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Cities as places and topics of studies: Mapping research clusters across disciplines

In research articles, cities usually occur as topics (e.g., subjects or actors) or places of studies (e.g., sites, destinations, locations, or spaces). Investigation of more general patterns is rare because research usually focuses on individual cities. We use science mapping, based on Scopus data and Vosviewer visualization software, to examine city-related research across journals and disciplines (subject areas), and to assess how multiple city functions are reflected in journals. Comparable European Union capital cities (Berlin, Madrid, Rome, and Warsaw) serve as models. The patterns are remarkably similar regardless of the city. National and regional journals are the most common publication venues. Research takes place within three major disciplinary clusters: 1) the social sciences, and arts and

humanities, 2) medicine, and 3) natural/technical sciences (environmental, earth and planetary, agricultural, and biological sciences). Medicine shows an early prevalence, and recently the social sciences have been strongly represented in these studies. Although the relationships are based on different journals, they are comparable for all cities and can be used to assess cities of similar size. This study was conducted just before the Covid-19 pandemic, and it can serve as a reference to identify research patterns before and after because the outbreak may bring about changes in future city-related research.

Keywords: cities, science mapping, research fields, bibliometrics, visualization

1 Introduction

Cities feature prominently in research articles. They usually appear in different contexts: first, as an investigative field (e.g., culture, geography, history, medicine, or urban planning) and, second, specific cities as places or typologically defined areas (e.g. capital cities, Asian cities, or smart cities) and also metaphorically (e.g., the city as a lab, network, assemblage, business, classroom, or platform). Therefore, cities can serve as topics for research (e.g., as actors, relations, brands, case studies, examples, engines, experiments, factors, drivers, instruments, etc.), or come about as sites where a particular study has taken place: as a destination, location, locale, setting, site, space, and so on. Our purpose is not to theorize about how cities are studied academically.

In the context of the conceptual background of our empirical study, we merely state that the growing complexity of social, spatial, environmental, and technological intertwining is reflected in both the heterogeneity of analyses and attempts to integrate them. This is especially true for urban and regional studies in the treatment on particular, general, and relational attributes of the urban (Hočevar, 2005; Cox & Evenhuis, 2020). The issue of object/subject/topic/treatment can be blurred. Thus, for example, very heterogeneous “living” actors of the city such as planners, politicians, artists, entrepreneurs, researchers, media, and so on can be treated together with “inanimate” aspects such as land, museums, manufacturing plants, publications, and studies. Both subjects and objects of the city or in the city, regardless of their affiliation, have an agency of a sort to form a network of functions, connections, or assemblage, which can be translated into the actor as a whole. To provide a rough illustration of such an interweaving, we cite research perspectives derived from the epistemological premise of ANT (Actor–Network Theory) and socio-material assemblage concepts analysing relations between entities and their constituent elements (Latour, 2005; Brenner et al., 2011; Gutzmer, 2016). Human and nonhuman actors, so-called actants, function together, which is reflected in external relations.

On the other hand, many empirically oriented articles tend to focus on individual cities where specific issues are addressed: cultural activities, the economy, the environment, food and nutrition, health and disease, history, pollution, tourism, traffic, urban forestry, urban morphology, and so on. Although many articles focus on specific or typologically grouped cities, the work that deals with the city as a research site is less frequent or at least ambiguous when used. For example, the term *laboratory* has been used to refer to the city as a place of research and also to illustrate a type of field research (Karvonen & Heur, 2014). In addition, even research paradigms can be named

after cities, such as the Chicago School of (Urban) Sociology (Gieryn, 2006; Guggenheim, 2012). In the context of ANT, the city as a laboratory figures as an actant, whether it is a metaphor or a concrete and actual site. More specifically, smart cities and urban sustainability have also been investigated as topics through quantitative bibliometric methods (Ingwersen & Serrano-López, 2018; Wang et al., 2019; Marvuglia et al., 2020), although not based on specific cities. Kadi (2019) included all European capitals and focused on gentrification. Berlin, Rome, and Madrid (the subjects of our study) were addressed in the context of history by Therborn (2002) and Gómez et al. (2018), in the framework of city branding (de Rosa et al., 2019), and in a study on the share of publications of the world's major agglomerations (Grossetti et al., 2014). Research fields in relation to cities were identified by Nunes et al. (2019), who used the journal classification system of research areas of the Web of Science.

Cities as central themes are most often found in the social sciences, where comparative studies have developed a number of quantitative and qualitative comparative techniques (Ward, 2010), which sometimes also try to balance the many divides (e.g., wealth, geography, and political systems) in comparative research (Robinson, 2011). Cities are also the subject of research in the life sciences; for example, in the plant sciences and environmental science (e.g., the case of Berlin; Sukopp, 2008), or climate research (Lamb et al., 2019). In this respect, the areas of urban research as identified by Raynor (2019) were more inclusive (also involving environmental factors and natural resources) but they were based only on cities in Australia. More comprehensive comparisons of different cities are however rare. In the studies pertaining to information sciences (e.g., bibliometrics and science mapping), cities are most frequently addressed in the sense of tracking affiliation (author's address), as well as metropolitan units, regions, countries, and so on (Bartol & Hočevar, 2005; Frenken et al., 2009; Matthiessen et al., 2010). Maisonobe et al. (2017) investigated global cities in the context of scientific output and scientific disciplines. Bornmann & de Moya-Anegón (2019) examined German cities with regard to the concentration of scientific activities. Also evaluated were scientific cooperation between cities and institutions (Leydesdorff & Persson, 2010) and the output of cities on specific topics, for example, urban globalization (Kanai et al., 2018). Various contexts of cities based on *The Rise of the Network Society* (Castells, 1996) have also been “scientometrically” evaluated (Zhen et al., 2020).

Mapping of specific topics is often carried out using visualization software (e.g., Vosviewer, CitNetExplorer, CiteSpace, and Pajek). Hajduk (2017) investigated city logistics. Visualizations identified clusters of different schools of thought in the relationships between cities (Peris et al., 2018). Cities as

primary sites of knowledge were also assessed for intellectual property output (i.e., patents; Kogler et al., 2018). In a study on medicine and public health, cities were evaluated on issues relevant to the aging of the population (de Oliveira et al., 2019; Xiang et al., 2020). Various bibliographic elements in publications (countries, journals, title words, author keywords, etc.) were visualized in environmental sciences (e.g., cities' ecological infrastructure; Sun et al., 2020). Terms dealing with trees and parks in the city were mapped into clusters by Xing and Brimblecombe (2020). Sometimes, the principal publications were assessed, for example, on the topic of creative cities (Rodrigues & Franco, 2020). Article keywords (*urban*, *city*, or *cities*) were also used (Kirby, 2012). However, big-data approaches are also possible, taking into account the need for informed interpretation (Zook et al., 2019).

We examine and compare cities in the context of the functions as reflected in different areas of publishing. An additional motivation was the onset of the health emergency caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). However, we do not address Covid-related citations (as yet) in relation to urban matters. The time lapsed (less than one year at the time of this study) is still too short. We would rather find out what the line of research was before the crisis in order to provide a basis for possible more complex comparative studies in the future. Many previous quantitative studies that have looked at cities have focused primarily on the city as the site of an author's institution, but this is not very informative for a city in the context of its functions. Our aim, in contrast, is to examine a city as the setting of a study or as a direct research topic, or both. Thus, we do not study a city as a bibliographic "address" but the city as an "actor". We compare equivalent cities in different countries in order to assess parallels that perhaps transcend assumed differences. The hypothesis is that, although the cities considered in this study belong to very different geographical and linguistic contexts and have undergone historical development, the research fronts are quite similar. We assume that this is reflected not only in the choice of academic publication channels and in a similar ratio between national and international journals, but also in the topics investigated by researchers. The hypothesis is examined through the analysis of bibliographic and text data.

The bibliographic data (i.e., growth patterns over several decades, journal titles, languages, co-authorship, and country of affiliation) provide the basis for comparison whereby elementary patterns of similarity can be assessed on the basis of weighing publishers' data. However, these should be complemented by an assessment of distribution along disciplinary lines. Here, our preliminary pilot analysis suggests that there is a shift in emphasis toward the social sciences as well as the arts and humanities that is similar across the cities studied.

Disciplinary development can be more precisely determined by using advanced visualization software to construct maps based on text data. We not only identify distinctive clusters of research topics, and possible interconnections and links, but also detect the development in time that underpins preliminary information from the bibliographic data. Again, these patterns are very similar across cities, regardless of the potentially very different publication venues (e.g., journals).

2 Materials and method

Our preliminary pilot revealed an important share of city-related articles in national and regional journals (also in national languages). Therefore, we chose the Scopus database over Web of Science (WOS) although WOS has recently introduced the ESCI (Emerging Sources Citation Index) in its Core Collection promoting regional and specialty area publishers. Visualization and clustering used Vosviewer software. The analysis covers all articles up to 2019 (Scopus command: `pubyear < 2020`). Analysis of text data was conducted on the abstracts of the articles. The title field cannot be used because this field contains both the translated title (English) as well as the original title, where the words from the original titles skew visualizations.

The target was selected European cities. Given the very different city size, it only made sense to compare not only equivalent cities but also larger cities, which have usually more connections (Levinson, 2012). In addition, a sufficient number of records are required for the visualizations to reveal applicable clusters. We checked major cities with a population around one million and upward. We excluded London, Paris, and Moscow because these cities are much larger and would thus merit a comparison on their own. Next, there was the challenge of disambiguation: does a name really refer to the city in question or perhaps only denote a phenomenon, procedure, or concept named after the city? For example, there are at least fifteen cities called Berlin or Rome (Pouliquen et al., 2006). The uniform solution was to include both the name of the city and the respective country (both as a noun and adjective) in the retrieval. It is possible that an article is about the city, but the abstract (or keywords) will not include the country name. This is a limitation. However, the procedure of including countries is consistent because the location by country maximizes search precision (Overell & R uger, 2008) due to the absence of ambiguities (Volz et al., 2007).

We compared, on the same principles, major European Union (capital) cities: Amsterdam (constitutional capital), Athens, Berlin, Brussels, Bucharest, Budapest, Copenhagen, Madrid, Prague, Rome, Stockholm, Vienna, and Warsaw. Accordingly,

Table 1: City name occurring in the title in intersection with the respective country, and the number of records.

TITLE(city)	Total	TITLE-ABS-KEY(country-n. OR country-a.)	TITLE(city) AND TITLE-ABS-KEY(country-n. OR country-a.)
Berlin	11,747	Germany OR German	3,778
Madrid	4,868	Spain OR Spanish OR Spaniard	2,954
Rome	7,249	Italy OR Italian	2,411
Warsaw	3,065	Poland OR Polish OR Pole	2,071

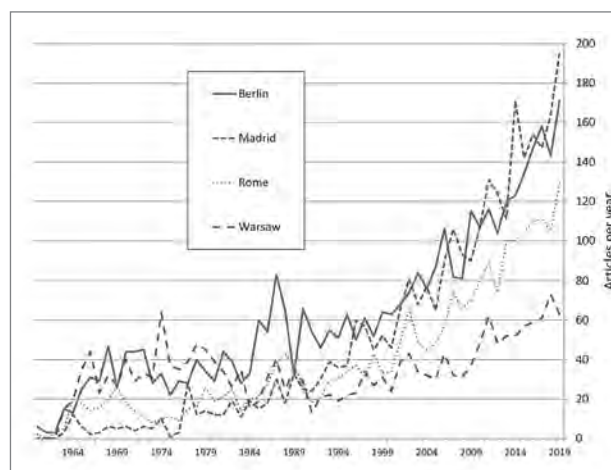
we coupled each city with the respective country noun (*n.*) and country adjective (*a.*). Two terms were usually enough, with some exceptions (Holland/Dutch/Netherlands, Denmark/Danish/Dane, etc.). Finally, we selected all (capital) cities that returned more than 2,000 articles (*ar*) or review articles (*re*), with the respective city in intersection with the corresponding country. The search statement was thus designed as follows:

(TITLE(city) AND TITLE-ABS-KEY(country-n. OR country-a.) AND DOCTYPE(ar OR re) AND PUBYEAR < 2020

The cities meeting the criteria were Berlin, Madrid, Rome, and Warsaw (Table 1). We do not provide the demographic statistics on these cities because these are available in many data sources (e.g., in Internet 1). According to different urban typologies (cities as local administrative units, functional urban areas, metropolitan regions, etc.), Berlin, Madrid, and Rome are fairly comparable regarding their size and demographics (depending on typology). Warsaw is somewhat smaller. These cities were also ranked very similarly in studies by Csomós (2017) and Hanna and Rowley (2019).

Table 1 also provides the number of all city names (column 2: Total), in addition to the numbers applicable in this study (column 4). For example, there are 11,747 and 7,249 articles with *Berlin* and *Rome* in the title, respectively; for Madrid and Warsaw, this share is lower. Berlin, for example, frequently has only figurative historical and political connotations (e.g., *Berlin Wall*). Rome also carries references to antiquity. Thus, the city name alone is not suitable for retrieval because the names have special uses, such as metonymy or polysemy.

We also examined major non-capital cities. Munich and Hamburg returned just over one thousand articles each, and Milan about 1,270. The endonym *Milano* retrieved additional records. It seems that the endonym has also acquired international use. This is not the case with Rome (Ital. *Roma*) because the term *Roma*, in relation to Italy, invariably refers to the ethnic group. The major metropolis Barcelona, which features prominently in research publications, returned almost 2,500 articles. Here we also included Catalonia/Catalan. However, this city was not included in our study because we limited our study to one city per country. In this respect, Madrid was

**Figure 1:** Yearly growth of articles referring to the cities (illustration: authors).

somewhat more in line with the other three cities, which are also capital cities.

3 Results and discussion

3.1 Yearly growth of articles

The increase in targeted articles has been steady, with some fluctuations (Figure 1). Before 1960, such articles are rare. Articles about Madrid show the most vigorous growth. Warsaw and Berlin present similar trends at first. The steady beginning, and then some decline (Warsaw) or surge (Berlin), only stabilizes (with an upward trend) in the early 1990s, likely on account of “normalization” of political situation in central and eastern Europe.

The once-divided Berlin reflects contributions from both German states: the Federal Republic of Germany (West Germany) and the German Democratic Republic (East Germany). The place of publication cannot be ascertained very precisely given the weak and deficient Scopus inclusion of country data (discussed later in this study). As inferred from journal titles (Table 2), the high counts in mid 1980s are not attributable to special events because most are mapped to the subject area of medicine. Similar applies to Warsaw. The still weak standings of Warsaw in the last decade likely reflect the economic

Table 2: Number of journal articles by top five journals.

City and journals	Articles
Berlin	
Zeitschrift fur arztliche Fortbildung	67
Gesundheitswesen	38
Berliner und Munchener tierarztliche Wochenschrift	36
Deutsche Gesundheitswesen	35
Geburtshilfe und Frauenheilkunde	28
Madrid	
Estudios geograficos	68
Revista espanola de salud publica	67
Boletin geologico y minero	42
Enfermedades infecciosas y microbiologia clinica	39
Revista clinica espanola	38
Rome	
Nuovi annali d'igiene e microbiologia	55
Annali di igiene medicina preventiva e di comunita	53
Annali dell istituto superiore di sanita	33
Medicina nei secoli	31
Atmospheric environment	23
Warsaw	
Przeglad epidemiologiczny	113
Roczniki panstwowego zakladu higieny	101
Archiwum historii medycyny	64
Polski tygodnik lekarski	63
Przeglad lekarski	53

situation and lower research and development funds available to research institutions in transition (Odrobina, 2016).

3.2 Journals and articles

Subsequent records cover all Scopus articles up to 2019 (pub-year < 2020). Journals show strong “national” patterns. Most of the top five journals have an original title in the national language, although many also publish articles in English. In addition, most are mapped to medicine (Table 2). The journal names in Table 2 are spelled out as in Scopus. All consecutive words are lowercased for consistency.

Figure 2 shows journals that each published at least four articles on the subject of our study. The five principal journals (from Table 2) are located at the beginning (left side) of the *x*-axis. The number of articles per journal quickly decreases. The very long tail of journals that published three, two, and one article is not shown. Such inversely proportional patterns are very similar for all cities and exhibit clear characteristics of power laws. Incidentally, such power law patterns were also found in other processes contingent on the scaling functions of city size (Bettencourt et al., 2007).

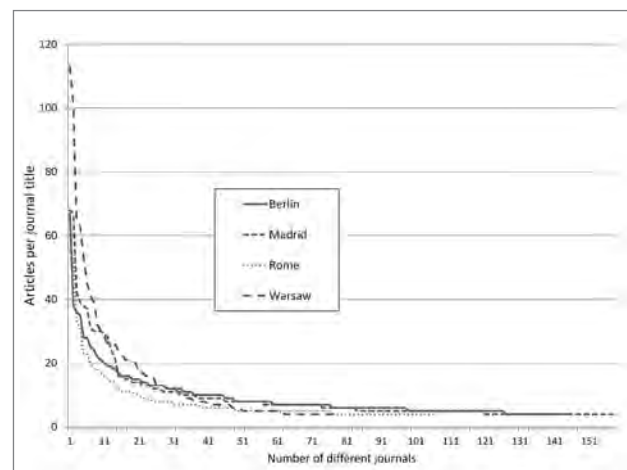


Figure 2: Inversely proportional decreasing number of different journals and articles per journal (illustration: authors).

Table 3: Four cities as sites or topics in article titles, authors' affiliation, language of articles.

	Articles		Articles		Articles		Articles	
Site/Topic	Berlin	3,778	Madrid	2,954	Rome	2,411	Warsaw	2,071
Affiliation	Germany	1,817	Spain	2,239	Italy	1,315	Poland	972
	<i>Berlin</i>	<i>1,479</i>	<i>Madrid</i>	<i>1,943</i>	<i>Rome/Roma</i>	<i>1,190</i>	<i>Warsaw/Warsz.</i>	<i>907</i>
	US	271	US	160	US	185	US	72
	UK	186	UK	98	UK	137	UK	40
	France	55	France	60	France	65	Germany	38
	Canada	51	Germany	38	Germany	50	France	15
	Netherlands	49	Italy	38	Spain	38	Italy	9
	Switzerland	47	Portugal	23	Australia	26	Netherlands	9
	Austria	40	Canada	17	Netherlands	21	Belgium	8
	Italy	34	Mexico	16	Canada	19	Russian F.	8
	Australia	32	Australia	15	Belgium	17	Czech R.	6
Language	Ger	1,772	Spa	1326	Ita	609	Pol	1,206
	Eng	1,876	Eng	1,678	Eng	1,648	Eng	799
	<i>Eng in 1995</i>	<i>0.41%</i>	<i>Eng in 1995</i>	<i>0.43%</i>	<i>Eng in 1995</i>	<i>0.71%</i>	<i>Eng in 1995</i>	<i>0.59%</i>
	<i>Eng in 2019</i>	<i>0.79%</i>	<i>Eng in 2019</i>	<i>0.69%</i>	<i>Eng in 2019</i>	<i>0.94%</i>	<i>Eng in 2019</i>	<i>0.86%</i>

We also checked some citation patterns. The journals in the same linguistic group cite similar journals quite strongly. Other studies have also detected effects of geography and distance on knowledge flows (Pan et al., 2012; Abramo et al., 2020). In our case, we assume this to be attributable to the subject addressed: the city featured in the article title and was thus relevant in a specific geographic context. However, has the representation of journals been steady throughout the years?

3.3 Country and city of affiliation, language of articles

Roughly half of all articles were (co)authored from the country of the respective city (Table 3). Moreover, between 80 and 90% of articles from these countries were co-authored by authors from that particular city. However, US and UK authors hold second and third place everywhere. Similar US/UK dominance was also reported in some other studies (Okorie et al., 2014). Although the most important share of all articles was published in national journals, recent attention has shifted toward international publishing, although national journals still hold top place. Shares of national languages have been decreasing, English having by now taken the principal role.

Not all articles are supplied with author-country information. The numbers for Poland should have been much higher. For example, many of the 1,206 Polish-language articles were published from an “undefined” country. Such limitations have also been reported in WOS (Liu et al., 2018), but this seems to be much more considerable in Scopus, especially for older documents. The omission of a county is much more critical

than omission of language (Jacsó, 2009). We also detected deficiencies with city data. The affiliation-city field failed to correctly detect the city. Therefore, we needed to employ the complete affiliation field where, for example, Rome was frequently spelled out only in Italian. Warsaw was spelled out in Polish, but in various adjective/noun cases.

Co-authorship links are not very strong (Figure 3). Weak co-authorship between countries in Europe was also detected by Jokić et al. (2019). However, the US and UK are similarly linked with all countries. Visualization is thus in line with the numbers in Table 3. Articles from Spain are, on average, more recent (marked with a darker shade), and from Poland older (marked with a lighter shade), which is also in line with the data in Figure 1. In the case of Germany, we needed to construct a thesaurus in order conflate different variants. In the database country field, there were also *ddr* (Germ. *Deutsche Demokratische Republik*), *frg* (*Federal Republic of Germany*) and *west ger* (*West Germany*).

3.4 Subject areas

Figure 1 presents yearly progress, but we wished to see how this was reflected across the different research fields. Namely, research disciplines possess diverse publication patterns, and therefore journals are mapped to different subject areas. The journals in this study were mapped to twenty-seven Scopus subject areas. The patterns of scatter are remarkably similar, the top five categories being the same for all cities. Medicine is predominant, and the social sciences are ranked second. However, counts of research areas must not be generalized

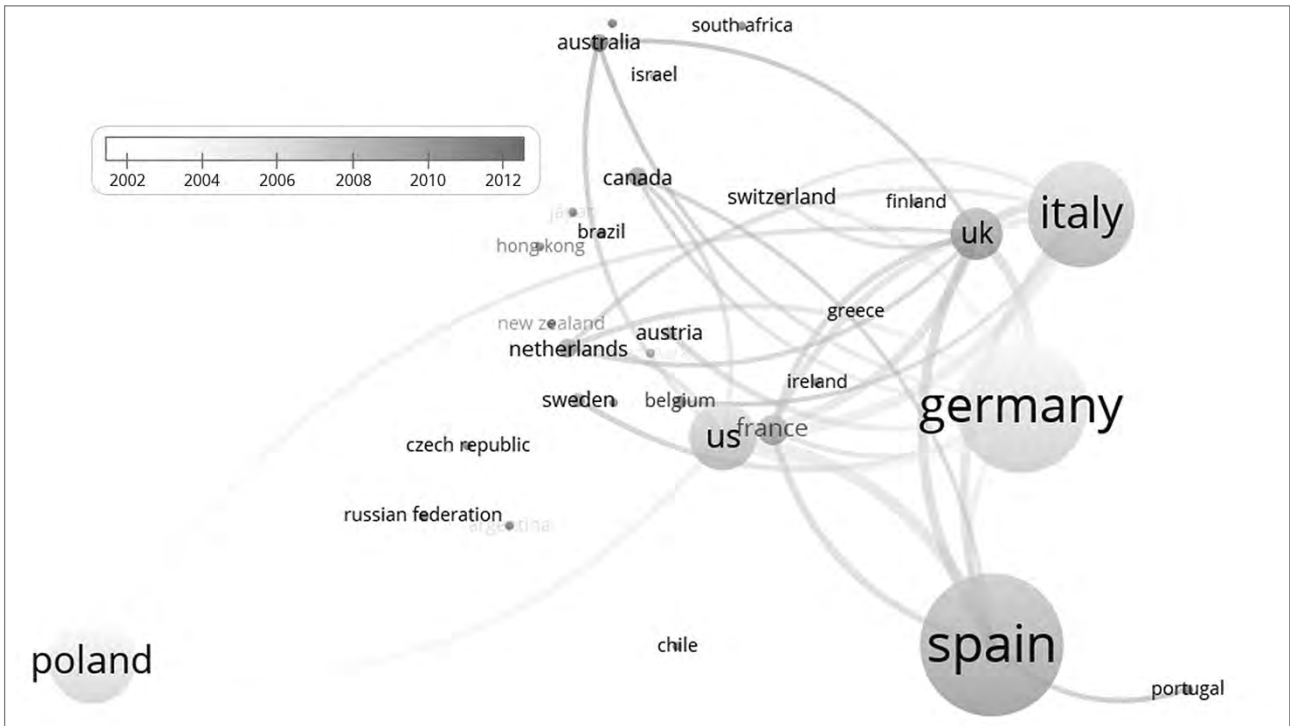


Figure 3: Co-authorship in articles by country of authors' affiliation (illustration: authors).

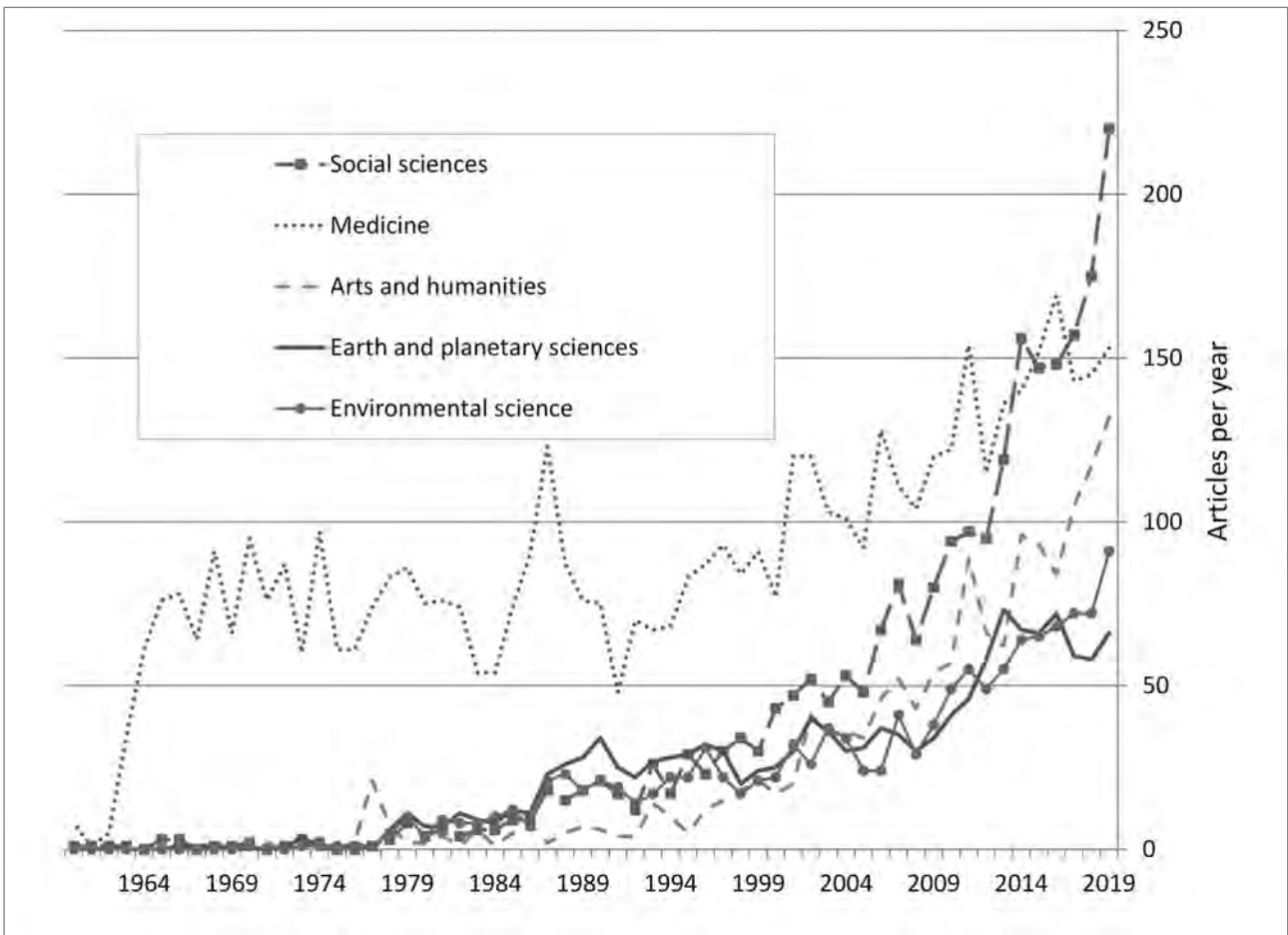


Figure 4: Growth of articles per Scopus subject area (illustration: authors).

too much because one journal can be mapped to several areas or to other areas than what one might expect (Hočevár & Bartol, 2016). Figure 4 (based on yearly growth) reveals detailed patterns: medicine has been overtaken by the social sciences for all cities. The category arts and humanities has also been progressing. Here one also needs to take into account the specifics of publication in “basic” disciplines and “strategic” disciplines (van Rijnsoever & Hessels, 2011). National research and development policies can also play a role in differences among different disciplines (Cugmas et al., 2019).

3.5 Clusters and time scale of related research topics

The last and the principal part of this study is based on text data (terms in abstracts) tackling the content of research taking place in the four cities. The terms (individual words and noun phrases) are arranged into clusters according to relatedness as detected by the software (we excluded terms from structured abstracts as well as the term *city*, which is found in virtually every abstract).

The first figure for each city (Figures 5, 7, 9, and 11) presents clusters of related and interconnected terms indicating research areas and topics. The circles representing associated terms are marked by a distinctive shade for each cluster. The second figure (Figures 6, 8, 10, and 12; the time scale of research topics) shows the same terms, but focuses on development in time. The darker (the more saturated) the circle, the more recent the average year. Circle size indicates the relevance of a term. The strength of links within each cluster and between clusters is shown with lines. These terms provide a general idea of research emphases and approaches. Each map consists of tens of thousands of terms, and so only selected labels are visualized (to avoid overlap), usually terms with at least ten occurrences.

Employing the same principles for all maps facilitates comparison on the same basis. The number of terms varies among the cities, depending on the number of articles as well as city-specific terminology. Identification of clusters, the timescale of averages, and the number of terms are defined by the algorithms explained in the program manual (van Eck & Waltman, 2019). The interpretation of clusters (i.e., research subjects) employs the categorization scheme of Scopus subject areas. All maps are based on articles from the complete Scopus database up to 2019 (pubyear < 2020).

3.5.1 Berlin

The visualization program identified 47,000 terms, which occur at least ten times in 3,778 articles (Figures 5 and 6). Only the most relevant terms are shown. Three different clusters can be noticed. The strongest cluster (on the right) pertains to medicine and related research. As shown in Figure 4 (previous subsection), medicine was especially strong in earlier periods, hence some strong accents of light shades (Figure 6). This figure complements Figure 5 in terms of time tendencies. The more general terms occur more frequently and are thus larger. Topics of more recent importance can be noted to the right (darker shades). Because they are recent, they occur in smaller numbers (hence smaller circles).

The lower left cluster (Figures 5 and 6) presents topics that pertain strongly to the social sciences, as well as arts and humanities, business, economics, and other related areas. Even though these are separate subject areas in Scopus, it is apparent that the research is interlinked, given the position in the cluster. Considering the recent advance of the social sciences, this cluster is expected to grow. The recent accents (darker shades) are obvious, and they include the terms *activist*, *debate*, *urban space*, and *urban development*. The most recent terms in this context are small and overlapping, and thus not visible (e.g., *gentrification*). Links between different clusters also exist. For example, at the bottom centre of Figures 5 and 6 are the terms *medical education* and *public health service*. This is an area of convergence between the medical and social sciences (i.e., interdisciplinarity).

The upper (smaller) cluster is defined by environmental science, followed by Earth and planetary sciences, engineering, agricultural and biological sciences, and so on. Some frequent terms can be highlighted: *agriculture*, *contamination*, *species*, and *water*.

Some contexts in which Berlin is highlighted specifically “as something”, as used verbatim in article titles, are the following: *Berlin as: a case study, an example, a capital, a model, a ... resort, a location, a destination, the virtual centre, the site, a creative field, a relic border, a natural and socioeconomic system*, and so on. Such contexts usually pertain to the social sciences and to arts and humanities, and they can also be figurative. In other (more frequent) contexts, Berlin appears as a “matter-of-fact” place of research: “during summer in Berlin,” “micro-geographic analysis for Berlin,” and so on.

3.5.2 Madrid

The maps are based on 2,954 articles and 47,000 terms (very similar to Berlin). The program identified five clusters (Fig-

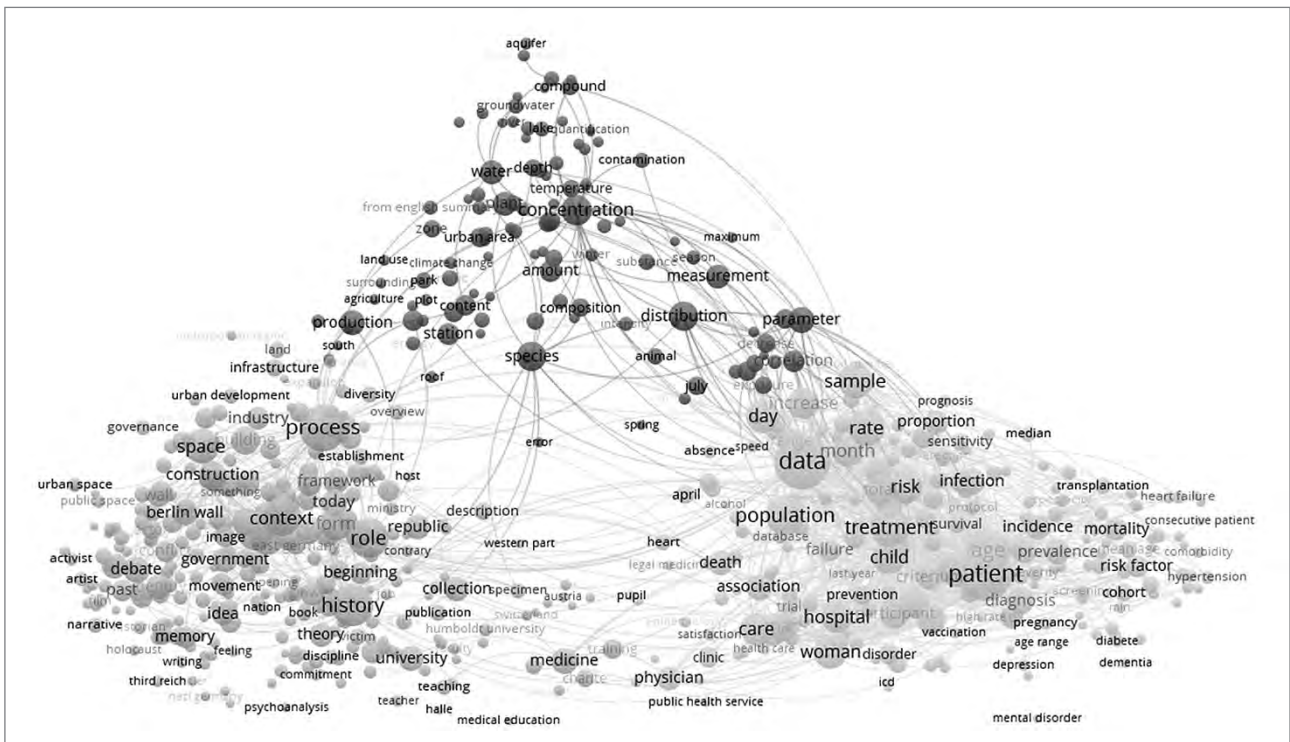


Figure 5: Clusters of interrelated research areas and topics (Berlin) (illustration: authors).

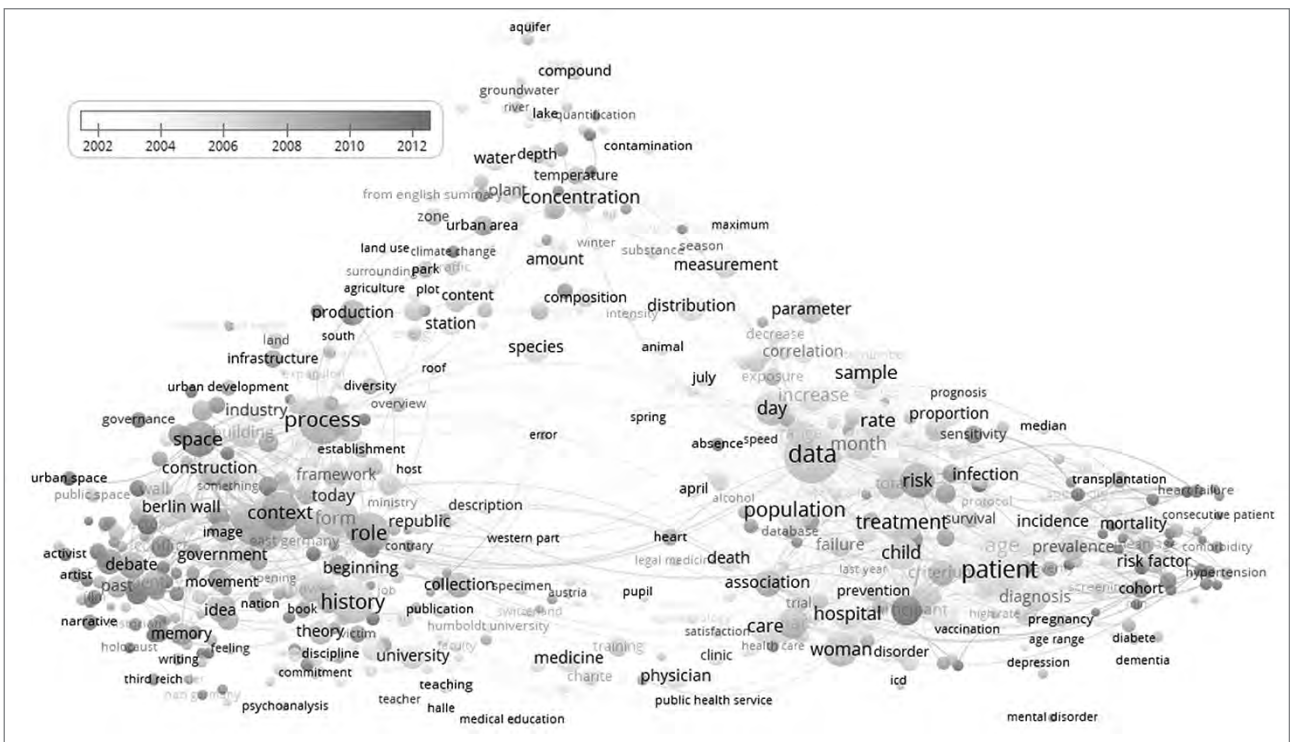


Figure 6: Time scale of research topics (Berlin) (illustration: authors).

ure 7) with two distinguishable (interlinked) clusters related to *Medicine* (right side of the map). The lower medical cluster involves epidemiology, microbiology (*disease, infection ...*). The upper medical cluster is more diverse, involving *age, man, woman ...* and also *blood pressure, diet, food*. Just as at Berlin, the educational issues in *Medicine* show connections with the

Social Sciences (bottom centre). *Social Sciences* (lower left) are again more recent and connected with *Arts and Humanities*. The two upper left clusters are marked by *Earth and Planetary Sciences, Environmental Science*, and also *Agricultural and Biological Sciences* and *Engineering*, in various interconnections. The left-most cluster is located closer to the *Social Sciences*

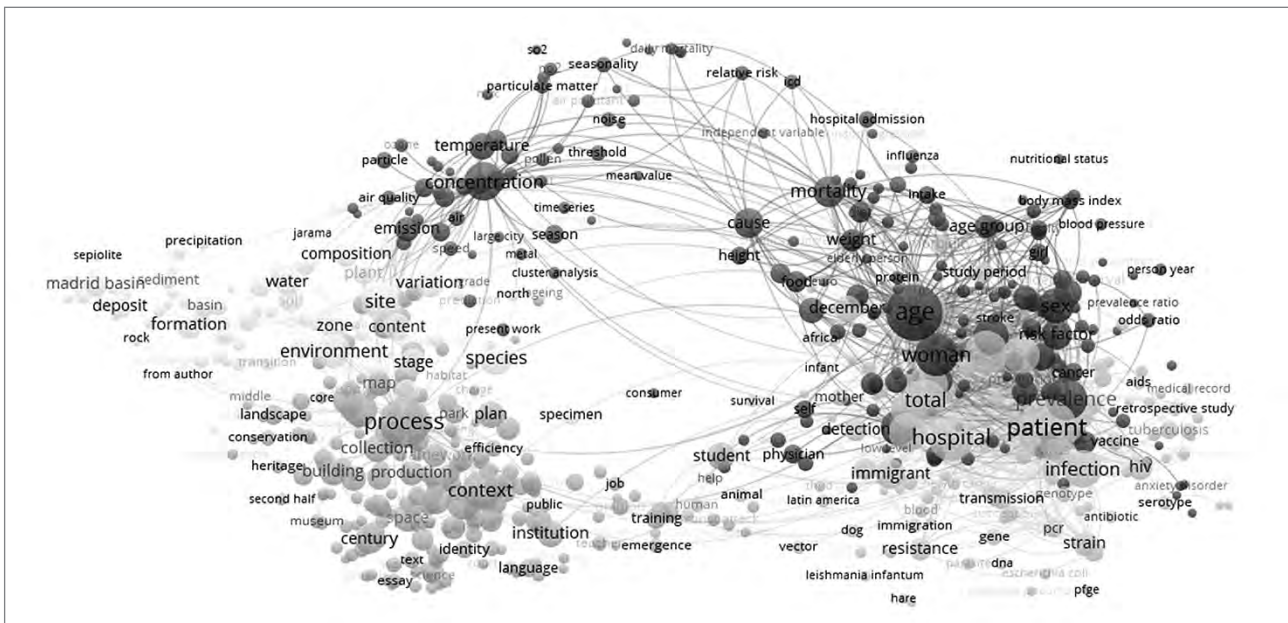


Figure 7: Clusters of interrelated research areas and topics (Madrid) (illustration: authors).

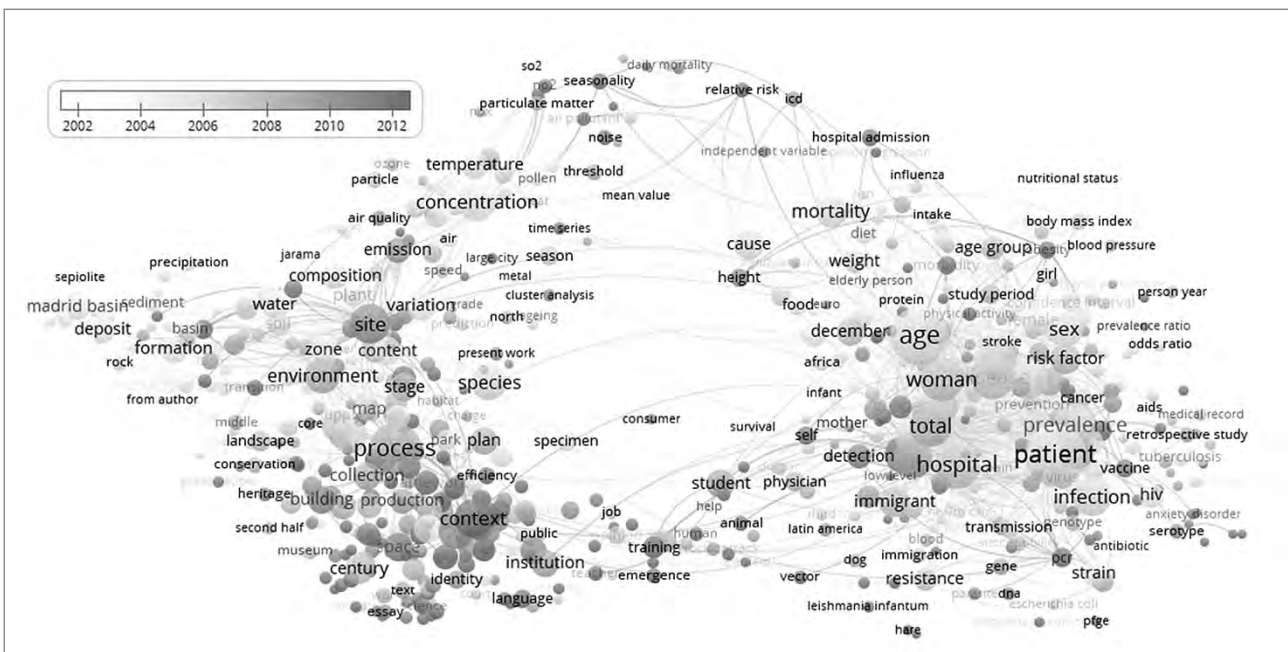


Figure 8: Time scale of research topics (Madrid) (illustration: authors).

below and contains, on average, the oldest topics (light shades, farthest left, Figure 8). We can note a dense “sub-cluster” of geological topics. Related environmental-biological topics are more recent. The upper cluster is linked with environment and pollution. It is also connected with the upper medical cluster reflecting the impact on the health of city dwellers.

In the articles, *Madrid* appears as a case study, an example, a key factor in sustainable mobility, a liberation from, a communication *ecosystem*, a *mercantile and financing institution*, and a *place of research*, as indicated by article titles such as

“Women living homeless ... *Madrid*”, “Epidemiology and etiology ... *Madrid*”, and “3D groundwater flow ... *Madrid* aquifer”.

3.5.3 Rome

Rome returned 2,411 articles. The figures are based on 38,500 terms mapped to three different clusters (Figure 9), showing similar structure as the clusters at Berlin. Again, medicine was strong in earlier periods (right cluster, lighter shades, Figure 10). The lower left cluster (social sciences and arts and humanities) is again more recent, showing convergence with medicine in the area of education. Also at Rome, the upper-left

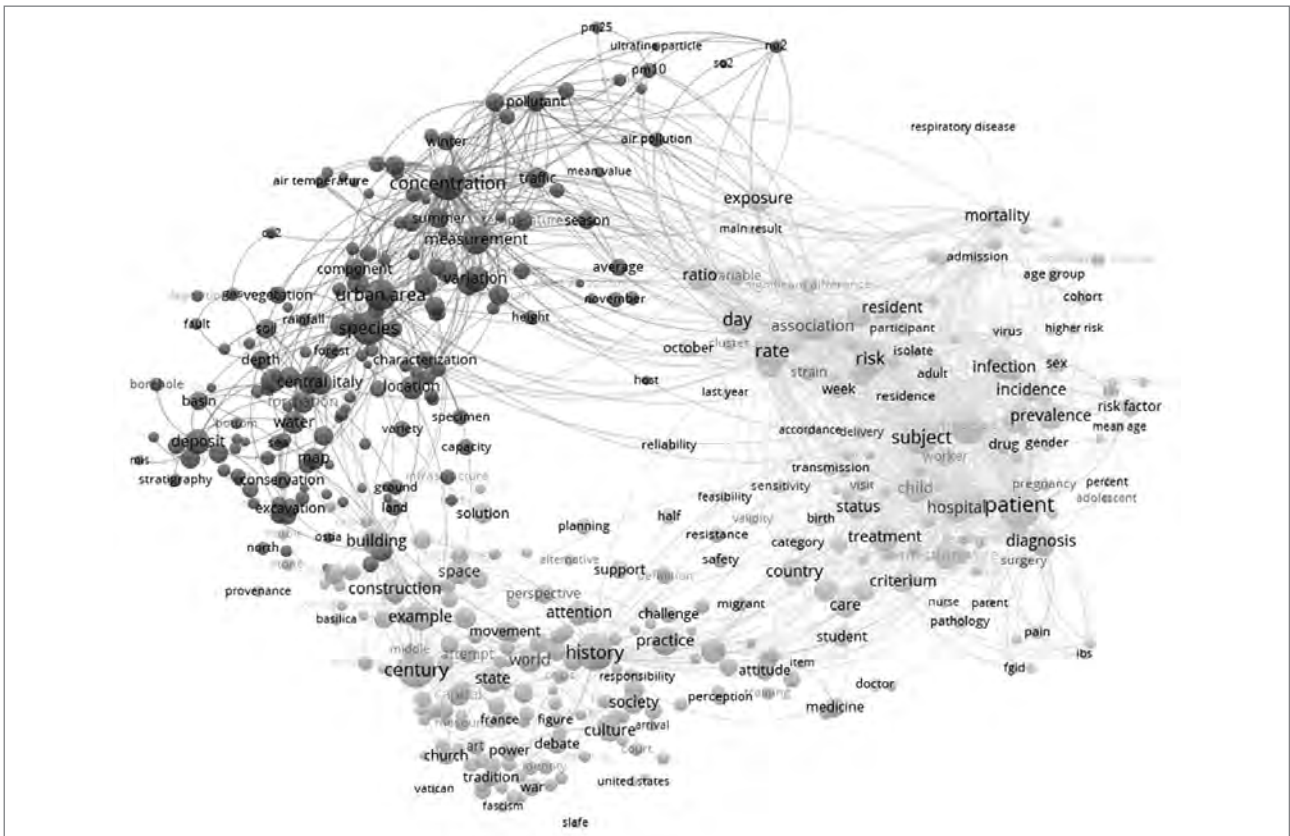


Figure 9: Clusters of interrelated research areas and topics (Rome) (illustration: authors).

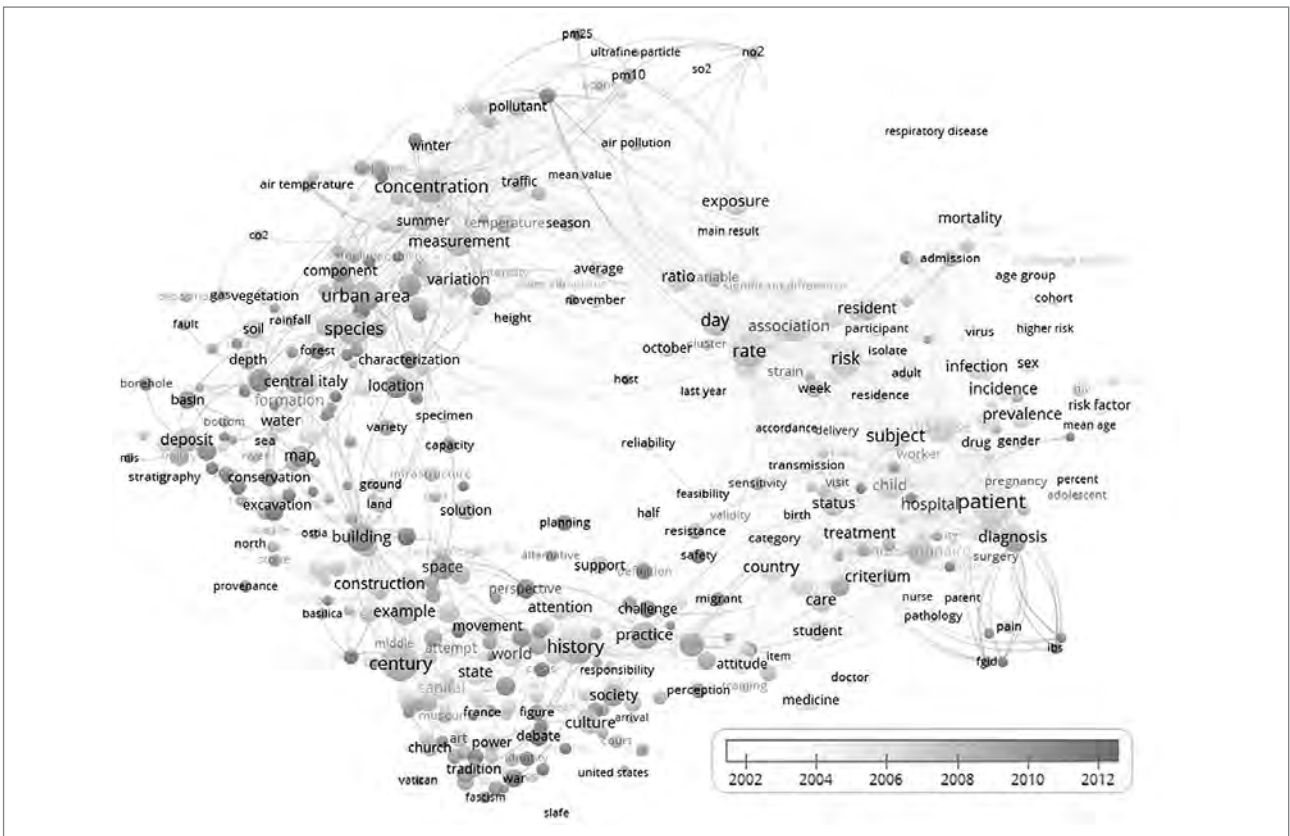


Figure 10: Time scale of research topics (Rome) (illustration: authors).

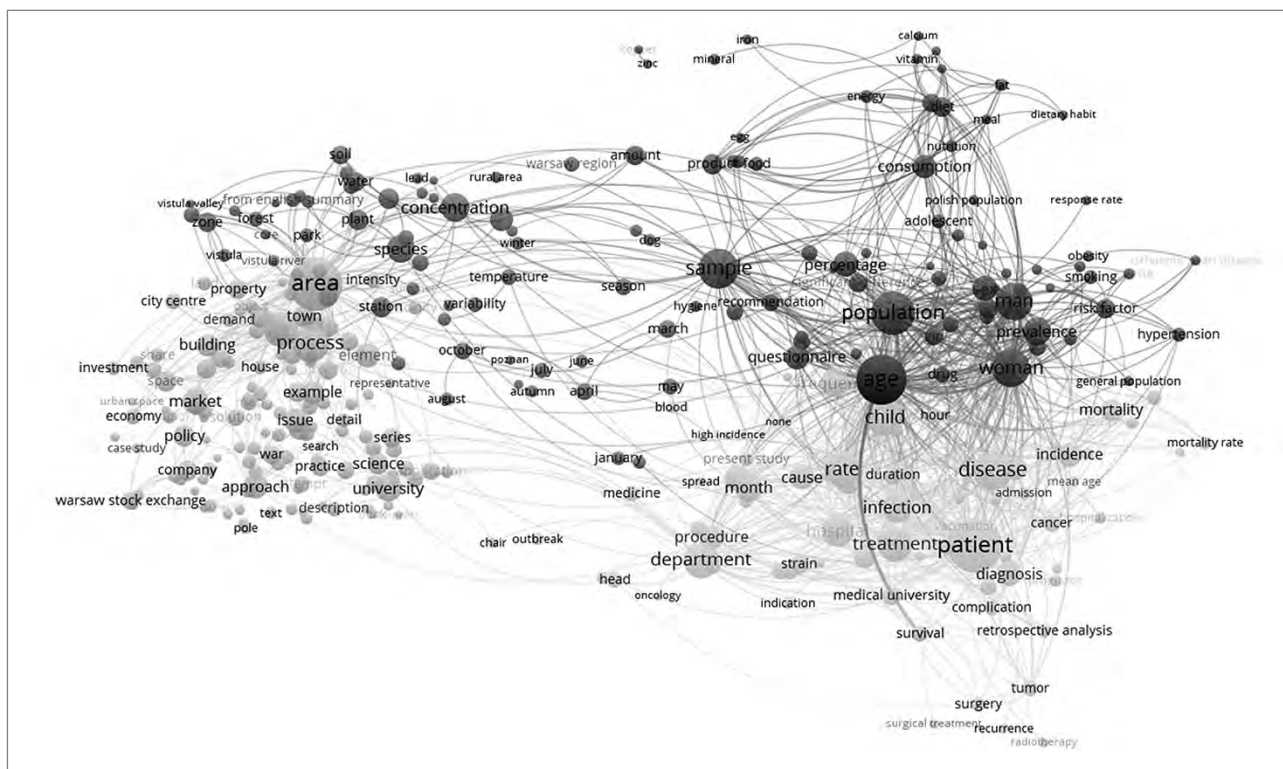


Figure 11: Clusters of interrelated research areas and topics (Warsaw) (illustration: authors).

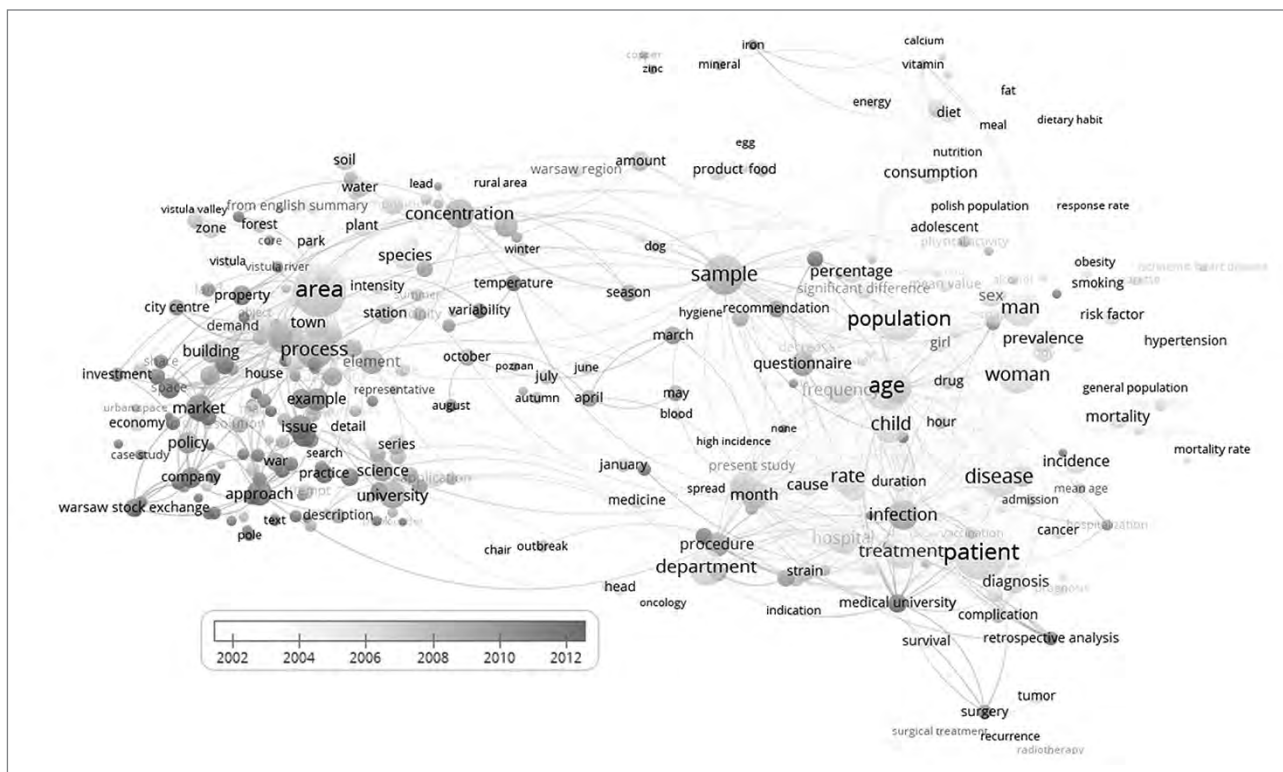


Figure 12: Time scale of research topics (Warsaw) (illustration: authors).

cluster is strongly linked with Earth and planetary sciences and environmental science, with terms such *conservation* and *excavation* located closer to the social sciences and the arts and humanities. At the top, there are topics related to climate and pollution, which lean toward medicine.

In the articles, *Rome* appears as *a window of observation, a full urban experience, a stage, the source, "Spanish Avignon", a capital, a memorial landscape, a destination, and a place of research*, as indicated by article titles such as "Recreational drugs ... *Rome*", "... Smart homes network in *Rome*", "Combined magnetic, chemical ... anthropic context in *Rome*", and "Urban regeneration process ... *Rome*".

3.5.4 Warsaw

Warsaw is linked to 2,071 articles. The 24,000 relevant terms are mapped to four clusters (Figure 11). Medical topics are contained in two (interconnected) clusters. The lower-right cluster reflects, for example, epidemiology (with the terms *disease* and *infection*). The two clusters to the left are somewhat interconnected. Many terms revolve around the generic term *area* with links to both clusters. The lower left cluster contains more recent research fronts (darker shades, Figure 12), which can again be labelled as related to the social sciences (and to an extent to the arts and humanities). The upper-left (smaller) cluster shows connections with Earth and planetary sciences, environmental science, and agricultural and biological sciences. These topics are, on average, older (lighter shades) than topics in the lower left. Average medicine-related topics are also discussed early on the time scale. This corroborates our previous assumption that the cumulative data in Table 3 no longer reflect the current situation of research articles.

In the articles found in Scopus, *Warsaw* appears as *a commuting centre, an air transport node, an example, a chief town, an endemic focus, and a place of research*, as indicated in titles such as "Local institutions of culture as urban ... *Warsaw*", "Short-term impact of PM2.5, PM10 ... *Warsaw*", "Postmodern architecture under socialism ... church in ... *Warsaw*".

3.6 The four cities in perspective

The aim was not to evaluate and compare cities on the basis of an author's affiliation, but to examine cities as objects (topics) and sites (locales) of research in order to map the multiple functions performed by heterogeneous agencies (actors) of a city as reflected in scholarly journals.

The study was based on the evaluation of the role of four capital cities (Berlin, Madrid, Rome, and Warsaw) that have experienced some differences in the more recent historical con-

text. These cities represent specific geographical and linguistic settings, ranging from the western/southern Mediterranean to central/eastern Europe. Nonetheless, the topics covered in the articles are remarkably similar across the four cities, which was our hypothesis about the similarities in disciplinary development. The clusters of topics clearly show not only comparable accents, but also similar research trends over time. The trends show a growing interest in city-related social issues.

The analysis included not only text data (disciplinary development) but also bibliographic data (scattering across publications). National and regional journals are important for all four cities. One might dismiss such journals as less important in the context of high-ranking international journals, but such journals can still provide an important avenue for presenting findings based on specific cities. This can complement research published in international studies that focus on general summaries, possibly with multiple authorship, in which individual contributions and local subject contexts are less clear. Similarities are also reflected in co-authorship and country of affiliation. The majority of articles are published by authors from the respective city. However, international collaboration is strongest with the authors from the UK, US, and France. Again, these patterns are very similar across all four cities.

4 Conclusion

The study found that city-centred research is being conducted in a few fairly well-defined major disciplinary clusters. Whereas medicine, which used to dominate, has stagnated, the social sciences now show the strongest presence. The arts and humanities have also made considerable progress. Less dynamic but steady is the growth of subjects in environmental science, and Earth and planetary sciences. Although journals have always played an important role in life sciences and related disciplines, it seems that journal articles have by now also been fully embraced by the social sciences. The results of different disciplines cannot be directly compared with each other because there are many factors that influence publication behaviour in specific disciplines.

Because the publication patterns are so similar for all four cities studied, our tentative guess is that this could be true for many other cities as well. In this respect, different cities of different sizes could also be compared, which remains to be investigated.

What will the future accents and research priorities in cities be? This study assessed the state of research at the end of 2019, just before the health emergency caused by coronavirus 2 (SARS-CoV-2) or the Covid-19 pandemic. In many cases, cities were particularly affected, although not all in the same way. This is where regional and national journals can play an im-

portant role. The connections and research links may generate different and more innovative trends in interdisciplinary cooperation, perhaps between the social sciences and medicine, and also involving other disciplines. True interdisciplinarity has been weak to date, but it could create new relationships. This needs to be pursued further.

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