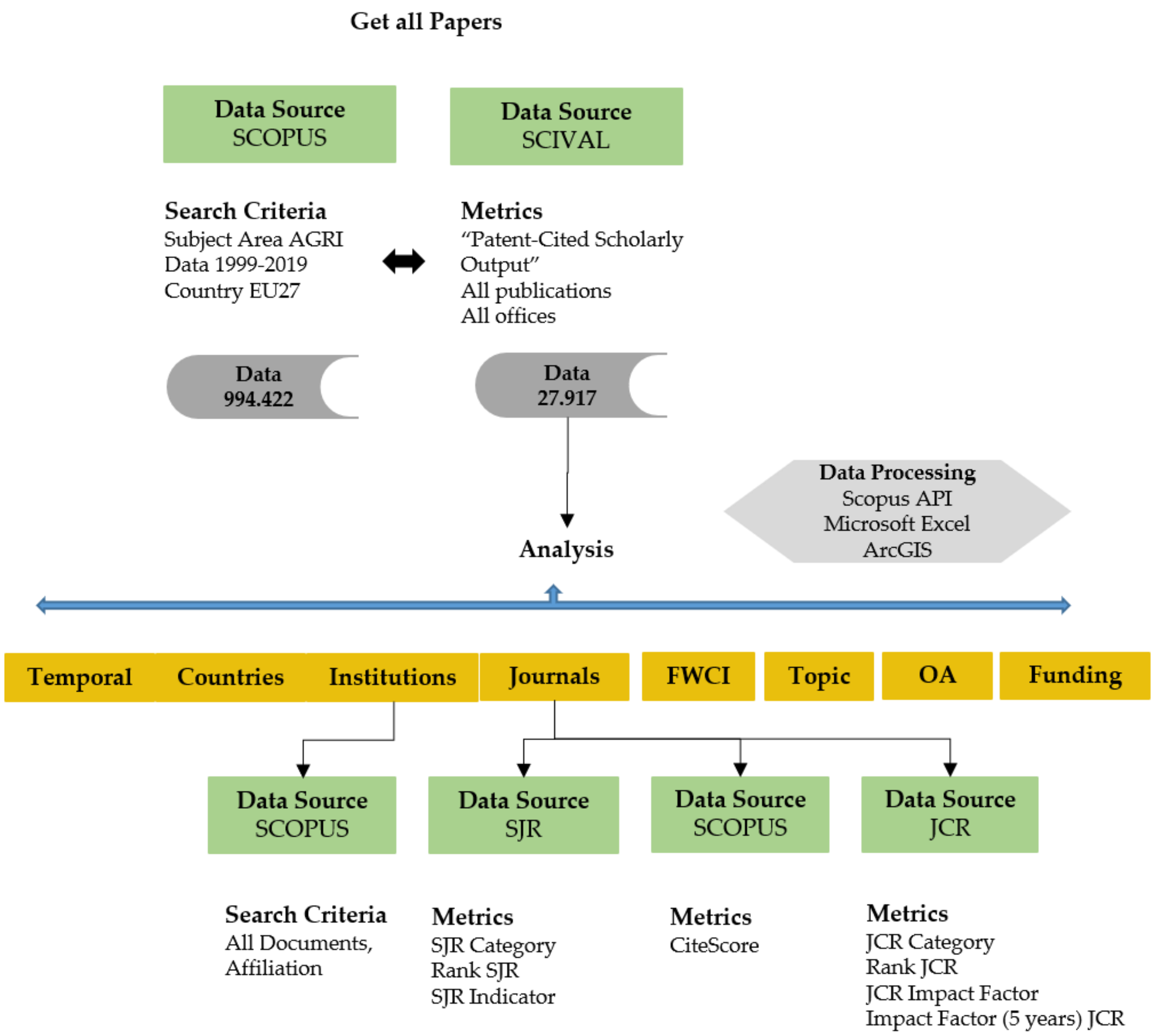

Figure 4-1. Methodology flowchart

In order to establish the degree of specialization of institutions, an indicator called degree of specialization (ESP-AGRI) has been developed. The ESP-AGRI indicator shows the degree of specialization of the institution with respect to this scientific category. This indicator calculates the percentage of publications of the analyzed subject with respect to the total number of publications (N-AGRI) of a given institution.

To complete the analysis of the data, bibliometric indicators have been obtained referring to the impact of the Top 20 journals in which the greatest number of papers have been published according to the search carried out. Thus, on the one hand, the indicators related to Scopus have been extracted: SJR Category, Rank SJR, SJR Indicator and CiteScore, and, on the other hand, they have been completed with the impact indicators of the other database referring to research, WOS–Journal Citation Reports (JCR). From JCR have been extracted JCR Category, Rank JCR, JCR Impact Factor and Impact Factor (5 years) JCR. These values have been obtained by searching in JCR, SJR and Scopus.

SJR and JCR classify journals based on different categories within a certain scientific field, assessing the position within the category based on the total number of journals classified in that category, resulting in the quartile in which they are positioned within the category.

The SJR Indicator and JCR Impact Factor measure the quality of scientific publications based on the citations obtained in each publication. Both indicators are calculated by dividing the citations in the year being evaluated (in our case 2019) to articles published in previous years by the total number of articles and reviews published in that period. The difference between both indicators is that the SJR Indicator considers the three previous years, therefore, the citation range is three years, while the JCR Impact Factor considers two years of citation. Based on the result obtained it is possible to establish a ranking of journals that allows to determine their quality.

At the end of 2016 [72], Scopus established a new indicator to measure the impact of a publication, CiteScore. Like the previous indicators, it measures the ratio of citations per article published in a given journal but extending the citation range to four years and including citations of a larger typology of documents (articles, reviews, conference proceedings, book chapters and data documents) published on Scopus in that 4-year period.

Finally, the Impact Factor (5 years) JCR, shows the average number of times articles from the journal have been cited in the JCR year published in the last five years. The calculation is like the previous indicators; it is obtained by dividing the number of citations in the JCR year by the total number of articles published in the previous five years.

Citation as a basis for assessing the impact of publications has its roots in Eugene Garfield who developed the concept of the available citation index [73]. Both the JCR Impact Factor and the SJR Indicator provide a numerical value that needs to be interpreted in terms of several factors. The main consideration is the number of citations, which is directly linked to the area of research, the year of publication and the type of publication. Despite being the most widely used index in many bibliometric studies, the JCR Impact Factor is also the most discussed index because of limitations such as asymmetry between numerator and denominator, differences between disciplines, insufficient citation range and asymmetry of underlying citation distributions [74]. On the other hand, the SJR index tries to rectify these deviations by weighting the links based on the closeness of the citation, extending the number of years considered in the citation and setting thresholds for self-citation within the journal itself [75]. The CiteScore index also extends the range of years in the citation, but by including all types of documents, on the one hand the differences between the different types of documents are eliminated, but on the other hand some critics say that this index favors Elsevier's publications which tend to publish a higher proportion of other types of documents apart from articles than other publishers [76].

Regarding affiliations, Scopus has been the database used to calculate the percentage of publications indexed between 1999 and 2019 in the scientific field of Agricultural and Biological Sciences with respect to the total publications of the Top 20 institutions that have published in the field. For this purpose, the total number of publications in the affiliation (Documents, affiliation only) has been considered.

On the other hand, it has been considered important to make an analysis of the research topics reflected in the publications that have been cited in patents. The Agricultural and Biological Sciences field covers many different subjects and SciVal uses the Topics to identify the predominant topics of interest. A Topic includes a set of documents with a common interest. They are clustered within SciVal based on direct citation analysis. Document reference lists are used for this purpose, so that a document can belong to only one Topic. But as newly published documents are indexed, they are added to the Topics using their reference lists. This makes the Topics dynamic and most of them increase in size over time.

Topics with similar research interests are grouped into Topic Clusters forming broader research areas and, in both concepts, Topic and Topic Cluster, prominence can be measured by two parameters: The Topic Prominence Percentile and the Topic Cluster Prominence Percentile. In both measures, prominence is calculated by SciVal by considering the number of citations received in the year with respect to citations received in the same and previous year, the number of views in Scopus in the year of publications in that and previous year, and the average number of citations in CiteScore in the year [77]. Prominence is therefore an indicator of the visibility and momentum of a given Topic, which is why it is important to analyze the percentage of publications in the Top20 journals that are in the first percentile (Top 10%). Note that these are indicators provided by the SciVal database.

While the Topics help us to see how visible the publications have been, it is the Field-Weighted Citation Impact (FWCI) that is the metric that allows us to determine whether the publication has reached the level of citation expected of it. The FWCI considers the year of publication, the type of publication and the discipline in which it is categorized, so that if the FWCI value does not reach the benchmark we can say that it has not exceeded the prospects set for that publication. The benchmark is 1, equal or above it is met in terms of citation, below it is not.

Since this study is based on the Europe of 27, it was considered interesting to analyze the sources of funding for research that is cited in patents. In this sense, together with other funding agencies, we wanted to see the role of the European Commission through the different Research Framework Programs that have been developed in this period (1999–2019): Fifth Framework Program 1998–2002 (FP5), Sixth Framework Program 2002–2006 (FP6), Seventh Framework Program (FP7) 2007–2013 and Horizon 2020 (H2020) 2014–2020.

Since the Budapest Declaration in 2002, there have been many public statements promulgating open access to scientific production without copyright restrictions. The European Commission itself requires open access publication of the results of research funded under its Framework Programs. Therefore, another element considered in this study is to analyze the impact of Open Access (OA).

4.4 Results and Discussion

For the search criteria in the Scopus database, and for the whole of the EU-27 in the Agricultural and Biological Sciences category, 994,422 records have been obtained. While for this same category in the SciVal database, and with the criterion of having been cited in at least one patent, there have been 27,917 records.

4.4.1 Global Temporal Trend

Figure 2 shows the evolution of articles published by the EU-27 countries in the category of Agricultural and Biological Sciences (N-AGRI) from 1999 to 2019. It can be seen that in the last 8 years they have stabilized at just over 65,000 publications.

Furthermore, the evolution of the studies cited in patents (N-AGRI-CP) is shown, and until 2012, the articles cited will stabilize at around 1500 studies. A research conducted in other discipline shows that the last 10 years of publications are not very significant in terms of being cited by patents [78].

The series of data shown in Figure 2, up to 2009, shows great stability in the publications cited in patents. However, the relevant fact is that, at the beginning of the series, in 1999, publications cited were 6% of the total, but this figure is slowly decreasing until it is 3% of the total in 2010. This means that the research effort in relation to technological transfer, patents, has fallen by half in 10 years, from 1999 to 2009. The average overall transfer for the EU-27 countries for this period (1999–2009) was 5%.

Regarding EU funding, the different framework programs have had a positive impact on the increase in publications in the field under study, except for H2020, which seems to keep the level reached in the previous scenario.

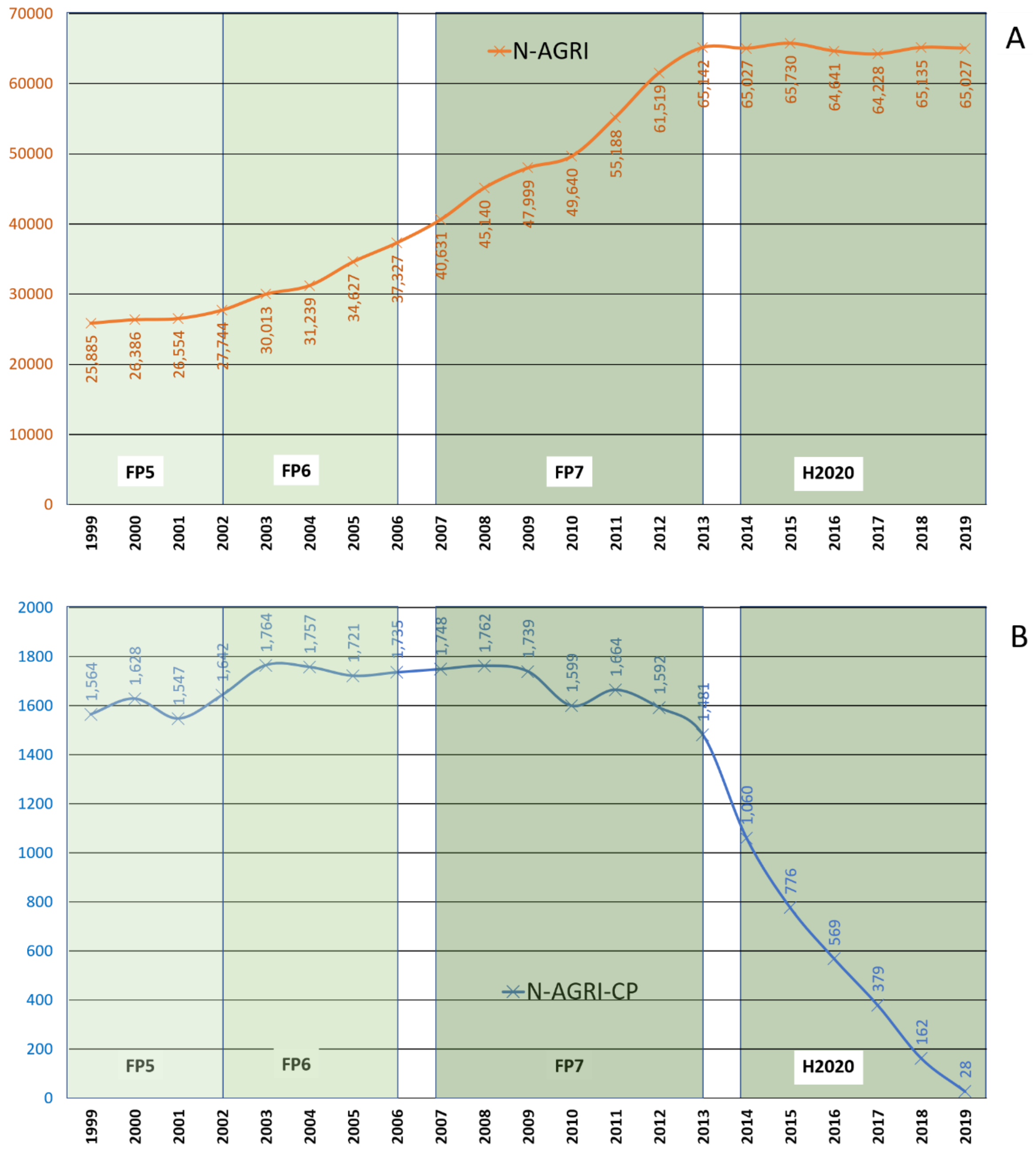

Figure 4-2. Agricultural and Biological Sciences publications: (A) total publication in EU-27 (N-AGRI), (B) cited by international patents (N-AGRI-CP)

4.4.2 Countries, Affiliations, and Collaborations

In this section, publication data are counted for each of the authors of a publication when establishing countries, affiliations, and collaborations. This is the system used by the Scopus and SciVal databases. Figure 3 shows both the scientific production of the EU-27 countries in green, and the scientific collaboration with the other countries of the world in red. The higher color intensity indicates the higher scientific production or collaboration with the EU-27. Of all these works, 40% are with international collaborations with another 130 countries. These collaborations are mainly with the United States (4123), the United Kingdom (2373), Switzerland (878), Canada (707), Australia (586), Japan (520), China (465), Brazil (263), Israel (256), and Norway (255). This list of countries is not surprising as they are *generally countries with a high research capacity, especially in the field of agricultural sciences. Others, such as Switzerland and Norway, have a geographical proximity to the EU-27 that makes them natural partners.*

In Figure 4 the distribution by country of the scientific production in Agricultural and Biological Sciences that is cited in patents is shown. It is led by Germany with more than 7000 studies, followed by France with more than 5000, and in third place Spain with more than 3000. This list of outstanding countries continues with the Netherlands and Belgium with more than 2000 publications.

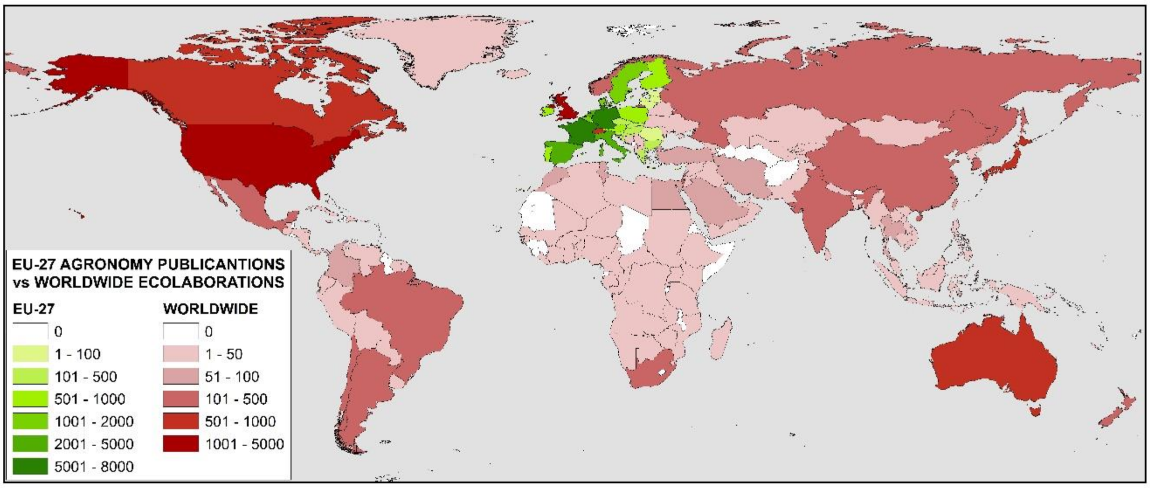

Figure 4-3. Worldwide production and collaboration of EU-27 publications cited in patents

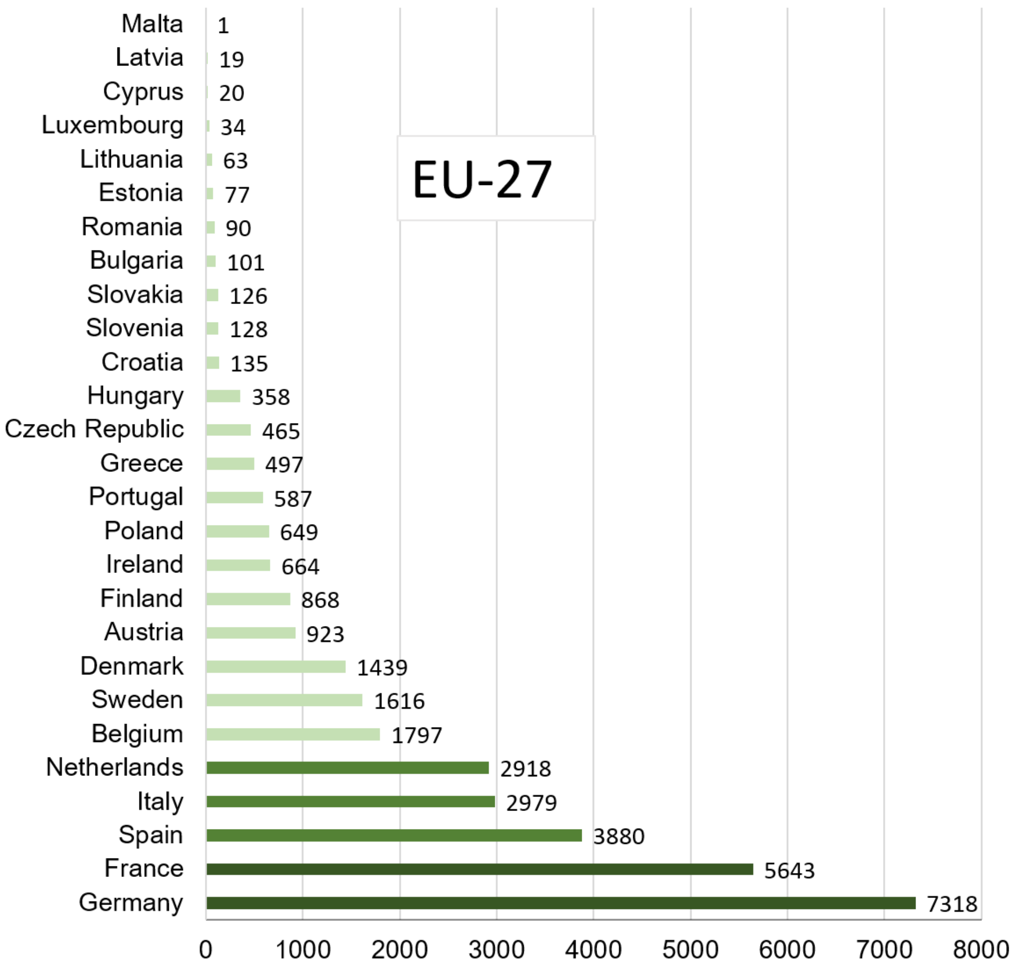

Figure 4-4. EU-27 publications cited in patents

The research carried out by the countries is carried out in specific institutions, which are the real leaders in this research. Table 1 shows the top 20 institutions. This table reflects both the total works published by each institution in this period (N) and those in the category studied (N-AGRI), and of these those that were cited in patents (N-AGRI-CP). The ESP-AGRI indicator shows the degree of specialization of the institution with respect to this scientific category. The TIP-AGRI indicator measures the level of transfer of an institution, the relationship between publications indexed in the Agricultural and Biological Sciences category and publications that have been cited in patents.

From the data in Table 1, there are only 3 institutions specialized in this scientific category, considering those that have more than 30% of their scientific production in it. This specialization is led by Swedish University of Agricultural Sciences (58%), AgroParisTech (52%), Wageningen University & Research (48%), and INRAE (38%). The other institutions have a degree of specialization that is already quite far away, between 4 and 20%.

Also, the high level of transfer can be verified, where they oscillate from 2 to 33% of the total of works published in this category by each one of these institutions. In this regard, it is important to note that, as can be seen, 8 institutions in France are in the top 20. It should be noted that the average overall transfer for the EU-27 countries for the period 1999–2009 was 5%. There are 10 institutions above 5%, and it should be remembered that the entire series is studied here, from 1999 to 2019, where transfer in the last 10 years is low until the technology or research is adopted by industry.

The INRAE (Institut National de Recherche en Agriculture, Alimentation et Environnement) in France has a transfer rate of 33% with a level of specialization of its publications of 38%. Also noteworthy is the case of Université Paris-Saclay (France), with a transfer of 12% despite the low level of specialisation of its publications (6%); the same happens with the Institut National de la Santé et de la Recherche Médicale (France) with a transfer of 11% and a specialization of less than 5%, and finally Institut Pasteur Paris with 12% transfer versus 11% specialization. A curious situation is that of the two institutions mentioned as highly specialized, but with a low level of transfer, Swedish University of Agricultural Sciences (2%), and Wageningen University & Research (4%).

About international collaboration, three institutions stand out in particular, United States Department of Agriculture (308), Harvard University (258), and University of Oxford (207).

Table 4-1. Agricultural and Biological Sciences Transference Index in Patents (TIP-AGRI)

Institutions	***N-AGRI-CP*** [1]	***N-AGRI*** [2]	***N*** [3]	***ESP-AGRI*** [4] ***(%)***	***TIP-AGRI*** [5] ***(%)***
CNRS	*2804*	*39,395*	*411,402*	*9.58*	*7.12*
INRAE	*2092*	*6356*	*16,563*	*38.37*	*32.91*
CSIC	*1458*	*22,974*	*110,344*	*20.82*	*6.35*
Wageningen University & Research	*1189*	*26,883*	*56,370*	*47.69*	*4.42*
Institut National de la Santé et de la Recherche Médicale	*884*	*8304*	*177,215*	*4.69*	*10.65*
Université Paris-Saclay	*734*	*6086*	*95,202*	*6.39*	*12.06*
Ghent University	*683*	*14,620*	*94,557*	*15.46*	*4.67*
University of Copenhagen	*662*	*15,892*	*99,175*	*16.02*	*4.17*
National Research Council of Italy	*442*	*14,586*	*139,335*	*10.47*	*3.03*

Swedish University of Agricultural Sciences	437	15,912	27,592	57.67	2.75
KU Leuven	434	9573	120,699	7.93	4.53
Technical University of Munich	415	8138	104,312	7.80	5.10
Université de Montpellier	368	8414	49,926	16.85	4.37
University of Helsinki	366	13,856	84,064	16.48	2.64
Sorbonne Université	365	11,111	122,422	9.08	3.29
Utrecht University	362	8114	73,306	11.07	4.46
AgroParisTech	346	5693	11,001	51.75	6.08
Technical University of Denmark	340	6801	65,011	10.46	5.00
Universidad Autónoma de Madrid	340	5991	72,892	8.22	5.68
Institut Pasteur Paris	296	2459	22,126	11.11	12.04

[1] N-AGRI-CP Total number of publications classifies as Subject area Agricultural and Biological Sciences (ASJC) cited in patents. [2] N-AGRI Total number of publications published by the institution in period 1999–2019 classifies as Subject area Agricultural and Biological Sciences (ASJC). [3] N Total number of publications published by the institution in period 1999–2019. [4] ESP-AGRI = N-AGRI x 100/N. [5] TIP-AGRI = N-AGRI-CP x 100/N-AGRI.

4.4.3 Top Journals Used for the Publications Cited in Patents

Table 2 lists the top 20 journals in which these patent-cited works have been published. These 20 journals account for 14,217 articles out of the total 27,917, which is half of the publications (50.93%). The mega-journal PLos ONE stands out for the number of publications with 3379 articles. In 2014 Binfield [43] defined the four main criteria for a mega-journal: a very broad thematic scope, scientific solvency of the article, open access generally through APC (article processing charges) and a broad editorial board of academic publishers. Under these four criteria, PLos ONE appears in 2006. Since its launch, its number of publications has increased until it reaches its maximum in 2013 with 32,055 documents indexed in Scopus, from this moment on the number of documents indexed in Scopus has decreased to 16,316 in 2019. Categorized in both SJR and JCR as Multidisciplinary, it is positioned in the first quartile in SJR while moving to the second quartile in JCR.

Taking SJR as a reference, all the journals are positioned in at least one of their categories in the first quartile. However, if positioning in JCR is analized, of the Top20 journals studied, three do not reach a position in the first quartile. To the already mentioned PLos ONE, one must add European Food Research and Technology and International Journal of Systematic and Evolutionary Microbiology.

The dominant categories in SJR are Plant Science and Genetics with 7 journals indexed in these categories followed by Food Science and Medicine (miscellaneous) with 6 journals in each category. In JCR the Plant Science category are indexed 8 journals and in Food Science & Technology 6 journals. From the editor's point of view, nine of the Top20 Journals have been published in the United States, the remaining eleven have been published in European countries: United Kingdom, Netherlands, and Germany.

SciVal employs the ASJC (All Science Journal Classification) categories to classify Scopus sources, i.e., journals. Note that the same journal can be assigned one or more categories of the ASJC classification. The following field names are classified under the subject area Agricultural and Biological Sciences:

- *Agricultural and Biological Sciences (all)*
- *Agricultural and Biological Sciences (miscellaneous)*
- *Animal Science and Zoology*
- *Agronomy and Crop Science*
- *Aquatic Science*
- *Ecology, Evolution, Behavior, and Systematics*
- *Food Science*
- *Forestry*
- *Horticulture*
- *Insect Science*
- *Plant Science*
- *Soil Science*

Table 4-2. Top 20 Journals and their metrics. (Data 2019)

Journal	N	SJR Category. Rank SJR	SJR Indicator	CiteScore Scopus	JCR Category. Rank JCR	JCR Impact Factor	Impact Factor (5 Years) JCR
PLoS ONE	3379	Multidisciplinary. 10/145-Q1	1.023	5.2	Multidisciplinary Sciences. 27/71-Q2	2.740	3.227
Journal of Virology	1885	Insect Science. 2/145-Q1 Immunology. 31/225-Q1 Microbiology. 19/158-Q1 Virology. 9/71-Q1	2.406	7.9	Virology. 8/37-Q1	4.501	4.288
Applied and Environmental Microbiology	1628	Food Science. 11/327-Q1 Biotechnology. 33/324-Q1 Ecology. 30/391-Q1 Applied Microbiology and Biotechnology. 8/119-Q1	1.594	7.1	Microbiology. 39/136-Q2 Biotechnology & Applied Microbiology. 37/156-Q1	4.016	4.597
Journal of Agricultural and Food Chemistry	1427	Agricultural and Biological Sciences (miscellaneous). 33/298-Q1 Chemistry (miscellaneous). 61/463-Q1	1.086	6.1	Agriculture, Multidisciplinary. 4/58-Q1 Chemistry, Applied. 15/71-Q1 Food Science & Technology. 21/139-Q1	4.192	4.290
Plant Physiology	758	Plant Science. 13/483-Q1 Genetics. 21/346-Q1 Physiology. 8/186-Q1	3.616	12.5	Plant Sciences. 10/234-Q1	6.902	7.520
Plant Journal	655	Plant Science. 16/483-Q1 Cell Biology. 31/300-Q1 Genetics. 28/346-Q1	3.161	9.8	Plant Sciences 13/234-Q1	6.141	6.629

Food Chemistry	*576*	*Food Science. 10/327-Q1* *Analytical Chemistry. 8/126-Q1* *Medicine (miscellaneous). 185/2754-Q1*	*1.775*	*10.7*	*Chemistry, Applied. 5/71-Q1* *Food Science & Technology. 6/139-Q1* *Nutrition & Dietetics. 10/89-Q1*	*6.306*	*6.219*
Plant Cell	*510*	*Plant Science. 6/483-Q1* *Cell Biology. 20/300-Q1*	*5.399*	*14.1*	*Plant Sciences. 6/234-Q1* *Biochemistry & Molecular Biology. 23/297-Q1* *Cell Biology. 23/195-Q1*	*9.618*	*10.144*
Journal of Experimental Botany	*343*	*Plant Science. 19/483-Q1* *Physiology. 15/186-Q1*	*2.647*	*9.8*	*Plant Sciences. 14/234-Q1*	*5.908*	*7.011*
International Journal of Food Microbiology	*327*	*Food Science. 22/327-Q1* *Safety, Risk, Reliability and Quality. 13/394-Q1* *Microbiology. 37/158-Q1* *Medicine (miscellaneous). 298/2754-Q1*	*1.364*	*7.4*	*Microbiology. 35/136-Q2* *Food Science & Technology. 23/139-Q1*	*4.187*	*4.226*
Phytochemistry	*323*	*Horticulture. 9/90-Q1* *Plant Science. 106/483-Q1* *Biochemistry. 208/456-Q2* *Molecular Biology. 255/414-Q3* *Medicine (miscellaneous). 821/2754-Q2*	*0.763*	*4.9*	*Plant Sciences. 47/234-Q1* *Biochemistry & Molecular Biology. 155/297-Q3*	*3.044*	*3.374*
Plant Molecular Biology	*308*	*Agronomy and Crop Science. 11/363-Q1* *Plant Science. 27/483-Q1* *Genetics. 66/346-Q1* *Medicine (miscellaneous). 191/2754-Q1*	*1.730*	*7.6*	*Plant Sciences. 42/234-Q1* *Biochemistry & Molecular Biology. 138/297-Q2*	*3.302*	*4.065*
Current Biology	*301*	*Agricultural and Biological Sciences (miscellaneous). 4/298-Q1*	*3.958*	*13.8*	*Biology. 3/93-Q1*	*9.601*	*10.174*

		Biochemistry, Genetics and Molecular Biology (miscellaneous). 17/271-Q1 *Neuroscience (miscellaneous). 0/151-Q1*			*Biochemistry & Molecular Biology. 24/297-Q1* *Cell Biology. 24/195-Q1*		
Theoretical and Applied Genetics	*290*	*Agronomy and Crop Science. 3/363-Q1* *Biotechnology. 23/324-Q1* *Genetics. 54/346-Q1* *Medicine (miscellaneous). 154/2754-Q1*	*1.968*	*7.2*	*Agronomy. 5/91-Q1* *Plant Sciences. 18/234-Q1* *Genetics & Heredity. 37/178-Q1* *Horticulture. 2/36-Q1*	*4.439*	*4.603*
Journal of Dairy Science	*287*	*Animal Science and Zoology. 10/429-Q1* *Food Science. 17/327-Q1* *Genetics. 88/346-Q2*	*1.440*	*5.4*	*Agriculture, Dairy & Animal Science. 5/63-Q1* *Food Science & Technology. 37/139-Q1*	*3.333*	*3.432*
Journal of Food Engineering	*276*	*Food Science. 23/327-Q1*	*1.338*	*7.5*	*Engineering, Chemical. 28/143-Q1* *Food Science & Technology. 16/139-Q1*	*4.499*	*4.332*
European Food Research and Technology	*264*	*Food Science. 88/327-Q2* *Biochemistry. 237/456-Q3* *Biotechnology. 107/324-Q2* *Chemistry (miscellaneous). 123/463-Q2* *Industrial and Manufacturing Engineering. 85/484-Q1*	*0.654*	*3.8*	*Food Science & Technology. 58/139-Q2*	*2.366*	*2.341*
Planta	*253*	*Plant Science. 50/483-Q1* *Genetics. 107/346-Q2*	*1.259*	*5.4*	*Plant Sciences. 41/234-Q1*	*3.390*	*3.687*
PLoS Genetics	*223*	*Ecology, Evolution, Behavior and Systematics. 15/663-Q1* *Cancer Research. 17/214-Q1* *Genetics. 19/346-Q1* *Molecular Biology. 29/414-Q1*	*3.744*	*9.0*	*Genetics & Heredity. 26/178-Q1*	*7.528*	*8.555*

		Genetics (clinical). 7/99-Q1					
International Journal of Systematic and Evolutionary Microbiology	*204*	*Ecology, Evolution, Behavior and Systematics. 122/663-Q1* *Microbiology. 56/158-Q2* *Medicine (miscellaneous). 504/2754-Q1*	*1.020*	*4.2*	*Microbiology. 86/136-Q3*	*2.415*	*2.415*

Using the above classification, it is possible to establish for the publications studied, in which field names they have been classified. Note that the indexing of articles in the scientific categories is done by the indexing category of the journal. This information is provided directly by Scopus, see Figure 5. In this case, Scopus indexes the same work in all the scientific categories in which the journal in which it is published is indexed. Three different groups can be clearly seen, the 3 that are around 20% (Food Science, Plant Science, Agricultural and Biological Sciences (all)), those that are 5–10% (Agronomy and Crop Science, Insect Science, Ecology, Evolution, Behavior and Systematics, Animal Science and Zoology) and those that are below 3% (Horticulture, Aquatic Science, Soil Science, Forestry, Agricultural and Biological Sciences (miscellaneous)). Therefore, the transfer in patents is mainly led in the field of food science, followed by plant science. The first three categories account together for almost 60% of all these publications (59.3%).

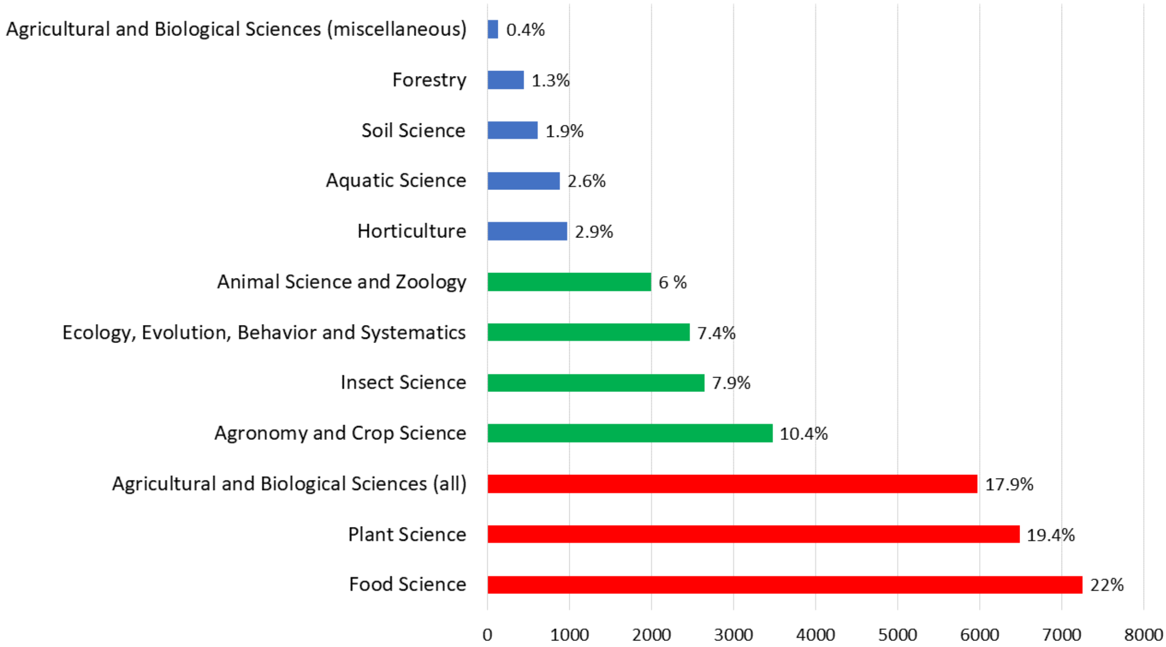

Figure 4-5. Field names for ASJC on Agricultural and Biological Sciences

Of all the papers published in journals, 2020 of them were review papers, this means the 7.3%. Note that in the total scientific production of this category the review works are only 3.4%. This means that they are very important studies in the patent field, as they reflect the state of the art in a particular field and provide a context for the patent. Finally, it should be mentioned that all these publications have had an average of 6 authors. This should be the number considered then as the average of authors for these in this scientific field.

4.4.4 The Quality of the Articles

The journal's quality criteria do not measure the quality of individual articles published in that journal. A journal can publish articles of excellent quality that may be overlaid by others of lesser quality, resulting in an overall count that determines the final quality of the journal. The FWCI (Field-Weighted Citation Impact) allows the quality of an article to be measured, so that if its value equals or exceeds the value 1, the article has exceeded the citation expectations for that article.

This section analyses only data from articles cited in patents (N-AGRI-CP). Figure 6 shows how in the Top20 of journals with the highest transference, in four of them more than 90% of the published articles have equaled or exceeded the FWCI's benchmark 1. This means that more than 90% of the articles have had a higher-than-expected citation level for the year of publication, the type of publication and the discipline in which it is categorized. Plant Cell stands out with 98.2% of its articles with a value equal to or greater than 1. Five journals place between 80 and 89% of their articles with a value equal to or greater than the benchmark. Seven do so with 70–79% of their articles. Of the Top20 the lowest value is 50.8% of the articles in the European Food Research and Technology journal.

Together with the FWCI, Figure 4 also shows the percentage of articles in the Top20 journals that are in the Topic and Topic Cluster's Top 10%. These values are obtained from the analysis of the Topic Prominence Percentile and the Topic

Cluster Prominence Percentile, showing the percentage of publications with a percentile equal to or greater than 90% (first decile).

If the analysis is focused on the Top 10% Topic, the highest value is reached by Plant Journal with 81.2% of its articles placed in that Top 10%, followed by International Journal of Food Microbiology (76.8%) and Plant Cell (73.9%). The lowest value is in Theoretical and Applied Genetics with 32.4%. If the Topic Clusters are considered, in the top 10% among the three highest values there is Plant Cell with 65.1% of its publications, Plant Journal with 60% and Plant Physiology with 55.4%. The lowest value is again found in Theoretical and Applied Genetics with 13.8%.

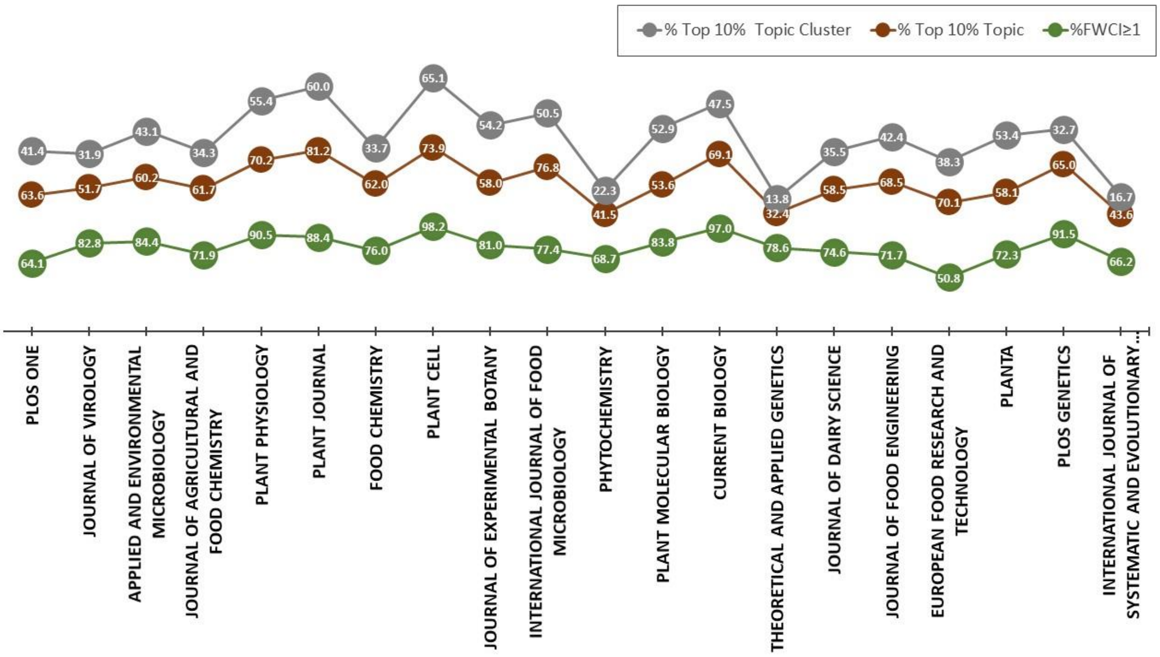

Figure 4-6. Percentage of articles FWCI ≥ 1, Top 10% Topic y Topic Cluster

4.4.5 The Open Access and European Funding Agencies

In this section an analysis is made of the publications that have been funded by European programs and of those that are in open access, always within the field of study.

There are different types of open access, commonly referred to as open access "routes" or "pathways". Gold Open Access allows free access to the final article, as published, and can be used in accordance with the conditions established by the license of use. The second option is Green Open Access, where the final reader will also have access to the final article. The difference between the two ways is that through the first option (Gold Open Access) the deposit and therefore access to the article is made through an open access journal with peer review and generally upon a fee for APC (Article Publishing Charge). In the second way (Green Open Access), the author deposits the article, once accepted (postprint) or an unreviewed article (preprint), in a website or digital resource repository, without having to pay APC, although a period of embargo is usually imposed by the journal in which the full text cannot be accessed, a period of time that can oscillate between 6 and 24 months. In addition to these two routes, there is a third route, Bronze Open Access, in which articles are accessible in full text from the editor's website but cannot be reused as they do not have a license to do so. There is also a fourth way, which we can call hybrid (Hybrid Open Access) which refers to hybrid open access journals in which there are both subscription and open access articles, in this case the author pays for publishing in open access. And finally, it would be the fifth way, it is the diamond route, about those journals, generally from government institutions or scientific associations, which publish in open access without payment by the author.

In Agricultural and Biological Sciences category, 3288 publications have been found, funded by both EU and member country research programs. This is less than 12% of the total. Of these, 548 publications appear to be funded by the EU in its various research programs discussed above, i.e., 17% of those funded through some form of research program. In summary, EU-funded research accounts for 2% of all published work.

An analysis of the papers in OA, shows that among the 548 papers funded by the EU, 399 are not in OA, i.e., 73%. Of these, if they are OA, i.e., 149, there are 23 in OA Gold, 93 in OA Green, 24 in OA Bronze, and 9 in OA Hybrid.

This section highlights the low impact on the number of scientific publications that the EU's research programs have had in the Agricultural and Biological Sciences category, in relation to being cited in patents, as they have meant 2% of the total number of published papers. And that only 27% of the papers funded have been in some form of OA.

4.4.6 Topics of the Publications Cited in Patents

The topics covered for all these publications can be summarized in 2 fields: Topic Cluster name, and Topic name. Table 3 shows the first 20 Topic Cluster names and Topic names.

There are many genetic issues in the main topic cluster names. Gene-expression analysis is increasingly important in biological research related to plant breading. It is therefore not surprising that the most relevant topic cluster name is, Arabidopsis, Plants, Genes. Arabidopsis thaliana is a small weed of the cruciferous family that has become one of the most important systems for the study of many aspects of plant biology [78]. Its unique characteristics offer several advantages when considering it as a research model. Firstly, it is a true diploid with a very short life cycle (6–8 weeks), of self-pollination, and produces numerous seeds that remain viable for many years [79]. Its rapid growth allows the analysis of many individuals in a minimum space and therefore, the consequent rapid amplification of the genotypes useful for later studies [80]. Secondly, its compact genome with relatively few repeated sequences and a low DNA content [81], makes it by far the smallest known genome higher plant, and therefore an ideal system for genetic and molecular studies. Thirdly, it can be transformed by Agrobacterium tumefaciens and through the Ti plasmid it is possible to introduce genes of interest and keep them stable [82].

The second relevant topic cluster name related to genetics is Metagenome, Probiotics, Bacteria. Metagenomics is a set of techniques for determining the microbial population that can be found in each environment, studied in the community context [83].

It is interesting to note the large number of topic cluster names related to food and nutritional properties: Cheeses-Caseins- Milk; Breads-Starch-Glutens; Tea-Polyphenols-Anthocyanins; or Olea- Oils-Oils and Fats. The consumer is increasingly demanding and directly influences the supply and demand for dairy products, demanding higher quality products. They choose between the lipid and protein components of milk and those present in cheese, such as fatty acids, caseins, and whey proteins. The Food Industry usually seeks to increase milk protein, especially casein, which is considered to be the best quality [84]. Likewise, there is a growing demand for gluten-free products has encouraged the design of many gluten-free bakery products [85]. And related to Polyphenols, phenolic compounds are mainly considered to be responsible for the main organoleptic features of foods and beverages of plant origin, in particular their color and taste properties. They also contribute to health and are associated with the consumption of diets high in fruit and vegetables or drinks of vegetable origin such as wine or tea [86]. Much research highlights the beneficial health effects of the Mediterranean diet, which is distinguished by the consumption of virgin olive oil as the main source of dietary fat [87], of course this is linked to the olive orchard (Olea europaea).

Another of the Topic Cluster names related to food is that of Wines, Vitis, Grapes. It is not surprising that the organoleptic qualities of wine are the subject of major studies given the high economic value of this industry. The final taste of the wine is influenced by many factors, but perhaps the most decisive ones are on the one hand the variety of grape used as raw material, and in this there is a market trend towards monovarietal wines, and on the other hand the species of wine yeast used, as each species of wine yeast performs a specific metabolic activity, and therefore determines the final concentrations of flavor compounds in the final wine. Of the studies cited in patents, it is worth highlighting the one related to the quantitative determination of the odorants of fifty-two young red wines from different grape varieties: Garnacha, Tempranillo, Cabernet Sauvignon and Merlot [88]. And another important study is related to the function of yeast species and strains in wine flavor [89].

Finally, another food-related topic cluster name is Drying, Moisture Determination, Thermal Processing (Foods). Of the most cited papers in this field, two are reviews. The first related to the phenomenon of shrinkage of foodstuffs observed during different dehydration processes [90], and the other with thermal pasteurization, which is known to be used to reduce microbial populations in foods, but which has the disadvantage of destroying heat-sensitive nutrients and food qualities such as taste, color, and texture [91]. But as research papers themselves in this field highlight studies in food *processing and preservation of ultrasound techniques [92], and those related to the mentioned technique and the interesting compounds of the grape (bioactive substances such as anthocyanins) [93].*

Table 4-3. Top 20 Topic Cluster names and Topic names

Topic Cluster Name	*N*
Arabidopsis, Plants, Genes	*2464*
Cheeses, Caseins, Milk	*905*
Metagenome, Probiotics, Bacteria	*858*
Breads, Starch, Glutens	*574*
Viruses, Mosaic Viruses, Phytoplasma	*423*
Tea, Polyphenols, Anthocyanins	*388*
HIV-1, HIV, HIV Infections	*368*
Wines, Vitis, Grapes	*347*
Cellulose, Lignin, Cellulases	*344*
Salmonella, Escherichia Coli, Listeria Monocytogenes	*313*
Shoots, Explants, Callus	*289*
Ethylenes, Apples, Fruit	*284*
Olea, Oils, Oils and Fats	*278*
Drying, Moisture Determination, Thermal Processing (Foods)	*275*
Broiler Chickens, Laying Hens, Swine	*269*
Spermatozoa, Semen, Oocytes	*263*
Plants, Rhizosphere, Rhizobium	*253*
Adenoviridae, Neoplasms, Dependovirus	*251*
Hepacivirus, Hepatitis B Virus, Hepatitis C	*251*
Photosystem II Protein Complex, Photosynthesis, Chlorophyll	*244*

The topic names are more specific and therefore less numerous in terms of their appearance, but it is interesting to indicate to which topic cluster name they belong, as shown in Table 4. It can be verified that among the 20 most important topic names, 7 are from the Topic Cluster name of Arabidopsis, Plants, Genes. On the other hand, two are from the second most important topic cluster name, "Cheeses, Caseins, Milk" and other two from the third "Metagenome, Probiotics, Bacteria".

Table 4-4. Top 20 Topic names

Topic Name	***N***	***Topic Cluster Name***
Cinnamyl Alcohol Dehydrogenase, Lignification, 4-Coumarate-Coa Ligase	*123*	*Arabidopsis, Plants, Genes*
Virgin Olive Oil, Oleuropein, Elenolic Acid	*121*	*Olea, Oils, Oils and Fats*
Nicotiana Benthamiana, Taliglucerase Alfa, Molecular Farming	*107*	*Viruses, Mosaic Viruses, Phytoplasma*
Hepatitis C Virus, Virus Internalization, RNA Replication	*102*	*Hepacivirus, Hepatitis B Virus, Hepatitis C*
Lactobacillus Amylovorus, Bifidobacterium Animalis, Probiotic Agent	*95*	*Metagenome, Probiotics, Bacteria*
Endoreduplication, Arabidopsis, Leaf Growth	*89*	*Arabidopsis, Plants, Genes*
Immunologic Receptors, Passalora Fulva, Plant Immunity	*84*	*Arabidopsis, Plants, Genes*
Anthocyanins, Chalcone Isomerase, Dihydroflavanol 4-Reductase	*83*	*Arabidopsis, Plants, Genes*
Rennet, Milk Protein Concentrate, Caseins	*79*	*Cheeses, Caseins, Milk*
Glucose-1-Phosphate Adenylyltransferase, Starch Synthase, Endosperm	*73*	*Breads, Starch, Glutens*

Glucosinolates, Neoglucobrassicin, Glucoerucin	72	Glucosinolates, NF-E2-Related Factor 2, Brassica
Coffee Beans, Coffea Arabica, Melanoidins	71	Coffee, Caffeine, Energy Drinks
Bacteriocins, Lactobacillales, Biopreservatives	68	Metagenome, Probiotics, Bacteria
Gynoecium, Flowering, Carpels	68	Arabidopsis, Plants, Genes
Strigolactones, Orobanche, Striga Hermonthica	67	Arabidopsis, Plants, Genes
Neutralizing Antibodies, Human Immunodeficiency Virus Vaccine, GP 140	65	HIV-1, HIV, HIV Infections
Adenoviridae, Adenovirus Receptor, Human Adenoviruses	64	Adenoviridae, Neoplasms, Dependovirus
Peptidyl-Dipeptidase A, Protein Hydrolysates, Antihypertensive Effect	64	Cheeses, Caseins, Milk
Pulsed Electric Fields, Pasteurization, Heat Inactivation	64	Drying, Moisture Determination, Thermal Processing (Foods)
Systemic Acquired Resistance, S-Methyl Benzo(1,2,3)Thiadiazole-7-Carbothioate, Salicylic Acids	64	Arabidopsis, Plants, Genes

If an analysis is made by the individual words of the Topic Cluster name and Topic name, Table 5 is obtained. The topic clusters include those related to genetics or molecular biology, such as Genes, Arabidopsis, Metagenome, Genome, etc. Additionally, those related to specific foods such as Cheeses, Milk, Breads or Oils. The third group can be understood as covering food related constituents such as Caseins, Probiotics, Glutens, or Starch. It is noteworthy that there is a Topic Cluster name of specific animals, swine. Regarding the Topic names, food issues predominate, especially those related to dairy products such as Probiotic Agent, Lactobacillales, Rennet, Pasteurization, or those related to cereals such as Dough or Glutens.

Table 4-5. Main words for the top 20 Topic Cluster names and Topic names

Topic Cluster Name	N	Topic Name	N
Genes	2907	Arabidopsis	500
Plants	2841	Probiotic Agent	267
Arabidopsis	2464	Lactobacillales	204
Neoplasms	1504	Nicotiana Benthamiana	166
Bacteria	1027	Virus Internalization	142
Caseins	905	Rennet	138
Cheeses	905	Dough	135
Milk	905	Hepatitis C Virus	135
Metagenome	858	Carotenoids	132
Probiotics	858	Endosperm	129
Genome	722	Anthocyanins	127
Viruses	672	4-Coumarate-Coa Ligase	125
Glutens	620	Pasteurization	125
Breads	574	Cinnamyl Alcohol Dehydrogenase	123
Starch	574	Lignification	123
Escherichia Coli	562	Elenolic Acid	121
Oils	482	Virgin Olive Oil	121
Swine	481	Agrobacterium	121
Mosaic Viruses	423	Plant Immunity	120
Phytoplasma	423	Glutens	119

4.5 Conclusions

This paper provides a comprehensive analysis of the current approach to research in the agricultural and biological sciences from the perspective of technology innovation transfer, using patent citation of scientific output as an indicator. This type of approach is encompassed within the Triple Helix concept, where the efforts of academia, industry and governments are brought together.

The great challenge of agriculture as an economic activity and of agronomy as a science is to provide food for the world's population. The European Union is a geographically densely inhabited area with a long tradition of agricultural research. In the 1999–2019 period, almost one million papers have been published by the EU-27 countries in Agricultural and Biological Sciences category. Since 2013 these publications have stabilized at around 650,000 per year. Only 2.8% of these publications have been cited by patents. That is about 1700 per year, decreasing in the last 10 years, this is the estimated period of the impact of scientific production on patents. These papers have had an average of 6 authors. And the review articles have accounted for 7% when, in this scientific field as a whole they account for 3.4%.

Systematic benchmarking of results is necessary to help take steps towards improving one's own scientific activity in order to collect information and to have a framework for the future. In addition, this allows the concepts on which the evaluation of academic performance or publications is based, i.e., benchmarking based on indicators, to identify best practices for the improvement of the initial situation. Therefore, for further benchmarking purposes, the main results are shown below as an initial framework.

The results validate the relevance of applying bibliometric indicators to patent. Forty percent of this research has been carried out in collaboration with 130 countries outside the EU-27. This certainly shows the great collaboration that exists between the EU-27 countries and the rest of the world. The top 5 countries in this regard are Germany, France, Spain, Italy, and the Netherlands. The institutions that lead this research cited in patents are the central research institutions of the countries mentioned above: CNRS (France), INRAE (Italy), or CSIC (Spain). This is probably due to the large volume of scientific production that these institutions have. If attention is paid to the degree of specialization of the institutions, understood as the percentage of articles in the Agricultural and Biological Sciences category in relation to the total number of published works, there are 3 institutions with more than 30%, these are Swedish University of Agricultural Sciences (58%), AgroParisTech (52%), Wageningen University & Research (48%), and INRAE (38%).

The journals used for this scientific production are mainly indexed in the SJR Plant Science, and Genetics categories, followed by Food Science. According to the JCR classification they would also be Plant Science, and in Food Science & Technology. 90% of the published articles have equaled or exceeded the FWCI's benchmark 1, this means that the articles have had a higher-than-expected citation level for the year of publication, the type of publication and the discipline in which it is categorized. If the analysis is focused on the Top 10% Topic, the highest value is reached by Plant Journal with 81.2% of its articles placed in that Top 10%, followed by International Journal of Food Microbiology (76.8%) and Plant Cell (73.9%).

This manuscript highlights the low impact on the number of scientific publications that the EU's research programs have had in the Agricultural and Biological Sciences category, in relation to being cited in patents, as they have meant 2% of the total number of published papers. And that only 27% of the papers funded have been in some form of OA.

The Top 3 Topic Cluster names were: "Arabidopsis, Plants, Genes", "Cheeses, Caseins, Milk", and "Metagenome, Probiotics, Bacteria". The Top 3 Topic names were: "Cinnamyl Alcohol Dehydrogenase, Lignification, 4-Coumarate-Coa Ligase", "Virgin Olive Oil, Oleuropein, Elenolic Acid", and "Nicotiana Benthamiana, Taliglucerase Alfa, Molecular Farming".

In summary, the research topics most reflected in patents are those related to genetics (Arabidopsis, Metagenome, Genome), with major food issues (Cheeses, Milk, Breads or Oils and with food and beverage products of great concern at present (Caseins, Probiotics, Glutens, or Starch).

The use of patents for decision-making is not yet a widespread tool on all innovative research fronts, this work can be a benchmark for future policy decisions on the directions research institutions should take in their future development. The results provide evidence of the potential of the methodology developed and the metrics obtained to represent the patent transfer contributions of national science systems as an indicator of technological innovation.

From this point of view, the current strategic research plan of both the EU-27 and its member countries' systems should seek to enhance the development of the science base for an industry based on transfer to industry. Transfer to patents *has proven to be long term, and university rankings and demands on researchers are short term. Trying to link the two issues would improve the search for innovations for industry itself, which in the end would translate into an improvement in the quality of life of citizens.*

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Capítulo 5.

Worldwide Research Trends on Desalination

5 Capítulo 5. Worldwide Research Trends on Desalination

5.0 Abstract

It is a fact that the world's population has increased twofold in the last 50 years, which has meant that the availability of freshwater for all required activities, industrial use, agriculture, and domestic use, has become increasingly scarce. In addition to these factors, 40% of the world's population lives less than 100 km from the coast. All these factors make desalination a key factor for the sustainability of the world's population. In this study, a bibliometric study has been carried out on all publications related to desalination. An exponential growth has been detected since 2008. The top 4 categories are environmental sciences (28 %), engineering (27 %), chemical engineering (11 %), and chemistry (10 %). The top 3 most productive in this scientific field have been China, USA, and India. Within the top 20 institutions, 8 are from China and 4 from Saudi Arabia, the top 3 being Ministry of Education China, Chinese Academy of Sciences, and Massachusetts Institute of Technology. An analysis of the scientific communities in which these works are grouped, and which represent the world trends in research in this field has found: Reverse osmosis (27%), Renewable energy

desalination (26%), Thermal desalination (14%), Brine (13%), Electrodialysis (8%), Membrane distillation (7%), and les tan 2% Microbial desalination and Freeze desalination.

5.1 Introduction

One of the major problems affecting people around the world is inadequate access to safe drinking water (Shannon et al., 2010). Water scarcity can be considered a natural phenomenon, but it may also be human-induced. There is an estimated amount of freshwater on the planet to meet the needs of the world's population of about seven billion people. The problem is its distribution in time and space. Moreover, much of it is wasted, polluted, and unsustainably managed. About one third of the rural population in developing countries lives in arid and semi-arid regions and faces recurrent water scarcity (Ganiaris et al., 2019).

In the world in 2017, the last year with known data, 3881 billion cubic metres of freshwater were extracted (Worldbank, 2021), of which 71% was for agricultural use, 17% for industrial use and 12% for domestic use (see table 1). If this classification is made according to the wealth of the country, see table 1, a great imbalance in water use is observed, where the most striking feature is that domestic use is almost three times higher in high-income countries than in low-income countries.

Table 5-1. Water distribution (%) by sector according to the country's level of wealth (Worldbank, 2021)

	Country				
Sector	High income	Upper middle income	Lower middle income	Low income	Average
Agriculture (%)	43.3	71.2	88.1	90.6	71
Industry (%)	40.5	15.4	4.0	2.7	17
Domestic (%)	16.2	13.4	7.9	6.7	12

If one examines the World Bank's data on Renewable internal freshwater resources per capita (cubic meters), figure 1, one can see that in the last 50 years, freshwater per capita has fallen by half (Worldbank, 2021), from 12,000 m^3 in 1967 to 5732 m^3 in 2017. Although it is not the purpose of this paper to analyze the causes of this water shortage, it should be noted that in 1967, there were 3462 million people and in 2017, there were 7509 million, i.e. the world population has doubled in 50 years.

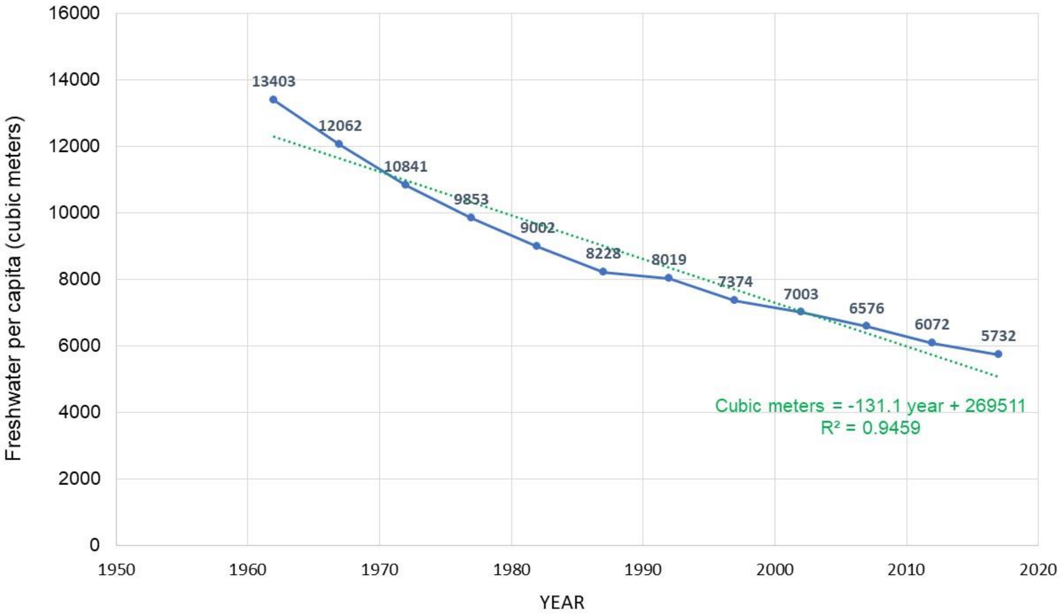

Figure 5-1. Renewable internal freshwater resources per capita (cubic meters) from 1962 to 2017

The UN Human Development Report 2006 and the World Health Organization (UNESCO et al., 2011) recommend that 50–100 liters per capita per day (l/c/d) of water should be piped into households for human development (Watkins et al., 2006) and to maintain adequate health (Howard & Bartram, 2003) E.g. For South Africa, the goal is 'households with at least 25 liters of potable water per person per day within 200 m of a household, not interrupted for more than 7 days per year' (Cole et al., 2018).

More than 40% of the world's population (more than 2.8 billion people) live within 100 kilometers of the coast (UNESCO et al., 2011). This means that a large part of the world's population faces water scarcity, and another large part of the world's population faces water supply constraints due to lack of infrastructure to take water from rivers and aquifers or the desalination of seawater and brackish water. In view of the data, short-term solutions must be searched for and desalination may therefore be a major contribution in view of the high population density close to the coasts.

The aim of this work is to examine all the scientific literature on desalination worldwide to analyze research trends in this field. To this end, a bibliometric study will be carried out, analyzing the evolution of publications by year, the countries and affiliations that contribute most to this scientific field, and through the key words of the articles, analyzing the scientific communities in which these works can be grouped.

In the literature, some bibliometric studies on desalination can be found. Some of them based on WoS between 1997 and 2012.The main conclusion was that the seven major industrialized countries (G7) USA, Italy, Japan, Germany, UK, Canada and France published the majority of the world articles (Yang et al., 2018). Regarding the WoS categories, these publications were centered on Engineering Chemical (53 %) and Water Resources (44 %). And the five most frequently used keywords, excluded desalination, were: "reverse osmosis", "seawater", "solar energy", "electrodialysis" and "nanofiltration".

Another study based on Scopus but limited to Arab world research productivity from 1976 to 2015 (Zyoud & Fuchs-Hanusch, 2015). This is for Saudi Arabia, Egypt, Jordan, Palestine, Lebanon, Qatar, Bahrain, Kuwait, Morocco, Tunisia, Syrian Arab Republic, UAE, Iraq, Sudan, Yemen, Algeria, Comoros, Djibouti, Libya, Mauritania, Oman, and Somalia. Among these, the top 3 were Saudi Arabia, Egypt and UAE. The main categories found were Chemical Engineering (57 %), Engineering (43 %), and Environmental Science (40%). Regarding the main institutions, the top 3 were from Saudi Arabia: King Saud University, King Fahd University of Petroleum and Minerals, and King Abdullah University of Science and Technology. There are also bibliometric papers on desalination that focus on a single country such as Korea (Lee et al., 2021).

Other bibliometric studies focus on a single technology such as forward osmosis (Ang et al., 2019). This study was based on Scopus and for the period 1967 to 2018, and they analyze 1462 article records. They found that the top 5 countries were: China, USA, Singapore, Australia, and South Korea. The top 5 most productive institutions in forward osmosis were: National University of Singapore (Singapore), Nanyang Technological University (Singapore), University of Technology Sydney (Australia), Yale University (USA), King Abdullah University of Science and Technology (Saudi Arabia). Another example is related to brine production.

5.2 Methodology

This analysis was based on searches of Scopus databases. Although the historical content of Scopus dates to 1788, the search was limited from 2000 to 2020. The search was conducted using the search term "desalination (TITLE-ABS-KEY (desalination)". The Scopus API was used for automatic data retrieval. Data processing was carried out with different tools. Microsoft Excel, Gephi and ArcGIS for the analysis and representation of the results, see figure 2.

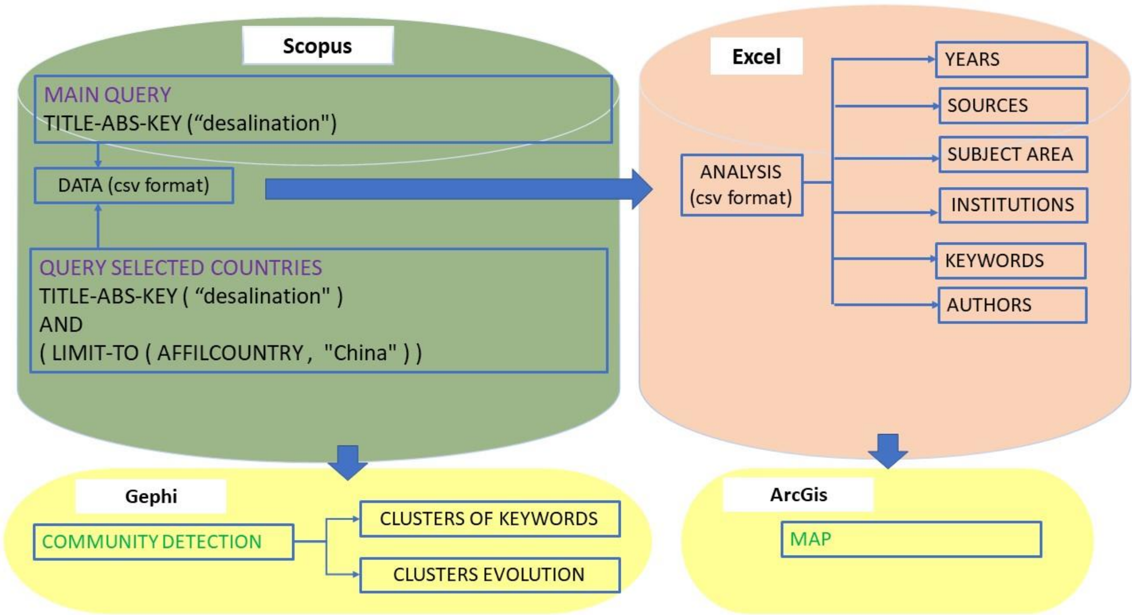

Figure 5-2. Methodology

5.3 Results

5.3.1 Evolution trend

All the scientific production data collected in the Scopus database with the search term "Desalination" has been retrieved. So, 35845 results have been obtained. Figure 3 shows the evolution of all publications related to desalination in the period between 2000 and 2020. Two periods are highlighted. The first one from 2000 to 2008, where the scientific production was below 1000 publications per year. The second period from 2009 to 2020 with more than 1000 publications per year has an exponential growth but reaches its maximum in 2016 with more than 3000 publications per year, a rate that is reached again in the last year studied, 2020.

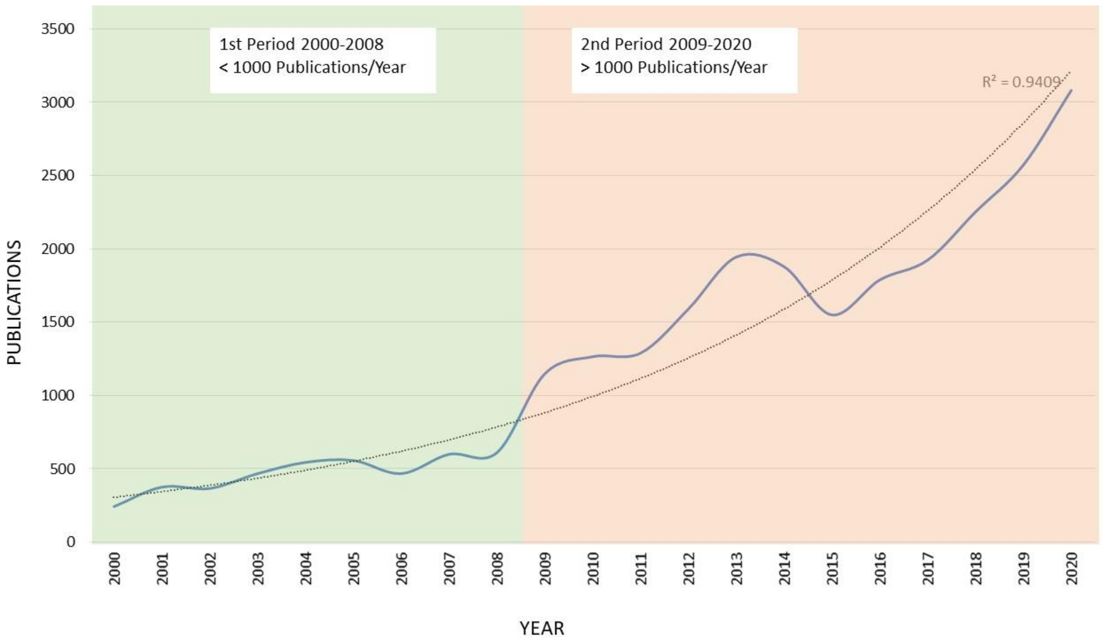

Figure 5-3. Evolution of the worldwide scientific production in desalination

5.3.2 Subjects from worldwide publications

The scientific categories in which the research is classified are important to determine from which point of view the problem to be solved or the problem to be solved is approached. The scientific categories are assigned by the classification made by the Scopus database itself; this is done according to the category in which the journal that publishes these works is indexed.

Figure 4 shows the distribution by categories of all this scientific output. The two top categories are environmental sciences (28 %) and engineering (27 %). The third, fourth and fifth are chemical engineering (11 %), chemistry (10 %) and materials science (9 %). In sixth position is the energy category (5 %), and the other categories are not very relevant as they are below 2 %. The evolution of the scientific categories is also shown in figure 1. As expected, the first two, environmental sciences and engineering, follow a parallel growth. However, the next three, chemical engineering, chemistry, and materials science, show how materials science is catching up with the other two. Finally, the category of energy is increasing a lot, especially in the last 5 years.

The most cited article in the engineering environmental sciences category is a review on reverse osmosis desalination (Greenlee et al., 2009). The most cited article in the engineering category is a review on membrane distillation (Alkhudhiri et al., 2012) which in turn is the third most cited in the environmental sciences category. For the categories of Chemical Engineering and Energy the most cited article is also a review but in this case about solar thermal collectors and applications (Kalogirou, 2004). Finally for the categories of chemistry and materials science the most cited article is the same, and it is also a review, about forward osmosis (Cath et al., 2006). Note that if a journal is indexed in two categories, the work will be indexed in both categories. Although they are not among the main categories found, it is worth noting two articles that are from the multidisciplinary category and are by far the two most cited in relation to desalination. The most cited is about increasing water supply through safe reuse of wastewater and efficient desalination of seawater and brackish water (Shannon et al., 2010). The second most cited article reviews possible reductions in energy demand through state-of-the-art seawater desalination technologies (Elimelech and Phillip, 2011).

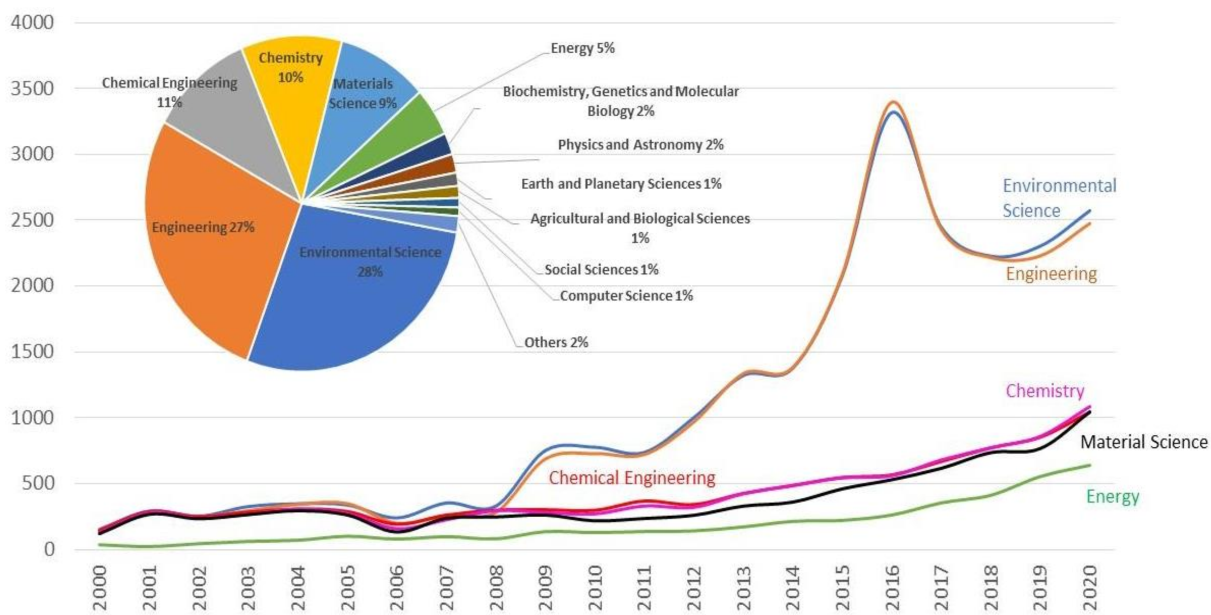

Figure 5-4. Distribution and evolution of Scopus categories on Desalination

The type of publication is an index of the maturity of the technology studied, where a high percentage of books would indicate that the topic is well known, and a high percentage of conference publications would indicate the opposite, a very new technology. In this study, book chapters account for only 2%, conference papers 9% and articles 87% (article 83% and review 4%). Therefore, it can be considered that desalination is a mature technology.

5.3.3 Countries, affiliations, and their main topics

The scientific distribution by country is important to show which countries are making the greatest scientific efforts in this field. Figure 5 shows a world map with the ranking according to the number of publications on desalination. In a first comment, it can be stated that all countries in the world have studies on desalination, except for some African countries, and in Asia, Mongolia, which is landlocked.

With more than 2000 publications in order of rank are China, USA, India, Iran, and South Korea. With more than 1000 publications the following countries can be found: Saudi Arabia, Australia, Spain, Egypt, and United Kingdom.

Once the countries have been studied, it is important to pay attention to the institutions that carry out this research, to identify which are the main centres of research and, if possible, to determine which are the priority lines of this research. Figure 6 shows the institutions with more than 200 scientific contributions to the field of desalination. The first two are from China and stand out from the rest: Ministry of Education China and Chinese Academy of Sciences. The third is from the USA, Massachusetts Institute of Technology. The fourth and fifth are from Saudi Arabia: King Abdullah University of Science and Technology and King Saud University. Note that Saudi Arabia is the world' s first country in seawater desalination, with an estimated four out of every five litres of water consumption in the country coming from desalination.

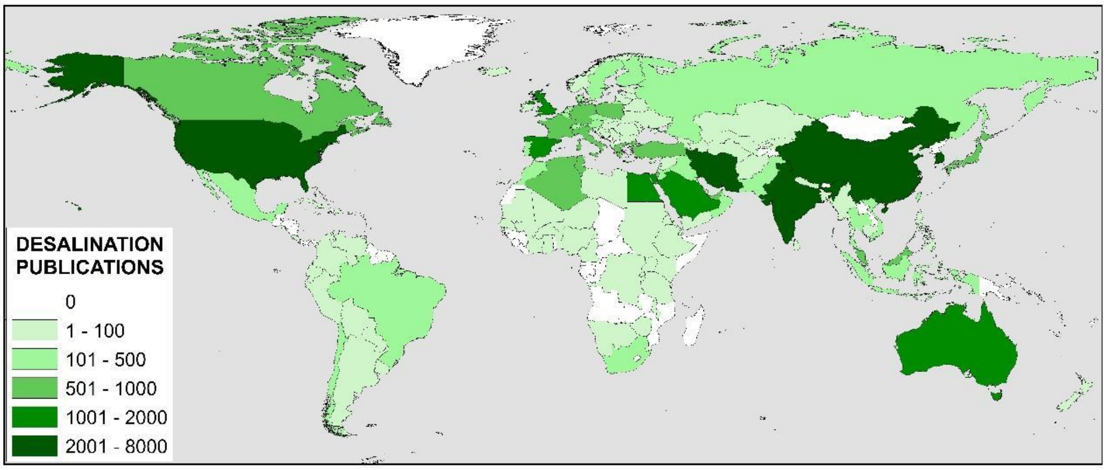

Figure 5-5. Worldwide geographical distribution of the scientific production on desalination

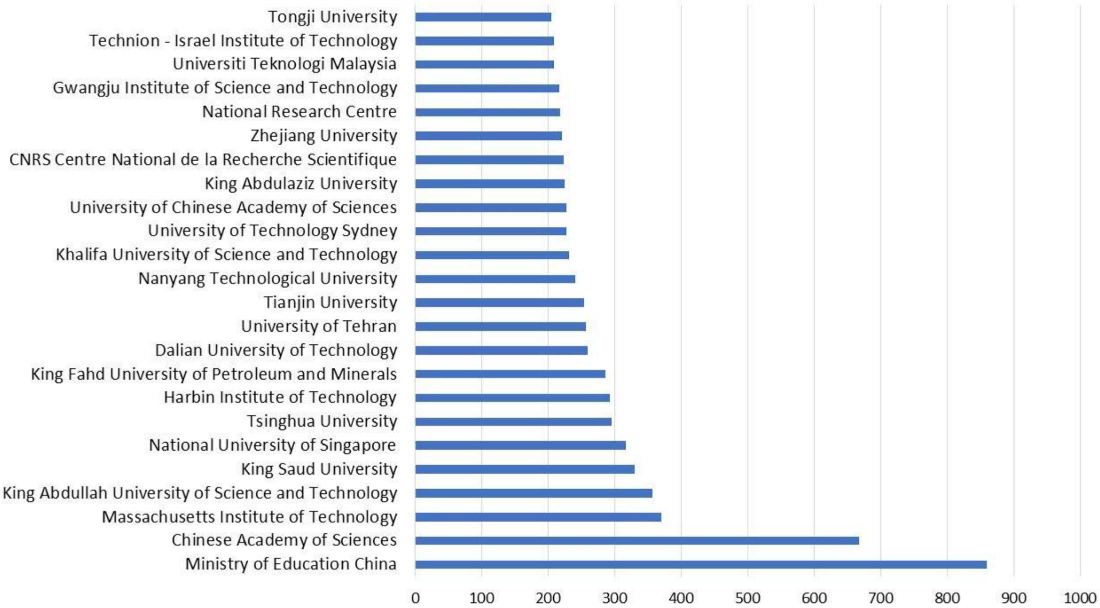

Figure 5-6. Main institutions in the scientific production of the desalination

Table 2 shows the top 4 keywords of the top 20 affiliations. Among the top 20 affiliations 8 are from China and 4 from Saudi Arabia. In overall terms, there is little difference between the objectives of these institutions, as the first four keywords are almost the same for all of them: Seawater, Membrane, Reverse Osmosis, and Water Filtration. The only differences detailed that may be of interest are from MIT (Massachusetts Institute of Technology) for Energy Efficiency, from Tsinghua University for Capacitive Deionization, from King Fahd University of Petroleum and Minerals for the keywords of Humidity Control and Humidification-dehumidification; from University of Tehran for Exergy, Solar Energy and Distillation, from University of Chinese Academy of Sciences for Hydrophilicity.

Table 5-2. Top 20 affiliations and their main keywords

Affiliation	***N***	***Country***	***Keywords (Desalination excluded)***			
			1	***2***	***3***	***4***

Ministry of Education China	*860*	*China*	*Water Filtration*	*Seawater Desalination*	*Seawater*	*Membranes*
Chinese Academy of Sciences	*668*	*China*	*Membranes*	*Water Filtration*	*Membrane*	*Sodium Chloride*
Massachusetts Institute of Technology	*371*	*USA*	*Water Filtration*	*Reverse Osmosis*	*Seawater*	*Energy Efficiency*
King Abdullah University of Science and Technology	*357*	*Saudi Arabia*	*Seawater*	*Membrane*	*Reverse Osmosis*	*Water Filtration*
King Saud University	*330*	*Saudi Arabia*	*Seawater*	*Distillation*	*Saudi Arabia*	*Reverse Osmosis*
National University of Singapore	*317*	*Singapore*	*Water Filtration*	*Seawater*	*Membranes*	*Osmosis*
Tsinghua University	*296*	*China*	*Water Filtration*	*Seawater*	*Seawater Desalination*	*Capacitive Deionization*
Harbin Institute of Technology	*293*	*China*	*Water Filtration*	*Membrane*	*Seawater Desalination*	*Water Treatment*
King Fahd University of Petroleum and Minerals	*287*	*Saudi Arabia*	*Water Filtration*	*Reverse Osmosis*	*Humidity Control*	*Humidification-dehumidification*
Dalian University of Technology	*260*	*China*	*Distillation*	*Water Filtration*	*Seawater*	*Heat Transfer*
University of Tehran	*257*	*Iran*	*Water Filtration*	*Exergy*	*Solar Energy*	*Distillation*
Tianjin University	*254*	*China*	*Seawater*	*Water Filtration*	*Membranes*	*Reverse Osmosis*
Nanyang Technological University	*241*	*Singapore*	*Membrane*	*Water Filtration*	*Reverse Osmosis*	*Osmosis*
Khalifa University of Science and Technology	*232*	*United Arab Emirates*	*Water Filtration*	*Distillation*	*Membranes*	*Seawater*
University of Technology Sydney	*228*	*Australia*	*Membrane*	*Forward Osmosis*	*Seawater*	*Osmosis*
University of Chinese Academy of Sciences	*228*	*China*	*Membrane*	*Sodium Chloride*	*Water Filtration*	*Hydrophilicity*
King Abdulaziz University	*225*	*Saudi Arabia*	*Distillation*	*Water Filtration*	*Saudi Arabia*	*Membranes*
CNRS Centre National de la Recherche Scientifique	*224*	*France*	*Reverse Osmosis*	*Membrane*	*Water Filtration*	*Seawater*
Zhejiang University	*221*	*China*	*Water Filtration*	*Membranes*	*Reverse Osmosis*	*Seawater*
National Research Centre	*218*	*Egypt*	*Reverse Osmosis*	*Membranes*	*Water Filtration*	*Seawater*

5.3.4 Keywords from worldwide publications

Desalination systems can use different energy sources such as thermal, mechanical, electrical and chemical, which has given rise to a first classification. They can also be classified according to the desalination process, and thus we have evaporation-condensation, filtration and crystallization techniques. Some of the desalination technologies are still under development, such as solar chimney, greenhouse, natural vacuum, adsorption desalination, membrane distillation, membrane bioreactor, direct osmosis and ion exchange resins (Alkaisi et al., 2017). At the commercial level, the most widely used technologies are reverse osmosis (RO), multistage flash desalination (MSF) and multi-effect distillation (MED). In these technologies, research seeks to exploit renewable sources such as wind, solar and biomass energy (Curto, et al, 2021). The top 10 keywords related to desalination are, globally, as follows: Capacitive Deionization, Electrodialysis, Water Desalination, Electrosorption, Ion Exchange Membrane, Activated Carbon, Brackish Water, Membrane Capacitive Deionization, Energy Consumption, and Ion-exchange Membranes.

Table 5-3. Top 20 keywords related to desalination

Rank	***Keyword***	***N***
1	*Desalination*	*3702*

2	*Capacitive Deionization*	*993*
3	*Electrodialysis*	*553*
4	*Water Desalination*	*360*
5	*Electrosorption*	*358*
6	*Ion Exchange Membrane*	*319*
7	*Activated Carbon*	*282*
8	*Brackish Water*	*274*
9	*Membrane Capacitive Deionization*	*270*
10	*Energy Consumption*	*257*
11	*Ion-exchange Membranes*	*228*
12	*Limiting Current Density*	*217*
13	*Reverse Osmosis*	*203*
14	*Carbon Nanotubes*	*189*
15	*Water Treatment*	*186*
16	*Capacitive Deionization (cdi)*	*171*
17	*Membrane*	*156*
18	*Cdi*	*134*
19	*Concentration Polarization*	*131*
20	*Carbon Electrode*	*120*
21	*Deionization*	*103*

5.3.5 Worldwide Research Trends: Cluster analysis

However, the previous analysis of the key words would not be exhaustive if it were not done accurately and considering the relationship between all the published works. For this purpose, the clusters in which all the publications can be grouped have been detected by using the Gephi software. Figure 7 shows the clusters found and the relationship between them. Of these, only 8 clusters are meaningful since their relative importance is greater than 1%, and among these they account for 99.1% of the studies. The names of the clusters have been set according to the most frequent or representative key words of each cluster. The 20 key words of each cluster are listed in tables 3, 4 and 5.

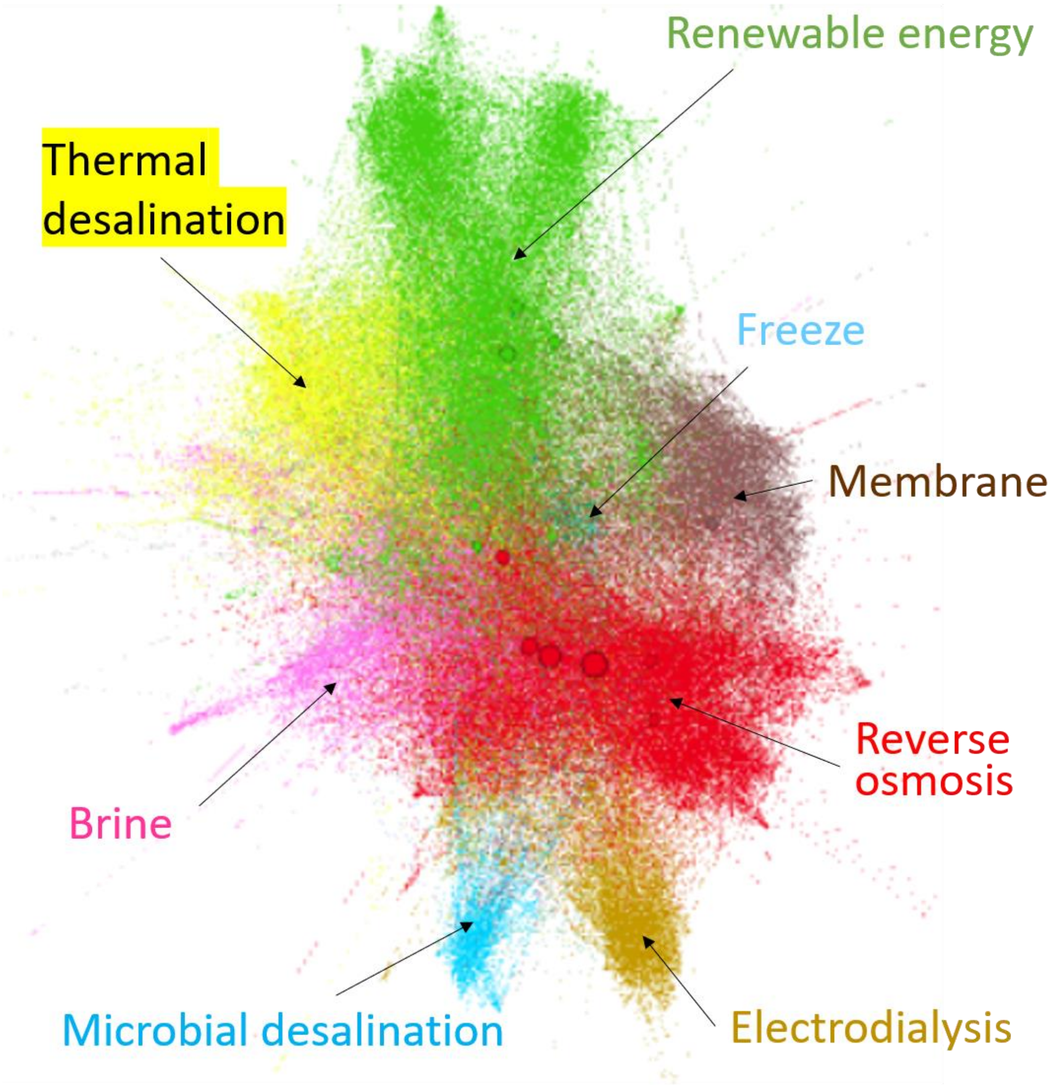

Figure 5-7. Relationship between desalination publications

Table 5-4. Main Clusters (Figure 8), weight and names

Cluster Name	***Weight (%)***	***N***
Reverse osmosis	*27.16*	*1*
Renewable energy desalination	*26.06*	*2*
Thermal desalination	*14.34*	*3*
Brine	*13.07*	*4*
Electrodialysis	*7.62*	*5*
Membrane distillation	*7.19*	*6*
Microbial desalination	*1.73*	*7*
Freeze desalination	*1.62*	*8*

The cluster 1 designated as Reverse osmosis is the most important in terms of size with 27.16% of the total output. Table 4 lists the main keywords of this cluster. As an important note, it is observed that it leads the first 20 keywords of its cluster. In other words, these terms are more in this community than in any other community. It analyzes the problems associated with reverse osmosis. From membrane problems to energy demand. It is closely related to other communities, especially with the membrane and brine community, as well as with the use of renewable energies. Occupies the center of the diagram. Reverse osmosis membrane technology has developed over the past 40 years to a 44% share in world desalting production capacity, and an 80% share in the total number of desalination plants installed worldwide (Greenlee et al., 2009). Reverse osmosis (RO) is a pressure-driven process in which a semipermeable membrane rejects dissolved components present in the feed water. This rejection is due to size exclusion, charge exclusion, and physicochemical interactions between the solute, solvent, and membrane (Malaeb et al., 2011). Reverse osmosis membrane technology has developed over the past 40 years to reach a share of 44% of global desalination production capacity and 80% of the total number of desalination plants installed worldwide (Greenlee et al., 2009). Spiral wound elements can use any of four commonly defined membrane technologies, which are microfiltration (0.01-0 micron), ultrafiltration (500-100,000 Da), nanofiltration (100-500 Da), and reverse osmosis (up to 100 Da) (Nicolaisen, 2003).

Reverse osmosis membranes are formed by polymerizing polyamide thin films on pure polysulfone and nanocomposite-polysulfone support membranes (Pendergast et al., 2010). Graphene oxide has also been explored to improve the performance of thin-film composite membranes (Akther et al., 2020). In recent years, reverse osmosis membrane technology is the most widely used technology in new desalination facilities and has been developed for both brackish and seawater applications (Pangarkar et al., 2011).

Promising experimental lines of work on the incorporation of nanoparticles, carbon nanotubes or graphene show promise as innovative desalination technologies with superior performance in terms of water permeability and salt rejection. However, only nanocomposite membranes have been commercialized, while others are still under development (Yi et al, 2017).

Cluster 2 is named Renewable energy desalination. This is the second largest community, with 26.06% of the keywords. Table 4 lists the main keywords of this cluster. Community focused on the use of renewable energy in water production. Almost all its keywords are specific to this community. It is mainly related to the thermal desalination, membrane, and brine clusters. The integration of renewable resources in desalination and water treatment is becoming increasingly attractive. This is justified by the fact that freshwater-scarce areas often have abundant solar energy, and these technologies have low operating and maintenance costs (Eltawil et al., 2009). Solar-assisted desalination has proven to be technically feasible; however, combined solar and fossil fuel desalination and desalination using low-grade waste heat could be very interesting at this time (Li et al, 2013).

Solar energy applications for desalination have been classified into four major areas: solar stills (Awasthi et al, 2018), solar pond water desalination plants (Tabor, 1975), multi-effect solar desalination plants (Toyama et al., 1983), and photovoltaic cells for water desalination plants (Mittelman et al., 2009). Also, two or more of these techniques are being successfully integrated (Luqman et al., 2020).

The seawater desalination technique using the dehumidification/humidification process is considered a promising method for small-capacity production plants (Narayan et al, 2010). It would be feasible to address the problem of water scarcity by desalinating seawater and brackish water; however, this operation requires large amounts of energy that, when produced from fossil fuels, can cause damage to the environment (Kalogirou, 2005). The integration of renewable resources in water desalination is becoming increasingly attractive. In addition, areas with a shortage of fresh water often have plenty of solar and wind energy available with low operating and maintenance costs (Eltawil et al., 2009)

Cluster 3 is named Thermal desalination. It is a community based on thermal desalination, mainly using the technique known as multi-effect distillation. Is the third largest community and concentrates 14.34 % of the keywords, table 4 lists the main keywords of this cluster, and is related to the renewable energy and brine communities, maintaining little relationship with the rest of the clusters. Has few specific keywords. Thermal desalination, or distillation, is one of the oldest ways of treating seawater and brackish water into drinking water. Thermal processes include the multistage flash, multiple effects boiling and vapour compression, cogeneration, and solar distillation, while the membrane processes include reverse osmosis, electrodialysis and membrane distillation (Shatat & Riffat, 2014). Thermal desalination, also called distillation, is one of the oldest ways of treating seawater and brackish water into drinking water. It is based on the principles of boiling or evaporation and condensation. The water is heated to the evaporation state. The salt is left behind while the vapor condenses to produce fresh water. At present, much of the thermal energy required is produced in steam generators, waste heat boilers or by backpressure steam extraction from power plant turbines (Shatat, & Riffat, 2014). The main thermal desalination processes are of two types: Multi-Stage Flash Evaporation (MSF) and Multi-Effect

Distillation (MED) (Nannarone et al., 2017). Currently, the thermal desalination industry is dominated by MSF processes. Other thermal desalination processes, including MED and the mechanical vapor compression process (Al-Juwayhel, et al., 1997), are on a very limited scale. The MED process is the oldest large-scale distillation method used for seawater desalination. Currently, 3.5% of the world's desalinated water is produced by MED plants. Its most obvious characteristics are high distilled water quality, high unit capacity, and high thermal efficiency (Nannarone, et al., 2017). In addition, MED has been traditionally used in the industrial distillation sector for the evaporation of sugar cane juice in sugar production and in salt production (Milow & Zarza, 1997).

Conventional desalination techniques powered by fossil fuels consume large amounts of energy; have a high environmental impact, and high costs. Abundant cheap and clean renewable energy sources are therefore a promising alternative for powering modern desalination processes (Abdelkareem et al., 2018) Water production costs can be reduced by using a hybrid system consisting of two or more desalination methods (Linares et al., 2016) Recently, commercially available energy recovery devices based on the positive displacement direct pressure exchange method have proliferated. This growing interest is since the technology can significantly reduce the energy consumption of new and existing saline water reverse osmosis (SWRO) systems. Since energy costs are increasing and can consume up to 75% of the total operating costs of a SWRO plant, the dissemination of this technology throughout the industry is important (MacHarg, 2003).

Table 5-5. Main keywords of Clusters 1 (Reverse osmosis), 2 (Renewable energy) and 3 (Thermal desalination)

Reverse osmosis		**Renewable energy**		**Thermal desalination**	
Keyword	**N**	**Keyword**	**N**	**Keyword**	**N**
Reverse Osmosis	510	Solar Desalination	291	Seawater Desalination	78
Forward Osmosis	264	Reverse Osmosis	289	Reverse Osmosis	68
Membrane	185	Solar Energy	255	Multi-effect Distillation	66
Seawater Desalination	181	Solar Still	222	Optimization	63
Nanofiltration	148	Renewable Energy	149	Exergy	62
Seawater	119	Seawater Desalination	131	Cogeneration	58
Pretreatment	114	Humidification-dehumidification	94	Solar Energy	49
Fouling	89	Humidification	78	Med	49
Ultrafiltration	65	Water Desalination	76	Msf	46
Interfacial Polymerization	64	Photovoltaic	69	Exergy Analysis	44
Water Desalination	63	Optimization	64	Solar Desalination	42
Biofouling	60	Dehumidification	61	Thermal Desalination	38
Membrane Fouling	59	Brackish Water	55	Adsorption	38
Water Treatment	58	Solar	45	Energy	29
Brackish Water	55	Solar Distillation	45	Simulation	28
Draw Solution	48	Seawater	42	Seawater	27
Polyamide	46	Simulation	39	Modeling	25
Boron	44	Solar Collector	39	Multi-effect Desalination	24
Electrodialysis	42	Wind Energy	37	Thermal Vapor Compression	23

Cluster 4 is concerned with the consequences of brine spills and proposes solutions to complete dewatering. They also deal with the process to reduce effluents and their concentration. It is closely related to the reverse osmosis and thermal desalination clusters. It groups 13.07 % of the keywords cited. Table 5 lists the main keywords of this cluster. The production of brine, which is a concentrated salt solution, is a consequence of desalination plant operation and faces significant environmental challenges due to its high salinity (Pramanik et al., 2017). Currently, several disposal methods have been practiced, such as surface water discharge (Lepikhin & Bogomolov, 2018), sewer discharge, deep well injection (LeGros, 1969), evaporation ponds (Ahmed et al., 2000), and land application (Mohamed et al., 2005). However, these brine disposal methods are unsustainable, are limited by high capital costs, and are not universally applicable (Panagopoulos et al., 2019).

Seawater desalination facilities continuously discharge brine into the coastal environment, which generally flows as a concentrated plume over the seafloor, eventually affecting benthic organisms (Frank et al., 2019). The recovery of chemicals from brine (Al Bazedi et al., 2014), such as electrolysis of sodium chloride brine to produce hypochlorite, can be a significant economic (Boal & Mowery, 2015) and environmental improvement. Brine disposal is one of the major concerns of many environmental issues associated with desalination. The production and growth of marine organisms is severely affected by discharge of brine in the desalination process (Ahmed & Anwar, 2012). In addition, the reject brine from inland desalination plants can alter the physical and chemical properties of the soil. The brine may also find its way to groundwater and can alter its properties (Khan et al., 2021).

Table 5-6. Main keywords of Clusters 4 (Brine), 5 (Electrodialysis) and 6 (Membrane desalination)

Brine		**Electrodialysis**		**Membrane desalination**	
Keyword	**N**	**Keyword**	**N**	**Keyword**	**N**
Reverse Osmosis	98	Capacitive Deionization	154	Membrane Distillation	268
Seawater Desalination	90	Electrodialysis	117	Direct Contact Membrane Distillation	67
Environmental Impact	52	Water Desalination	61	Seawater Desalination	49

Brine	*47*	*Electrosorption*	*53*	*Air Gap Membrane Distillation*	*47*
Nuclear Desalination	*40*	*Ion Exchange Membrane*	*37*	*Vacuum Membrane Distillation*	*45*
Brine Discharge	*34*	*Activated Carbon*	*23*	*Water Desalination*	*37*
Desalination Plant	*33*	*Brackish Water*	*19*	*Solar Energy*	*37*
Salinity	*31*	*Membrane Capacitive Deionization*	*18*	*Heat And Mass Transfer*	*24*
Seawater	*30*	*Energy Consumption*	*17*	*Modeling*	*21*
Electrodialysis	*30*	*Ion-exchange Membranes*	*17*	*Membrane*	*20*
Brine Disposal	*26*	*Reverse Osmosis*	*16*	*Solar Desalination*	*20*
Brackish Water	*25*	*Limiting Current Density*	*16*	*Seawater*	*17*
Sustainability	*23*	*Carbon Nanotubes*	*15*	*Mass Transfer*	*17*
Life Cycle Assessment	*21*	*Water Treatment*	*13*	*Optimization*	*16*
Water Desalination	*20*	*Capacitive Deionization (cdi)*	*13*	*Electrospinning*	*16*
Environment	*18*	*Membrane*	*12*	*Hydrophobicity*	*16*
Groundwater	*17*	*Concentration Polarization*	*10*	*Permeate Flux*	*16*
Wastewater	*17*	*Cdi*	*10*	*Temperature Polarization*	*16*
Water Management	*15*	*Seawater Desalination*	*9*	*DCMD*	*16*

The cluster 5, named Electrodialysis, is mainly concerned with the decontamination of water, not so much for the production of irrigation water, but for the extraction of elements from the water (Strathmann, 2010). Table 5 lists the main keywords of this cluster. It groups 7.62 % of the keywords cited and is mainly related to the clusters of microbial desalination and reverse osmosis. There are other desalination techniques that have not yet reached the importance of the above, but their technology is already well advanced for upcoming use on an industrial scale.

In electrodialysis, cation and anion exchange membranes are separated by a spacer gasket and form individual cells. If an electrolyte solution is pumped through these cells and an electrical potential is established between the electrodes, the overall result is that an electrolyte, i.e., a salt or an acid or a base, is concentrated in alternative compartments, while the other solutions are emptied of ionic components (Strathmann, 2010). A major problem affecting the efficiency of almost all membrane separation processes is membrane fouling. However, in electrodialysis the problem has been largely eliminated by regularly reversing the polarity of the applied electrical potential, which results in a removal of charged particles that have precipitated on the membranes (Katz, 1979). This technique has achieved some importance in very specific industrial processes such as the production of acids and bases from the corresponding salts (Nagasubramanian et al., 1977), the production of highly deionized water (Fang, 2006), the removal of ions from an aqueous solution (Welgemoed & Schutte, 2005), and the separation of acids and bases from mixtures with salts (Sata et al., 1995).

Cluster 6 is named, Membrane desalination. Table 6 lists the main keywords of this cluster. Membrane distillation is an emerging technology for desalination based on the vapor transport across the hydrophobic microporous membrane driven by the vapor pressure gradient across the membrane (Alkhudhiri et al., 2012). This cluster groups 7.19 % of the cited keywords, is mainly related to the clusters of renewable energies, freezing, and reverse osmosis.

Among the thermal-based technologies, membrane distillation is the most promising for improving performance with the availability of a waste heat source (Subramani & Jacangelo, 2015). Membrane distillation is a process in which hot water flows down one side of the membrane and evaporates through it due to a lower partial pressure of water on the other side (Lawson & Lloyd, 1997). It differs from other membrane technologies in that the driving force for desalination is the vapor pressure difference of the water across the membrane rather than the total pressure. Membranes for membrane distillation are hydrophobic. This allows water vapor to pass through, but not liquid water. The vapor pressure gradient is created by heating the source water, which raises its vapor pressure (Alkhudhiri et al., 2012). The four types of membrane distillation are:

- *Direct contact membrane distillation. The cold condensing solution comes in direct contact with the membrane and flows counter current with the raw water. This configuration is the simplest to set up. It is best suited for applications such as desalination and concentration of aqueous solutions, e.g. juices (Phattaranawik et al., 2003).*

- *Membrane distillation with air chamber. It includes an air chamber followed by a cold surface. This configuration is the most general and can be used for any application (Meindersma et al, 2006).*
- *Membrane distillation with sweep gas. A sweep gas removes water vapor and/or volatiles from the system. It is useful when volatiles are to be removed from an aqueous solution (Xie et al., 2009).*
- *Vacuum membrane distillation. Vacuum is used to remove water vapor from the system. It is also useful when volatile products are to be removed from an aqueous solution (Mericq et al., 2010).*

Cluster 7 is also involved in water decontamination but as a differential note, it uses the activity of microorganisms on the organic matter dissolved in the water to produce the necessary energy (Kim & Logan 2013). Table 6 lists the main keywords of this cluster. This cluster groups 1.73 % of the keywords cited and is a well-defined community with little contact with other clusters. It is close to the reverse osmosis and electrodialysis clusters but with no shared keywords. It has been demonstrated that microbial desalination cells can desalinate high-salinity water without any external energy source, but to date this process has not been systematically evaluated. Bioelectrochemical systems use electroactive microorganisms to degrade organic materials in waste to produce energy and/or chemicals (Sayed et al., 2020). These systems include applications such as microbial electrolysis cells, microbial desalination cells, and microbial electrosynthesis cells (Santoro et al., 2017). The idea starts from a basic microbial fuel cell that was modified by placing two membranes between the anode and cathode, thus creating an intermediate chamber for water desalination between the membranes (Cao et al, 2009). In the anode chamber of the cell, microbes work as biocatalysts to generate electrons by oxidizing organic compounds (e.g., in wastewater) and transfer them to the anode electrode (Pradhan & Ghangrekar, 2014), desalinating the water in the intermediate chamber.

Cluster 8 is a very interrelated cluster, revolves around desalination by freezing, using different variants. It occupies a central location in the diagram and is difficult to separate from other clusters. It accounts of 1,62% of keywords and only a few ones are specific from this cluster. Table 6 lists the main keywords of this cluster. Freeze desalination is a well-known technique for water desalination (Samuel, 1986). The main advantages of this process are the low energy requirement and low temperature operation compared to thermal desalination. Other advantages are less fouling and corrosion problems, the possibility of using cheap plastics or low-cost material, and the absence of pretreatment (Rahman et al., 2006). However, it presents some problems, especially salt entrapment in ice (Castillo-Téllez et al., 2020). Hydrate desalination can concentrate salts in saline water and produce fresh water through the formation of hydrate crystals. Hydrate desalination can produce desalinated water more cheaply than existing technologies (Khan et al., 2019) and is of great interest because the crystallization process can be operated at a much higher temperature compared with freeze desalination (usually slightly above the freezing point of water) and, therefore, the energy consumption for crystallization can be drastically reduced (Simmons et al., 2006). Although this technique has been known since ancient times, and there are several different processes that uses freezing to desalt seawater, however, the process has not been a commercial success in the production of fresh water. At this stage, freeze-desalting technology probably has better application in the treatment of industrial wastes than in the production of drinking water (Buros, 2000).

Table 5-7. Main keywords of Clusters 7 (Microbial Desalination), and 8 (Freeze Desalination)

Microbial Desalination		***Freeze***	
Keyword	***N***	***Keyword***	***N***
Microbial Desalination Cell	*59*	*Gas Hydrate*	*29*
Desalination	*47*	*Freeze Desalination*	*18*
Microbial Fuel Cell	*19*	*Seawater Desalination*	*10*
Wastewater Treatment	*15*	*Seawater*	*9*
Bioelectrochemical System	*12*	*Water Treatment*	*7*
Bioelectricity	*11*	*Cyclopentane*	*6*
Power Generation	*8*	*Sea Ice*	*6*
Bioenergy	*8*	*Cold Energy*	*6*
Electrodialysis	*7*	*Kinetics*	*5*
Forward Osmosis	*6*	*Freezing*	*5*
Microbial Desalination Cell (mdc)	*6*	*Reverse Osmosis*	*4*
Seawater Desalination	*5*	*Crystallization*	*4*

Wastewater	*5*	*Brine*	*4*
Electricity Generation	*5*	*Thermodynamics*	*4*
Microbial Desalination	*5*	*Hydrate*	*4*
Biocathode	*5*	*Refrigerant*	*4*
Energy Consumption	*4*	*Produced Water*	*3*
Produced Water	*4*	*Carbon Dioxide*	*3*
Microbial Electrolysis Desalination and Chemical-production Cell	*4*	*Water Desalination*	*3*

5.4 Discussion: challenges and perspectives

The new challenges of desalination can be summarised in this section. In recent years, desalination research has advanced at a considerable rate, especially since 2008, with new techniques and tools being developed that are already being used in many of the desalination facilities. The regions of the world best placed to adopt this technology are the gulf countries as they are the most water-scarce and have the most affordable energy (Juaidi et al., 2016a, Juaidi et al., 2016b), both conventional and renewable. Note that Arab countries have one of the highest per capita water consumption rates in the world, approximately more than 500 l/c/d, compared to less than 150 l/c/d in most developed countries, or the WHO minimum range of 50-100 l/c/d. Although in 1986 it was estimated that 1,369 l/c/d are needed for the normal functioning of a modern society (Falkenmark, 1986). Rethinking the components of a minimum estimated water requirement for human health and for economic and social development suggests that a country needs a minimum of 135 l/c/d (Chenoweth, 2008).

Until now, desalination has only been used in extreme circumstances due to the very high energy consumption of the process and, consequently, its high economic cost. The most advanced, multi-stage evaporative desalination plants have an energy consumption of more than 9 Kw/h per m3 of drinking water produced. Initially large desalination plants are built in locations where energy costs are very low, such as in the Middle East. Therefore, the use of renewable energies to achieve this goal is one of the greatest challenges in this scientific field.

The first will be to continue the search for a second life for desalination residues. This means producing useful chemicals from the concentrated brine, making desalination more cost effective (McGovern et al., 2014). The normal guideline for the drinking water we drink is usually 500 per million dissolved salts. Whatever the desalination process, the result is about 35% fresh water (up to 50% in very efficient plants) and 65% very salty brine. The desalinated water obtained is very pure. Water obtained by the distillation process has between 1 and 50 per million dissolved salts, while water obtained by reverse osmosis has between 10 to 500 per million per litre. Desalinated water is usually purer than the water we normally drink, which is why it is usually mixed with less pure water before distribution. The second challenge is to further develop desalination methods for providing safe drinking water to thousands of communities that currently have limited access to this resource and are relatively close to the coast (Grant et al., 2012). Desalination plants collect water from the sea through intakes off the coast or in beach wells, where the salinity is significantly lower and therefore the cost of desalination is reduced.

The water treatment industry is very competitive, employing several techniques such as reverse osmosis, distillation, electrodialysis and vacuum freezing. Today only reverse osmosis and distillation are commercially viable. But reverse osmosis desalination plants built in the 20th century had an energy consumption of more than 6 kWh per cubic metre of drinking water produced, due to low membrane efficiency, pressure drop limitations and lack of energy recovery devices.

Desalination of seawater for food production, i.e. protected crops that can afford the cost of desalination, e.g. in SE Spain, for greenhouse crops. And brine denitrification produced during polluted groundwater desalination in fertigation areas of SE Spain (Díaz-García et al., 2020; Díaz-García et al., 2021).

As research scenarios, it is worth mentioning that there are two close lines of research that may provide future opportunities for research regarding the desalination. The first one, the research around the problems generated by desalinated water and brine in the materials of the facilities, the corrosion. An important aspect related to desalination processes is the study of corrosion of materials, with special emphasis on metal pipes, evaporators, and other components of distillation facilities (Schorr et al., 2019). The chemically aggressive environment generated in some parts of SPS *desalination plant equipment can cause corrosion problems. Proper selection of materials with higher corrosion resistance is considered one of the most prospective approaches for the smooth and efficient operation of plants (Malik & Al-Fozan, 2011). The primary interest of plant designers and operators is to minimize corrosion to improve service life and reliability, and less emphasis has been placed on the effects of corrosion products on the environment (Oldfield & Todd, 1997). Corrosion of positive electrodes, in capacitive deionization cells for water desalination processes, is a major problem that may prevent them from becoming usable on an industrial scale (Cohen et al., 2013).*

And the second one is related to the advantage of the effects of electricity to mobilize salts and other elements within porous materials. This was named electroosmosis. The technology generated for desalination can be used in other disciplines, as in the case of the technique known as electroosmosis. It consists of the movement of liquid through a microporous medium under the influence of an applied electric field (Kohlrausch, 1897). The flow of water could be induced through a capillary by an external electric field. In other words, if soil is placed between two electrodes in a fluid, the fluid will move back and forth when an electromotive force is applied (Asadi et al., 2011). Electrokinetic remediation, variously referred to as electrochemical soil processing, electromigration, electrokinetic decontamination, or electroreclamation, uses electrical currents to extract radionuclides, heavy metals, certain organic compounds or mixed inorganic species, and some organic residues from soils and sludges (Acar et al., 1995).

5.5 Conclusions

Desalination is commonly adopted today to overcome freshwater scarcity in some areas of the world if brackish or salt water is available. Getting fresh water from the sea is, for everyone, the best technological opportunity to solve the water shortages that lie ahead. Over the last 20 years, much research has been carried out in this field and the different types of technologies applicable to desalination have been improved. The desalination research sector has been rising, especially since 2008. It has been seen that work is mainly focused on two main approaches, environmental sciences (28%) and engineering (27%). The other three relevant approaches are chemistry (11%), chemical engineering (10%) and materials science (9%), followed by energy (5%). The top 5 countries in this scientific field are China, USA, India, Iran, and South Korea. Among the top 20 affiliations, 8 are from China and 4 from Saudi Arabia. There are few differences between the objectives of these institutions, as the first four keywords of their publications are similar in all of them: Seawater, Membrane, Reverse Osmosis and Water Filtration.

Eight main scientific clusters have been found in global research related to desalination: Reverse osmosis, Renewable energy desalination, Thermal desalination, Brine, Electrodialysis, Membrane distillation, Microbial desalination, and Freeze desalination.

Lines of research have been identified to improve brine management strategies, both to limit negative environmental impacts and to help reduce the economic cost of brine disposal. This may contribute to the development of new desalination facilities and contribute to the supply of water for generations to come.

For water-scarce countries, desalination may be the only viable means of providing the water supply needed to sustain agriculture and support the population, although energy costs and technological limitations must be considered, but it is research in this field that will allow its use to expand. Finally, it should be noted that when brackish water is collected from wells, there is a significant risk that groundwater salinity will increase due to marine intrusion. This study provides a benchmark in global description of scientific productivity in desalination research. It is therefore necessary to address the gaps and delays in desalination research in many coastal countries. The scientific output data reveal a good scientific output in this field of research worldwide.

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6. Conclusión

El resultado global de esta investigación se ha materializado en cuatro publicaciones, tres de ellas publicadas en revistas de alto impacto según JCR y SJR y una cuarta en revisión en otra revista de alto impacto.

A continuación, se presentan las principales aportaciones de este trabajo de investigación.

Publicación 1. "The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study"

Este estudio ha analizado los documentos bibliométricos producidos entre 1996 y 2020. Se ha observado cómo se ha aplicado la bibliometría a la investigación en todos los campos científicos durante estos años. Para evaluar estos documentos se ha utilizado una metodología que ha demostrado ser válida para relacionar la producción científica en Scopus y WoS y vincularla con los indicadores bibliométricos a través de SciVal e InCites.

La primera conclusión que se extrae de este trabajo es que existe un crecimiento exponencial de las publicaciones entre 2000 y 2020 y que la mayoría de los documentos se indexan como artículos (72% en Scopus y 68% en WoS), frente a las revisiones (13% en Scopus y 14% en WoS). Tres países han liderado el número de documentos publicados: China con el 16 %, Estados Unidos con el 15 %, y en tercer lugar España con el 12,5 %. En este sentido, cabe destacar el papel de España en tercer lugar frente a los dos grandes países con mayor producción científica en términos absolutos.

Desde el punto de vista de las instituciones, existen diferencias entre las dos bases de datos analizadas. Sin embargo, los cinco primeros puestos del ranking son compartidos por las mismas instituciones: Universidad de Granada, Universidad de Valencia, Consejo Superior de Investigaciones Científicas (CSIC), Academia China de Ciencias y Universidad de Leiden. Una vez más, destaca el predominio de las instituciones españolas en este ranking. La colaboración internacional es sin duda un parámetro que permite conocer las sinergias en la producción científica. En este caso se ha demostrado que las instituciones situadas en los cinco primeros puestos del ranking no tienen un paralelismo entre *cantidad de producción y colaboración internacional, tienen un 30% de colaboración internacional, es decir, tienen una colaboración por debajo de la media, que sin estas instituciones es del 45%.*

En cuanto a los temas en los que se aplica la bibliometría, se han categorizado las publicaciones, y a pesar de las diferencias entre Scopus y WoS a la hora de clasificar las publicaciones, los resultados muestran que este tipo de estudios se han clasificado principalmente en las áreas más relacionadas con la Bibliometría. Según Scopus en orden de importancia: Ciencias Sociales e Informática, Medicina, Negocios, Gestión y Contabilidad, Ingeniería y Ciencias Ambientales. Según WoS: Ciencias de la Información y Biblioteconomía, Informática, Ciencias Ambientales y Gestión. Existe un alto grado de interés en la aplicación de la Bibliometría a otras disciplinas como elemento de análisis de su propio progreso.

Completando la categorización de las temáticas, en la indexación en Scopus la tendencia también muestra el predominio de los temas relacionados con la disciplina abordada en esta investigación: Índice H, Autocitación, Factor de Impacto, Topic Name. Dentro de los Topic Name, los que tienen más citas por documento son para el Topic Name Social Science and Humanities, Research Evaluation, Book Publishers tiene 45 citas por documento como promedio; y para el Topic Cluster Name, Decision Making, Fuzzy Sets, Models con 23 Cites por documento.

En InCites se incluyen mayoritariamente en el Macro Topic de Ciencias Sociales con un promedio de 14 citas por documento, en el Meso Topic de Bibliometrics, Scientometrics & Research Integrity, pero respecto a las citas por documento destaca el meso topic de Artificial Intelligence & Machine Learning (19 C/D). En el Micro Topic, el principal por número de documentos es Bibliometrics, pero en cuanto a citas por documento destaca sobre todo Fuzzy Sets con más de 30 C/D. Es decir, en las citas por documento destacan los temas de Informática.

El análisis de las fuentes muestra que, a pesar de los diferentes criterios de indexación del JCR y del SJR, hay variedad en las categorías en las que han sido indexadas. Las primeras posiciones, según el número de publicaciones, las ocupan las revistas especializadas en Bibliometría, pero también aparecen entre las 20 primeras revistas especializadas en Medicina o Medio Ambiente. En cuanto a la clasificación por cuartiles, un mayor número de revistas SJR se posicionan en el Q1 y Q2 en comparación con JCR, sin duda debido a los diferentes criterios de indexación aplicados por las dos bases de datos. Para completar la clasificación por cuartiles, factores de impacto y nivel de citación, se han utilizado dos métricas que permiten conocer el rendimiento de las fuentes en función de las citas recibidas y de las que se espera recibir. El CNCI de InCites muestra que 7 de las 20 están por debajo de 1 y el FWCI de SciVal muestra que 9 de las 20 también están por debajo de este umbral.

En el campo de la medicina, las principales áreas de investigación estudiadas fueron: Epidemiología, Pediatría, Ortopedia, Cardiología, Neurocirugía, Radiología, Oftalmología, Oncología, Cirugía Plástica y Psiquiatría.

En cuanto a la categoría de Ciencias Ambientales, se ha encontrado una menor difusión internacional, ya que sólo 83 países han trabajado en este campo. Los principales son China, España y Estados Unidos. En cuanto a las 10 primeras instituciones, se puede afirmar que sólo España y China son relevantes. España se centra en la sostenibilidad y China en el medio ambiente. En el campo de las Ciencias Ambientales, las principales áreas de investigación estudiadas fueron: Sostenibilidad, Desarrollo Sostenible, Cambio Climático, Ecología, Impacto Ambiental, Biodiversidad, Protección Ambiental, Gestión Ambiental, Salud Pública y Vigilancia Ambiental.

Las relaciones entre las citas de las publicaciones han permitido, con un análisis independiente, establecer clusters por palabras clave en función del nivel de citación. Estos 7 clusters fueron: Science Mapping, Research Productivity, Medical research, Environment, Psychology, Nursing e Engineering. En las 7 comunidades en las que se recogieron las 20 palabras clave principales, se observó de nuevo un predominio de los términos relacionados con la bibliometría aplicada a los diferentes clusters. También se han extraído los datos de las principales palabras clave por países, destacando la relevancia de China como país predominante en 4 de los 7 clusters analizados. El análisis independiente de la categoría de indexación de las revistas destaca que la Medicina y las Ciencias Ambientales son las áreas más relevantes en el ámbito de la bibliometría, después de las Ciencias Sociales y la Informática.

En conclusión, son muchos los parámetros que se pueden utilizar para ver la evolución de los estudios bibliométricos en el periodo analizado. En este caso, se han utilizado datos e indicadores bibliométricos para estudiar la evolución de esta disciplina a lo largo de los años y el rendimiento de las publicaciones. En cualquier análisis es importante partir de los objetivos del estudio para poder aplicar los valores métricos adecuados. En este sentido, no hay que olvidar las recomendaciones establecidas en el Manifiesto de Leiden y en la Declaración de San Francisco para hacer un uso adecuado de las métricas que permitan valorar correctamente la producción científica.

Publicación 2. "The Contribution of Spanish Science to Patents: Medicine as Case of Study"

Las universidades y, por extensión los centros o agencias de investigación, tienen el deber de producir conocimiento, que generalmente se mide por su producción científica en forma de publicaciones, que, si son de buena calidad, se incluyen en bases de datos internacionales que sirven de base para futuras investigaciones o desarrollos tecnológicos. Hoy en día, esta misión pretende extenderse a la resolución de los problemas de la sociedad en general y, específicamente, a las demandas del sector industrial. Hasta la fecha, este nuevo propósito no se ha podido medir fácilmente, salvo en forma de patentes que las propias universidades han desarrollado o solicitado. Sin embargo, este último aspecto sigue siendo el más importante de la investigación básica, que es probablemente el que implica una mayor financiación. Este estudio ha sido motivado por la necesidad de comprender el papel de la investigación pública en el desarrollo de la industria, que se refleja en la contribución al número de patentes. El objetivo es abordar una importante laguna en el sistema de investigación planteando el dilema de la investigación aplicada frente a la investigación básica realizada en las universidades y centros de investigación.

Este estudio establece una metodología para evaluar el impacto de la investigación universitaria en el sistema de patentes, analizando el impacto global de las universidades en las patentes internacionales. Para evaluar este paralelismo, se establece una metodología para relacionar la contribución de la producción científica española a las patentes internacionales a partir de su citación en las mismas. El estudio se ha realizado a nivel global, pero se ha reducido al campo de la medicina por el alto porcentaje (20%) de estudios citados en patentes relacionadas con este campo científico.

Se ha observado que la inversión global en investigación supone un aumento del número de publicaciones que han sido citadas en patentes. Por lo tanto, se muestra una relación directa entre la financiación y la transferencia. Al mismo tiempo, la colaboración internacional entre los autores españoles de estas publicaciones es una constante, como demuestra el alto nivel de colaboración con países como Estados Unidos, Reino Unido, o Alemania a nivel global y con Francia en el campo de la medicina. Además del protagonismo del organismo público de investigación (CSIC), las universidades son las instituciones que producen investigación aplicada y son citadas en las patentes. Se ha presentado un método que permite clasificar las universidades en función de la relación entre su producción científica global y la producción aplicada a las patentes. Los resultados obtenidos permiten observar que las universidades con un TIP (Índice de Transferencia en Patentes) superior al 5% (destacado) no son las que tienen un perfil principalmente tecnológico, como sería razonable pensar. Sin embargo, en el índice de transferencia de medicina en patentes (MED-TIP), son las universidades con facultades de medicina las que se posicionan en la parte alta de la tabla.

Como indicador de dónde está destacando la ciencia española a nivel de transferencia, se han considerado los Topics y los Topic Clusters. Además, el hecho de que los Topis destacados puedan predecir futuras asignaciones de financiación es muy útil. No obstante, no debemos de perder de vista que el hecho de que la prominencia represente la demanda y la visibilidad general no refleja necesariamente la importancia. El análisis de los Topic y Cluster Topic han determinado redes relacionando las publicaciones citadas en patentes tanto a nivel general como desde el punto de vista médico. La agrupación de Topics destacados se traduce directamente en la visibilidad de estas publicaciones.

Este estudio muestra que la investigación pública es fundamental para la I+D industrial, como refleja el número de patentes que se basan en este conocimiento y de forma significativa para la I+D en el campo de la Medicina. Los temas principales según la clasificación de la ASJC fueron Oncology (11,78%), Immunology and Allergy (9,48%), Infectious Diseases (7,1%), Cardiology and Cardiovascular (6,63%), Hematology (6,44%), Neurology (Clinical) (5,34%) y General Medicine (4,74%). En un análisis más detallado e independiente, permitió determinar los temas principales, que fueron: neoplasms, leukemia, DNA repair, human leukocyte antigen, Alzheimer disease, and carcinoma.

En contra de la idea de que la investigación universitaria genera un conocimiento abstracto de escasa utilidad para la sociedad en general, este estudio revela que la investigación pública y, sobre todo, la realizada en las universidades, sugiere nuevos productos en forma de patentes y, por tanto, ayuda al avance de la sociedad. Dado que las patentes son la base para que las industrias desarrollen un producto, dicha investigación llega así a la sociedad para mejorar nuestra calidad de vida.

En definitiva, desde el punto de vista bibliométrico, tanto bases de datos como Scopus o Web of Science, que proporcionan indicadores de calidad a nivel de publicación, como bases de datos como JCR o SJR, que cuantifican la calidad de las revistas, carecen de indicadores específicos que midan el impacto tanto de las publicaciones como de sus fuentes en su faceta de I+D. Por ello, se ha propuesto un ranking de revistas citadas en patentes como indicador de transferencia científica, ya que se nutre del propio sector industrial y en el que también pueden participar la universidad *y los centros de investigación. Así, para las universidades, se ha propuesto el TIP (Índice de Transferencia en Patentes) como indicador a largo plazo de la transferencia científica en patentes. A pesar de la complejidad de medir la tasa de retorno de la I+D, este trabajo abre nuevas perspectivas en el campo de la transferencia tanto de la ciencia básica como de la aplicada al proponer una clasificación tanto para las revistas como para los centros de investigación, todo ello basado en los trabajos citados en las patentes.*

Publicación 3. "Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27"

Esta publicación ofrece un análisis exhaustivo del enfoque actual de la investigación en la Agricultura y Ciencias Biológicas desde la perspectiva de la transferencia de innovación tecnológica, utilizando como indicador las citas de patentes de la producción científica. Este tipo de enfoque se engloba dentro del concepto de la Triple Helix, donde se aúnan los esfuerzos del mundo académico, la industria y los gobiernos.

El gran reto de la agricultura como actividad económica y de la agronomía como ciencia es proporcionar alimentos a la población mundial. La Unión Europea es una zona geográficamente muy poblada con una larga tradición de investigación agrícola. En el período 1999-2019, los países de la UE-27 han publicado casi un millón de artículos en el área de Agricultura y Ciencias Biológicas. Desde 2013 estas publicaciones se han estabilizado en torno a las 650.000 anuales. Sólo el 2,8% de estas publicaciones han sido citadas por patentes. Es decir, alrededor de 1700 por año, disminuyendo en los últimos 10 años, este es el periodo estimado del impacto de la producción científica en las patentes. Estos artículos han tenido una media de 6 autores. Y los artículos de revisión han representado el 7%, cuando en el conjunto de este campo científico suponen el 3,4%.

La evaluación comparativa sistemática de los resultados es necesaria para ayudar a dar pasos hacia la mejora de la propia actividad científica con el fin de recopilar información y tener un marco para el futuro. Además, esto permite que los conceptos en los que se basa la evaluación del rendimiento académico o de las publicaciones, es decir, la evaluación comparativa basada en indicadores, identifiquen las mejores prácticas para la mejora de la situación inicial. Por lo tanto, con el fin de realizar una evaluación comparativa, a continuación, se muestran los principales resultados como marco inicial.

Los resultados validan la pertinencia de aplicar indicadores bibliométricos a las patentes. El 40% de esta investigación se ha realizado en colaboración con 130 países de fuera de la UE-27. Esto muestra sin duda la gran colaboración que existe entre los países de la UE-27 y el resto del mundo. Los cinco primeros países en este sentido son Alemania, Francia, España, Italia y los Países Bajos. Las instituciones que lideran esta investigación citada en las patentes son las instituciones centrales de investigación de los países mencionados: CNRS (Francia), INRAE (Italia) o CSIC (España). Esto se debe probablemente al gran volumen de producción científica que tienen estas instituciones. Si se atiende al grado de especialización de las instituciones, entendido como el porcentaje de artículos en el área de Agricultura y Ciencias Biológicas respecto al total de trabajos publicados, hay 3 instituciones con más del 30%, estas son la Swedish University of Agricultural Sciences (58%), AgroParisTech (52%), Wageningen University & Research (48%), and INRAE (38%).

Las revistas utilizadas para esta producción científica están indexadas principalmente en las categorías SJR Plant Science, y Genetics, seguidas de Food Science. Según la clasificación del JCR serían también Plant Science, y en Food Science & Technology. El 90% de los artículos publicados han igualado o superado el valor de referencia 1 del FWCI, esto significa que los artículos han tenido un nivel de citación superior al esperado para el año de publicación, el tipo de publicación y la disciplina en la que se clasifica. Si el análisis se centra en el Top 10% Topic, el valor más alto lo alcanza Plant Journal con un 81,2% de sus artículos situados en ese Top 10%, seguido de International Journal of Food Microbiology (76,8%) y Plant Cell (73,9%).

Esta investigación pone de manifiesto el escaso impacto en el número de publicaciones científicas que han tenido los programas de investigación de la UE en el área de Agricultura y Ciencias Biológicas, en relación a ser citados en patentes, ya que han supuesto el 2% del total de trabajos publicados. Y que sólo el 27% de los trabajos financiados han sido en alguna forma de OA.

Los Top 3 Topic Cluster names fueron: " Arabidopsis, Plants, Genes ", " Cheeses, Caseins, Milk ", y " Metagenome, Probiotics, Bacteria ". Los Top 3 Topic names fueron: "Alcohol deshidrogenado cinamílico, Lignificación, 4-Cumarato-Coa Ligasa", " Virgin Olive Oil, Oleuropein, Elenolic Acid", y " Nicotiana Benthamiana, Taliglucerase Alfa, Molecular Farming ".

En resumen, los temas de investigación más reflejados en las patentes son los relacionados con la genética (Arabidopsis, Metagenome, Genome), con los grandes temas alimentarios (Cheeses, Milk, Breads or Oils) y con los productos alimentarios y bebidas de gran interés en la actualidad (Caseins, Probiotics, Glutens, or Starch).

La repercusión de la investigación básica en las patentes no es todavía una herramienta extendida en el campo de la investigación y la innovación, este trabajo puede ser un punto de referencia para futuras decisiones políticas sobre las direcciones que deben tomar las instituciones de investigación en su desarrollo futuro. Los resultados aportan pruebas del potencial de la metodología desarrollada y de las métricas obtenidas para representar las contribuciones a la transferencia de patentes de los sistemas científicos nacionales como indicador de la innovación tecnológica.

Desde este punto de vista, el actual plan estratégico de investigación tanto de la UE-27 como de los sistemas de sus países miembros debería tratar de potenciar el desarrollo de la base científica basada en la transferencia a la industria. La transferencia a las patentes ha demostrado ser a largo plazo, y las clasificaciones universitarias y las exigencias a los investigadores son a corto plazo. Intentar vincular ambas cuestiones mejoraría la búsqueda de innovaciones para la propia industria, lo que al final se traduciría en una mejora de la calidad de vida de los ciudadanos.

Publicación 4. "Worldwide Research Trends on Desalination"

La desalinización se adopta hoy en día para superar la escasez de agua dulce en algunas zonas del mundo si se dispone de agua salobre o salada. Obtener agua dulce del mar es, para todos, la mejor oportunidad tecnológica para resolver la escasez de agua que se avecina. En los últimos 20 años se ha investigado mucho en este campo y se han mejorado los distintos tipos de tecnologías aplicables a la desalinización. El sector de la investigación en desalación ha ido en aumento, especialmente desde 2008. Se ha visto que los trabajos se centran fundamentalmente en dos enfoques principales, las ciencias ambientales (28%) y la ingeniería (27%). Los otros tres enfoques relevantes son la química (11%), la ingeniería química (10%) y la ciencia de los materiales (9%), seguidos de la energía (5%). Los 5 primeros países en este campo científico son China, Estados Unidos, India, Irán y Corea del Sur. Entre las 20 primeras afiliaciones, 8 son de China y 4 de Arabia Saudí. Hay pocas diferencias entre los objetivos de estas instituciones, ya que las cuatro primeras palabras clave de sus publicaciones son similares en todas ellas: Seawater, Membrane, Reverse Osmosis y Water Filtration.

Se han encontrado ocho grupos científicos principales en la investigación mundial relacionada con la desalinización: Reverse osmosis, Renewable energy desalination, Thermal desalination, Brine, Electrodialysis, Membrane distillation, Microbial desalination y Freeze desalination.

Se han identificado líneas de investigación para mejorar las estrategias de gestión de las salmueras (Brine), tanto para limitar los impactos ambientales negativos como para ayudar a reducir el coste económico de su eliminación. Esto puede contribuir al desarrollo de nuevas instalaciones de desalinización y contribuir al suministro de agua para las generaciones venideras.

Para los países con escasez de agua, la desalinización puede ser el único medio viable de proporcionar el suministro de agua necesario para sostener la agricultura y apoyar a la población, aunque hay que tener en cuenta los costes energéticos y las limitaciones tecnológicas, pero es la investigación en este campo la que permitirá ampliar su uso. Por último, cabe señalar que cuando el agua salobre se recoge de los pozos, existe un riesgo importante de que la salinidad de las aguas subterráneas aumente debido a la intrusión marina. Este estudio proporciona un punto de referencia en la descripción global de la productividad científica en la investigación sobre desalinización. Por lo tanto, es necesario abordar las lagunas y los retrasos en la investigación sobre desalinización en muchos países costeros. Los datos de producción científica revelan una buena producción científica en este campo de investigación en todo el mundo.

Conclusiones generales

La revisión de las conclusiones obtenidas a lo largo de las publicaciones científicas derivadas de esta tesis, permiten afirmar que es necesario analizar y establecer métodos que permitan medir la relación entre la investigación básica y la investigación aplicada.

Este objetivo se ha alcanzado en el trabajo presentado al aplicar diferentes indicadores bibliometrícos que facilitan la medición del impacto de la investigación desarrollada y aplicada a patentes. Frente a los indicadores bibliométricos que se centran fundamentalmente en medir la calidad de las publicaciones, son escasos los indicadores que nos permiten medir la transferencia de la investigación a patentes entendidas éstas no sólo como el instrumento de protección de la propiedad industrial, sino como el elemento que refleja la innovación tecnológica. Éste es un tema pendiente para las bases de datos de referencia en el campo de la investigación, al que se ha contribuido desde este trabajo al proponer y aplicar un índice que mide el grado de transferencia en patentes (TIP).

Podemos concluir afirmando que es necesaria la medición de cómo revierte la investigación realizada desde los centros académicos y de investigación en la industria, incluyendo el tercer elemento fundamental en este binomio, las administraciones gubernamentales. Estos tres elementos (denominados Triple Helix), son la base de una buena gestión, transferencia e innovación de cara a la transparencia necesaria y demandada por la sociedad en la gestión de la investigación.

7. Publicaciones derivadas de la tesis

Publicación 1.

"The bibliometric literature on Scopus and WoS: the medicine and environmental sciences categories as case of study"

International Journal of *Environmental Research and Public Health*

MDPI

Article

The Bibliometric Literature on Scopus and WoS: The Medicine and Environmental Sciences Categories as Case of Study

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Abstract: In a broad sense, science can be understood as the knowledge contained in scientific manuscripts published in scientific journals. Scientific databases index only those journals that reach certain quality standards. Therefore, research and dissemination of scientific knowledge are essential activities for the growth of science itself. The aim of this manuscript is to assess the situation of medicine and environmental sciences among the bibliometric literature and to put it in perspective with the overall bibliometric publications in all scientific fields. The main countries publishing bibliometric manuscripts are China, USA and Spain. The latter country is ranked three out of the top five institutions according to the Scopus and WoS databases. In both databases, the average scientific collaboration of the top 20 institutions offers the same result, 41%. According to Scopus, the main subject categories in which this research falls are social sciences (38%), computer science (26%) and medicine (23%), while the environmental sciences category has 8%. In the analysis of the Medicine category alone, it has been observed that 136 countries have contributions in this field. The main countries are the United States, China and the United Kingdom. In the field of medicine, the main areas studied were: Epidemiology, Pediatrics, Orthopedics, Cardiology, Neurosurgery, Radiology, Ophthalmology, Oncology, Plastic Surgery and Psychiatry. With respect to environmental sciences, less international dissemination has been found, with only 83 countries having worked in this field. The main ones are China, Spain and the United States. Regarding the top 10 institutions, it can be stated that only Spain and China are relevant. Spain focuses on sustainability and China on the environment. The result of an independent keyword analysis of all published bibliometric manuscripts has shown that the main clusters are: Mapping Science (29%), Research Productivity (23%), Medicine (20%), Environmental Sciences (12%), Psychology (7%), Nursing (6%) and Engineering (4%). In short, medicine and environmental sciences are the most relevant areas in the field of bibliometrics after social sciences and computer sciences.

Keywords: bibliometry; Scopus; Web of Science; medicine; environmental science; sustainability

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1. Introduction

Bibliometrics, as a science-related discipline, aims to provide a set of tools for the assessment of scientific production. From its origin at the beginning of the 20th century to the present day, bibliometric studies have focused on different points of view. In 1917 Cole and Eales carried out the first bibliometric study through the statistical analysis of publications on comparative anatomy [1], thus initiating the use of bibliometrics for the measurement of scientific activity. Following this same approach, in 1926 Lotka focused his work on analyzing the scientific production of researchers with the so-called Lotka's Law of Productivity, a law that determines that the greatest number of authors publish the least number of publications, while the least number of authors publish the greatest number of publications [2]. In 1956, Price formulated the Law of Exponential Growth of Scientific Information, stating that it grows at a much faster rate than other social processes. Price also

Publicación 2.
"The Contribution of Spanish Science to Patents: Medicine as Case of Study"

International Journal of *Environmental Research and Public Health*

MDPI

Article

The Contribution of Spanish Science to Patents: Medicine as Case of Study

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Abstract: Investments in research and development (R&D) and innovation are expensive, and one wishes to be assured that there is positive feedback and to receive guidance on how to direct investments in the future. The social or economic benefits of investments in R&D are of particular interest to policymakers. In this regard, public expense in research, especially through universities, is sometimes being questioned. This paper establishes a measure of how research in Spain, and specifically in its universities, is involved. In this study, we have analyzed all the literature cited in the period 1998–2018 produced by Spanish institutions and which has been cited in at least one international patent, obtaining more than 40,000 publications from more than 160,000 different authors. The data have been surprisingly positive, showing that practically all public universities contribute to this subject and that there is a great deal of international collaboration, both in terms of the number of countries with which they collaborate and the prestige of the institutions involved. Regarding the specific scientific fields in which this collaboration is most relevant, biochemistry, genetics and molecular biology, and medicine together account for almost 40% of the total works. The topics most used by these publications were those of diseases or medical problems such as: Neoplams, Carcinoma, Alzheimer Disease, or human immunodeficiency virus (HIV-1). Oncology was according to the All Science Journal Classification (ASJC) the leading and central issue. Therefore, although the result of basic research is difficult to quantify, when it is observed that there is a return in fields such as medicine or global health, it can be said that it is well employed. In terms of journals from a purely bibliometric point of view, it has been observed that some journals do not have a great impact or relative position within their categories, but they do have a great relevance in this area of patent support. Therefore, it would be worthwhile to set up a rank for scientific journals based on the citations of patents, so the percentage of articles cited in patents with Field-Weighted Citation Impact (FWCI) >1, and as an indicator of scientific transfer from universities or research centres, the transference index in patents (TIP) is also proposed.

Keywords: Scival; patents; Spain; bibliometrics; Research and Development (R&D); social returns

1. Introduction

Basic needs are all those vital necessities that contribute directly or indirectly to a person's survival, and among the most basic or subsistence necessities could be considered those of health and food. Science must respond to the needs of society and to global challenges [1]. Scientific progress enables us to have a better quality of life [2,3], for example the field of health [4] provides us with new medication to treat diseases and, if not possible [5], at least to mitigate pain [6].

Publicación 3.
"Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27"

agronomy MDPI

Article

Transfer of Agricultural and Biological Sciences Research to Patents: The Case of EU-27

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Abstract: Agriculture as an economic activity and agronomy as a science must provide food for a constantly growing population. Research in this field is therefore becoming increasingly essential. Much of the research is carried out in academic institutions and then developed in the private sector. Patents do not have to be issued through scientific institutions. Patents from scientific institutions are intended to have a certain economic return on the investment made in research when the patent is transferred to industry. A bibliometric analysis was carried out using the Scopus and SciVal databases. This study analyses all the research carried out in the field of agronomy and related sciences (Agricultural and Biological Sciences category of Scopus database) by EU-27 countries, which has been cited in at least one international patent. The data show that out of about 1 million published works only about 28,000 have been used as a source of patents. This study highlights the main countries and institutions in terms of this transfer. Among these, Germany, France and Spain stand out in absolute terms, but considering the degree of specialization. Regarding their specialization the institution ranking is led by Swedish University of Agricultural Sciences (58%), AgroParisTech (52%), Wageningen University & Research (48%), and INRAE (38%). It also analyses which journals used for this transfer are most important. For these publications more than 90% of the articles have had a higher-than-expected citation level for the year of publication, the type of publication and the discipline in which they are categorized. The most-obtained research fields can be distinguished as those related to genetics or mo-lecular biology, those related to specific foods, such as cheeses, milk, breads or oils, and, thirdly, the group covering food-related constituents such as caseins, probiotics, glutens, or starch.

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1. Introduction

Agronomy is based on scientific and technological principles, and must study the physical, chemical, biological, economic, and social factors that, in one way or another, influence crop production [1]. Its fundamental basis is focused on studying human intervention in nature from an agro-productive point of view, or in other words, studying the agro-ecosystem as a specific model of human intervention in nature, with the aim of producing food and raw materials [2]. In short agronomy may be defined as the science of soil management and crop production [3].

The essential issue in agronomy is the study of the relationship between soil, plant, and environment, with the aim of maximizing yields, and reducing production costs, but doing so with responsibility and not at any price [4]. To do this, it is necessary to plan the processes, as well as to implement different measures to obtain the maximum use of natural resources, in order to produce more and improve production standards [5]. All this must be done paying special attention to non-renewable natural resources, which are in danger

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