



## Article

# Recognizing New Trends in Brain Drain Studies in the Framework of Global Sustainability

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**Abstract:** Scholars had been documenting the Brain Drain phenomenon producing scientific literature for more than 50 years. After three decades of slow but steady progress, literature about this concept has accelerated its progress and growth path, in line with the 9th sustainable development goal “Build resilient infrastructure, promote sustainable industrialization and foster innovation” Thus, the present article aims to define the current theoretical trends about the analysis of advanced intellectual human capital’s international migratory phenomenon. This study uses a scientometric methodology on a corpus of 1212 articles indexed to the JCR-WoS from Social Sciences. The period covered in the study is from 1965 to 2020. The paper looks to understand how researchers studied the brain drain concept over the last 55 years in various disciplines. The report covers 99 categories from the Journal Citation Report (JCR) index. Results show that there is a scientific research critical mass that is studying the brain drain phenomenon. The analysis shows thematic trends at the sources, discourses, and consolidates classic works and some novel authors. Those new scholars and theoretical trends lead to refocused analysis beyond countries with a high development level. Such movement constitutes a new challenge in this line of research toward studying the effects of the brain drain in the peripheral areas of knowledge production.

**Keywords:** brain drain; intellectual capital; international migration; cross-border cooperation; Scientific Elite; cooperation networks; literature; social sciences; scientometrics



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## 1. Introduction

A formal definition of brain drain is one that offers the thesaurus of the Education Resources Information Center-ERIC [1] as the “Loss of highly skilled or educated persons from one country, region, institution, or job sector to another, based on better pay, improved living conditions, expanded opportunities, between others”. Many influences generated locally and globally govern brain loss at the international level [2]. The loss of educated people can be associated with a lack of institutional capacity to absorb and use advanced intellectual capital [3]. The phenomenon generates a decrease in the intellectual capital of the country of origin, but at the same time, an increase in political instability and the degree of fractionation of that country [4]. Its measurement focuses on the migration of nationals with tertiary education, but mainly in physicians and professors [5].

In the mainstream literature, it is possible to identify as initial studies on the phenomenon known as ‘brain drain’ carried out by Johnson [6] publishing in *Minerva*. Johnson reports the severe implications, beyond the loss of public investment and effects on the salaries of state officials, expressed in the British concept of the ‘brain drain’ phenomenon of emigration of health personnel and universities generates on Canada’s social welfare. In turn, the author remarks that the concept of ‘brain drain’ is not exempt from the nationalist roots observed in the discussion of the phenomenon. Furthermore, Oteiza [7], publishing

in the International Labor Review, raises the costs for a less developed country, as in Argentina's case, in the emigration of engineers. Oteiza [7] shows that this brain drain has negative implications on the country's developmental possibilities.

On the other hand, Grubel [8] reflects on the USA's role as a destination country for the brain drain and the effects of said immigration on the international scene. Finally, Perkins [9] comments in Foreign Affairs magazine, based on International Relations, with perspective. In this, Perkins associates the Brain Drain phenomenon with the developmental possibilities of a nation and the limits to development in regions with low levels of advanced intellectual capital. The author argues that these countries are affected by the brain drain because people seek better personal development conditions.

Except for the cited work by Johnson [6], there are just a few works that could connote greater interest in the international scientific community. In Johnson's publication in *Minerva*, the document's citations in high impact journals (JCR-WoS) amount to around 50 citations to date. In the mid-1970s, the Portes [10] document arouses similar interest in citations to date. The authors' interest relates to the novelty that implies identifying specific determinants of a social phenomenon, such as brain drain. In any case, the article that elicits the most significant connotation in the first three decades of brain drain studies to date is the proposed economic model of Kwok and Leland [11]. Kwok and Leland's work mentioned above is still used today as part of some countries' public policies [12]. Among the policy implications, the authors mention: (1) A government information policy on foreign educational programs, which helps employers in the "qualification" of each graduate abroad's records. (2) Scholarships abroad with a "return clause", although it may be difficult to enforce them, and a "forced" return may entail other costs to society and may even distort scholarship applications leading the best students to seek other sources of help. (3) Return subsidies offer various benefits to students who do return, thus contributing to private placement with lower initial costs for the employer. However, in ignorance of the real effect on the individual decision to return to the country of origin, it can involve a costly universal application. Furthermore, (4) Development of elite educational programs that balance the gradient of educational quality prompts emigration, and it is a form of recognition of extraordinarily talented students' abilities since that high talent tends not to return [11].

Interestingly, in recent years, the topic of brain drain has gained such momentum that it has become necessary to adopt tools and methods to characterize a phenomenon that has been defined as dynamic and changing [13]. This resurgence of academic production motivates us to take a new look at this dynamic and changing phenomenon. Therefore, in the present work, we systematically study Brain Drain, *e.d.*, theoretical approaches about the Advanced Intellectual Capital international migratory phenomenon.

In particular, the physicians' emigration, this phenomenon affects human development indicators in developing countries, *ed.* infant mortality and vaccination rates. Mortality and vaccination rates are causally related to physicians' more significant number [14]. As Sherr et al. [15] point out, qualified intellectual capital is essential for the proper functioning of health systems, and its absence undermines the public health sector. It is a fact that this phenomenon mainly affects developing countries from where do migrants flow to rich countries. The cited flow and imbalance are not merely a qualified human resources global management problem. Flow and imbalance phenomena are related to uneven global development. Uneven global development leads to unequal global access to quality healthcare deepening unsustainability in some geographies [16]. Because it affects economic sustainability for life and sustainability for social equity [17], generating fragility to the sustainability of those states [18].

In the case of professors, it is crucial to study why do scientists choose to look for another "better place" to carry out their research [13]. Along with this, authors recognize that the strengthening of specific academic disciplines demands incorporating professors trained abroad. This strengthening is sought by higher education and research institutions due to the influence of having an international faculty [19]. Therefore, it is of high interest

to know the proportion of immigrant teachers in the entire teaching staff, the variations by discipline, the differences in foreign teachers' research performance in the academic system, and possible top-level foreign scientists' concentrations. Likewise, it is also relevant to study the proportion of foreign teachers who are unproductive or with a mediocre performance. The study of professors and scientists' loss will provide information to analyze national policies related to the higher education system's attractiveness and understand the phenomenon of entry and flight of qualified foreign professors, especially in countries with continuous brain drain on their borders [20].

The mix of factors to leave one country and choose another as a destination is complex [21]. Among the multiplicity of factors are comparative monetary benefits, the quality of family and individual life, the perception of better prospects for future generations, and social freedom and a liberal atmosphere. These parameters are recognized as crucial to affect decision-making [2,11,22,23]. Besides, in the academic sector, working in an excellent organizational climate, i.e., the search for job satisfaction inhibits the propensity to migrate, favoring job satisfaction with an administration that favors simplified procedures, research productivity, harmonious academic standards, and a meritocratic reward process [24].

As for the already mentioned factors that explain the brain drain, one can add the professional and academic ties with peers that remain in the country of origin and their propensity to return, in a reverse migration. Altogether, those factors give way to a brain drain and a more complex and dynamic phenomenon called brain circulation [21]. Saxenian [25] already recognized that the connections with the countries of origin, the circulation of brains, and the possibilities of telecommunication lead to a knowledge transfer toward destinations at peripheral areas of knowledge generation achieving cross-border cooperation. Saxenian [25] exemplifies such phenomenon with Chinese and Indian engineers that contribute to their countries technological development working from Silicon Valley. These circular actions of highly skilled migrants -HSM- in favor of developing their country of origin show a correct level of commitment that does not seem to diminish with time [26]. In fact, in some cases, this circulation is definitively imposed in the form of brain gain, which depends on the availability of some resources to finance certain research activities, on the offer of doctoral programs with international mobility or other international mobility programs [7,27].

Delivering a more critical point about the phenomenon of brain drain and brain gain has been analyzed and studied, Metcalfe [28] has pointed out that the disconnection between body and mind implied in the literature marginalizes the political identities of researchers as foreign citizens and their energies, affections, desires, and imaginations. Studying the brain drain phenomenon entails an understanding of academic mobility because of national strategies of innovation and economic competitiveness, affecting the sustainability in its technological development subdimension [17], and which leaves unexplored the epistemic and ontological change at the individual level. Instead, a nomadic political ontology approach permits academics' mobility to analyze the interrelations between nationalism, academic belonging, and transnationalism.

Many countries consider the brain drain phenomenon a fundamental problem of their economic policy [29]. This consideration about economic policy strengthens discussions regarding the possibility of reversing the brain drain and its impact on the economy [5,30]. Such an approach is becoming an increasingly crucial governmental concern to sustain vibrant economies and societies [31]. Furthermore, in some countries, the government decides to face a brain drain, given tertiary students' emigration [32]. Emigration of tertiary students has come to undermine national capacities to provide essential services in poor states, even implying a justified restriction to limit the flight of the minority of cases that this type of migration implies [33]. Problems with emigration are more substantial in small countries that are geographically close to the central regions of the Organization for Economic Cooperation and Development (OECD) that share colonial ties with OECD countries, and that direct most of their migratory flows to countries with selective quality immigration programs [4]. Nevertheless, the OECD countries do not always, or not all,

obtain only brain gains, since some are affected by flows between them; for example, the flow of European academics to US universities [30].

On the one hand, some governments consider the brain drain phenomenon as an economically productive phenomenon, based on remittances and direct transactions received by highly qualified human resources based abroad [2]. Moreover, on the other, the countries wish to create the conditions to promote and strengthen the productivity gains necessary to sustain economic growth, and they must be aware of how much and how quickly an uncontrolled academic implosion can occur [30]. In the same sense, brain drain or rather brain circulation, depending on their scientific experience abroad, can contribute to shaping local scientific systems, recognizing the potential of highly skilled migration to improve the development of a national academic system or at least the strengthening of specific disciplines [13,19]. In this sense, Stark et al.'s [34] findings show latency as regards the migratory freedom of highly qualified workers; brain drain and brain gain coexist; it can result in a higher average level of intellectual capital per worker in the country of origin. The higher intellectual capital per worker results from the asymmetry of information, the breadth of opportunities, and the structure of incentives. Also, the knowledge acquired by migrants abroad can return to their country of origin through diaspora networks [35], and the application of intellectual property rights increases the chances that brain drain becomes into brain gain [36]. Although in the face of academic mobility decisions, the scientometric impact of the science, technology, and innovation (ST&I) infrastructure has priority over the quality of life in the host country (Human Development Index, HDI). The combination of influencing factors gives complexity to government policies concerning national investments to address the flight and brain gain since both aspects must be considered [37].

The consolidation of national science and technology systems and their scientometric results are related to the formation of intellectual capital and brain circulation management [38]. Furthermore, bibliometric methods allow the study of brain drain at the micro-level and even adopt a scientometric approach that contributes, through the study of elite mobility, to understand its effects and implications in scientific policies [39,40]. Current studies of brain drain using scientometrics and bibliometrics methodology, in mainstream journals, focused mainly on the field of Information Science and Library Science [39,41–43]. Thus, assuming a proper approach to bibliometric or scientometric studies, these studies focused on the geographical mobility of scientists based on their affiliations [27,39,42,43], the effects on citation impact, academic collaboration, and competence [41,44,45], and its effects on national scientific and technological sustainability [46,47].

To be precise, this article's contribution to previous scientometrics studies is to address the brain drain phenomenon with a panoramic view. Furthermore, the present study approaches the brain drain phenomenon understanding it as a field of study by itself. Such a panoramic view is possible using massive metadata obtained in a varied disciplinary range of publications and considering brain drain in the last 55 years. Therefore, the present study does not address the migration phenomena itself but understands how researchers studied brain drain conceptualization in their diverse disciplines.

The existing literature on the brain drain from the South to the North has found several mechanisms affecting developing economies. However, some of the newly discovered effects remain debatable due to limited evidence. Therefore, some authors suggest a need to examine further how brain drain influences the formation of intellectual capital and, together with it, study the secondary effects of this phenomenon on technology [48]. Given the current possibilities of access to information and the abundance of metadata, there are new possibilities in science and technology studies and its measurement [49]. Such an approach means using massive data to measure, with the facilitation provided by scientometric tools, the concept of Brain Drain in the publications of the last 55 years. A scientometric study based on the abundance of metadata available today will allow us to ask the following research questions:

RQ1. Is there a critical mass of scientific research regarding the brain drain phenomenon?

RQ2. How has the study of the brain drain phenomenon evolved thematically and conceptually?

RQ3. Is it possible to identify classic authors on this topic? Are we facing the emergence of new reference authors?

## 2. Methodology

This research uses Scientometry as a systemic approach to understand trends in brain drain knowledge production. According to Vega and Salinas [50], this methodology's main objective is to assess scientific evolution and development and judge scientific policies related to certain aspects of economics and society. From this point of view, the scientometric meta-analysis presented here focuses on brain drain studies. The research process takes Web of Science—WoS [51] articles as a reference, given its recognized quality among researchers worldwide [52]. The authors selected the SSCI-WoS database because regarding Scopus, the journals indexed to SSCI-WoS have a high indexation duplicity in Scopus. However, the Scopus journals, which do not present a double indexing with the SSCI base, these have not been considered because “Scopus covers a superior number of journals but with lower impact and limited to recent articles” [53], (p. 24). In consequence, the analytic procedure of the present study preferred impact over number of journals.

Furthermore, this study methodology uses as the search vector [54] the “brain drain” construct that is present in articles indexed at the Journal Citation Report (JCR) of Social Science Citation Index, SSCI—that includes 50 social science disciplines (WoS Categories).

Data were explored for a recovery period between January 1956 and 14 December 2020 (oldest recovery: 1965), considering a thematic search, Field Label TS. Following the recommendations of Archuby et al. [55], the following search vector was used: (TS = (Brain NEAR/0 Drain)) AND Types of documents: (Article), Indexes = SSCI period = 1956–2020. Researchers obtained these records from 68 metadata fields extraction grouped as author identification, localization, affiliation; article/source identification, access, recuperation codes, citation; keywords, abstract, cited references, and funding (see Appendix A). Later, researchers analyzed the data set, using bibliometric rigor, looking to see if the knowledge production increases or not and achieve a critical research mass in an exponential growth form (Density-independent growth) [49–52]. Later, researchers determined contemporary literature when articles were produced [56–60]. Table 1 identifies each of these analytical methods [61].

**Table 1.** Type of data, methods, and results.

Type of Data	Unit of Analysis	Analytical Methods	Presentations of Results
Publication Year	Article	Exponential regression	Linear and shadow graph
Author	Article	Price's Law	Table
Journal	Article	Bradford's Law	Table
WoS Category	Article (Journal)	Counting and proportionality	Table
Citation article	Article	Hirsch index	Relational graph
Affiliation, Author, Keywords plus <sup>®</sup>	Article	Counting, co-authorship and co-occurrence	Relational graph
Terms	Article (Title and abstract)	Counting and co-occurrence	Relational graph

Research establishes the principles Web of Science Categories and its temporal trends, the prolific authors' concentrations according to Lotka's Law [59,62,63]. Then, researchers establish nucleus journals according to Bradford's Law [59,64–70]. Furthermore, researchers set thematic segments of journal concentration. Afterward, through the VOSviewer [71–75]. In parallel, the process produces a thematic study, high-use keywords plus<sup>®</sup> (KWP), keywords corrected by WoS—according to Zipf's Law [76–78]. Finally, the procedure produces a visualization with word cloud and relational graph de contemporary KWP [79,80].

In the final phase of this study, researchers use scientometry of quantity (production), quality (impact), and relationship [50,81]. Furthermore, researchers analyzed co-authorship

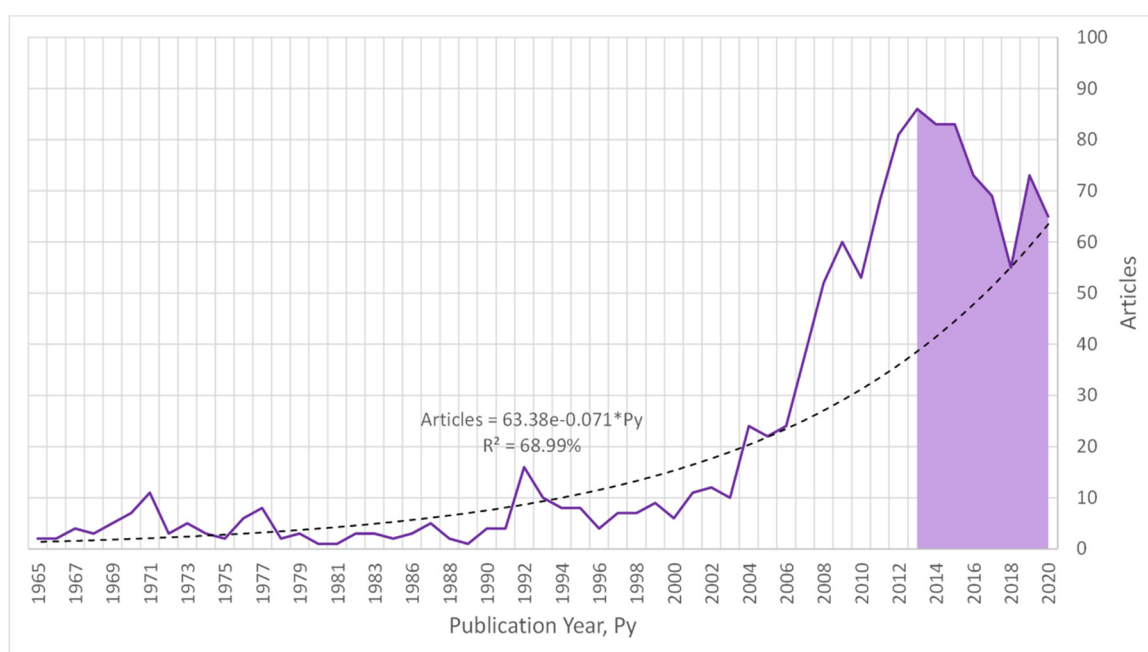


at the level of affiliation with institutions and authors. Researchers also identify highly cited articles in this step according to the Hirsch index [82–87]. The Hirsch index allows researchers to determine the classics and relevant contemporary articles. Finally, using the VOSviewer tool, researchers analyzed text data composed of titles and abstracts to identify high frequency terms and their time evolution trends [88–90].

### 3. Results

#### 3.1. Thematic Sources Trends Analysis

As a first relevant result, publications on brain drain achieve an exponential growth rate. That exponential growth rate gives a ground base to produce a scientometric meta-analytic study on the data set with 1212 articles in which a total of 2400 authors contribute, affiliated with 1249 organizations geographically distributed in 102 countries and territories identified in WoS (see countries and territories details in Appendix B and Table S1: Brain drain data set is a Supplementary Materials). Figure 1 reflects an exponential growth adjustment of 69%, highlighting the articles of the contemporary semi-period of knowledge production in the shadowed area.



**Figure 1.** Exponential increasing in the brain drain studies articles.

These research results proliferate in 99 categories of knowledge. All these categories emerge from the study of articles indexed at JCR-WoS journals (SSCI database). From those 99 categories, only 24 give a contribution that is equal to or exceeds 2% of the total scientific production on brain drain between 1965 and 2020, whether it be a single or a joint publication. For more detail about these categories, please see Table 2.

To have a clearer view about knowledge production, Figure 2 allows visualization of the temporal and thematic expansion that brain drain studies achieve, among the knowledge categories with the highest connotation ( $\geq 2\%$ ).

In Table 3, we present a journal nucleus where the discussion regarding brain drain is co-produced and concentrates a panoramic view of the WoS categories.

**Table 2.** Categories of Knowledge where contributions equal or exceed 2% of the total contribution in brain drain knowledge production between 1965 and 2020.

Web of Science Categories	ID	1965–1974	1975–1984	1985–1994	1995–2004	2005–2014	>= 2015	Articles	% of Contribution at 1212 <sup>1</sup>
Economics	WC01	8	1	10	24	211	137	391	32.3%
Demography	WC02	1	8	5	17	52	47	130	10.7%
Education & Educational Research	WC03	12	2	9	5	31	32	91	7.5%
Management	WC04	0	0	0	3	46	38	87	7.2%
Geography	WC05	0	0	2	1	38	37	78	6.4%
Public, Environmental & Occupational Health	WC06	2	1	2	6	38	28	77	6.4%
Development Studies	WC07	4	1	4	6	33	22	70	5.8%
Environmental Studies	WC08	0	0	0	2	29	28	59	4.9%
Regional Urban Planning	WC09	5	1	5	2	25	20	58	4.8%
Health Policy & Services	WC10	0	3	2	3	32	17	57	4.7%
Industrial Relations Labor	WC11	3	0	0	3	24	22	52	4.3%
Sociology	WC12	4	3	2	6	15	17	47	3.9%
Political Science	WC13	4	3	7	4	20	8	46	3.8%
Information Science & Library Science	WC14	1	2	0	10	14	18	45	3.7%
Social Sciences, Interdisciplinary	WC15	7	4	7	3	7	13	41	3.4%
International Relations	WC16	4	3	4	3	13	12	39	3.2%
Health Care Sciences Services	WC17	0	2	2	2	27	5	38	3.1%
Business	WC18	0	1	2	2	17	15	37	3.1%
Business, Finance	WC19	0	0	0	6	17	13	36	3.0%
Social Sciences, Biomedical	WC20	1	3	1	2	14	12	33	2.7%
Area Studies	WC21	1	3	0	2	14	8	28	2.3%
Computer Science, Interdisciplinary Applications	WC22	0	0	1	5	9	12	27	2.2%
Ethics	WC23	0	0	0	1	13	11	25	2.1%
Urban Studies	WC24	1	0	0	4	11	8	24	2.0%
Total in selection categories (% of contribution at 1212)		5%	3%	5%	10%	62%	48%		

<sup>1</sup> The percentages in the table are only contributions to total, by the multiple-indexation journals.

**Table 3.** Bradford zones for brain drain journal sources, between 1965 and 2020.

Zone	Articles (%)		Journals (%)		Bradford Multipliers
Nucleus	406	(33%)	33	(6%)	
1	399	(33%)	119	(23%)	3.6
2	407	(34%)	374	(71%)	3.1
Total	167		526		3.4

Thus, given a nucleus zone  $a = 33$  and a middle multiplier  $n = 3.4$ , the resulting summation of the geometric series (SSB) in Equation (1) is equal to:

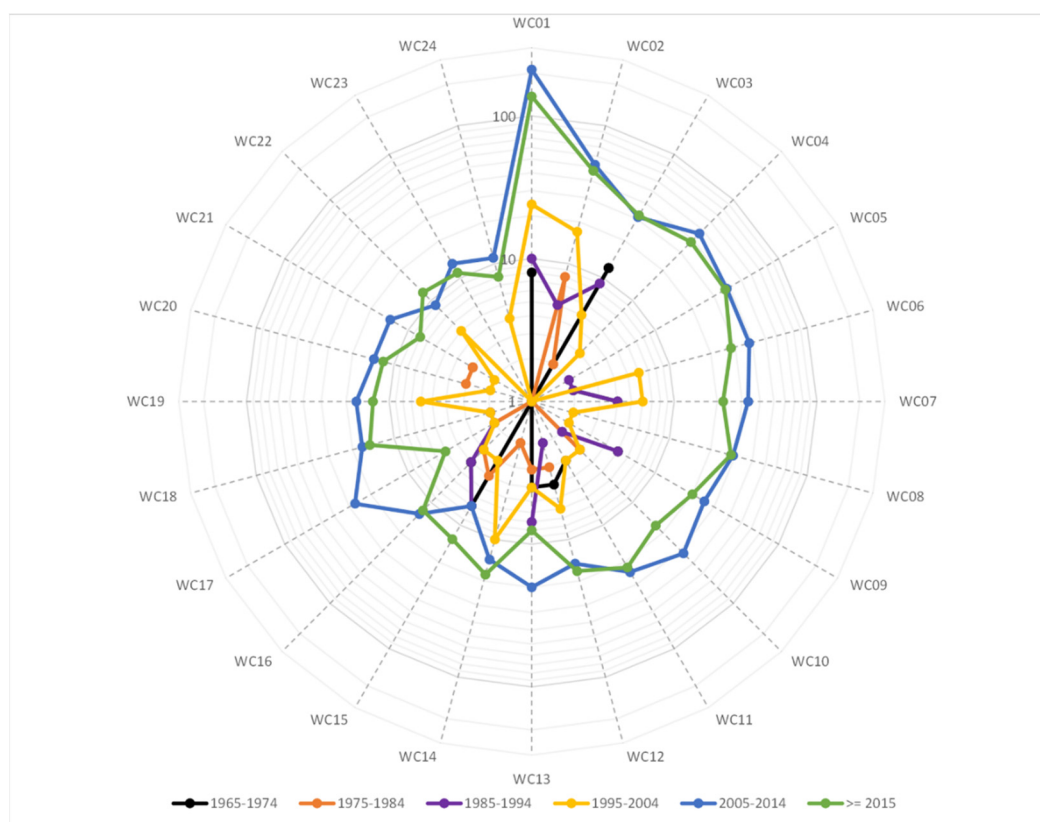
$$S_{SB} = \sum_{i=1}^3 (a * n^{i-1}) = 33 + 111 + 376 = 520 \quad (1)$$

Margin of error ( $\epsilon_p$ ) in Equation (2) of:

$$\epsilon_p = \left( \frac{(Real - Estimated)}{Real} \right) * 100 = \left( \frac{(526 - 520)}{526} \right) * 100 = 1.1\% \quad (2)$$

Such an error is considered not significant [68]. Consequently, the result can be recognized as a Bradford nucleus. Such a Bradford nucleus consists of the set of 33 journals

for the brain drain concept over the defined period. Table 4 presents details about the 33-journal Bradford nucleus.



**Figure 2.** Brain drain concept, temporal radial expansion of WoS categories.

Table 4 shows the increase in publications presented in the last periods analyzed among the Bradford core journals. From 39 articles in the first three periods to more than nine times articles published in the last three periods. Additionally, only 13 of these 33 specialized journals were published about brain drain in the first three periods. Furthermore, only 5 of these 13 specialized journals on the subject are sources of the initial articles on studies about brain drain; these are International Migration Review [91], Journal of Development Studies [92], Social Science and Medicine [93], Studies in Comparative International Development [94], and Minerva [6,95–97].

Additionally, the research process shows that among these journals, four thematic segments stand out: Economics and Politics (Area Studies; Business, Finance; Development Studies; Economics; Industrial Relations and Labor; International Relations; Management, and Political Science); Territory and Environment (Demography, Environmental Studies, Ethnic Studies, Geography, Regional and Urban Planning, Urban Studies); Science and Education Studies (Computer Science, Interdisciplinary Applications; Education and Educational Research; History and Philosophy of Science; Information Science and Library Science; Social Sciences, Interdisciplinary, and Sociology); and Health (Public, Environmental and Occupational Health; Social Sciences, Biomedical; Health Care Sciences and Services, and Health Policy and Services). The latter thematic segment is a relevant focus on professional sector mobility.

As topics and magazines about brain drain proliferate, brain drain also evolves as a social phenomenon. Such evolution allows the emergence of new concepts that demand further study. Based on 1369 metadata from keywords plus<sup>®</sup> type consistently connected, Figure 3 presents a visualization of new concepts that are developing. The figure presents newer conceptualizations by the circles in the colors yellow, orange, and red.

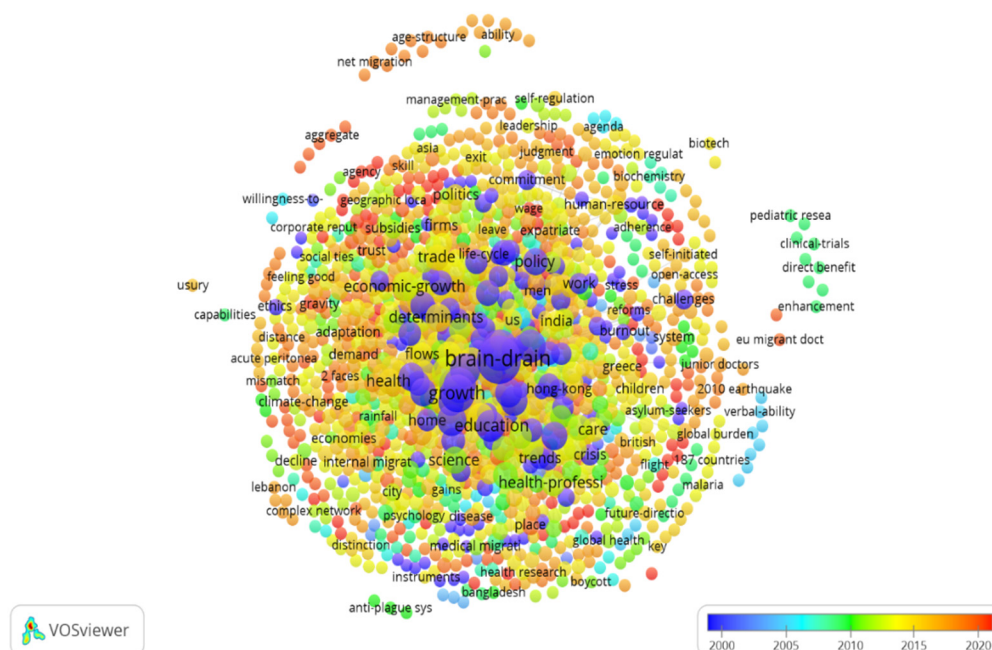


Table 4. Temporal trends of articles published in nuclear journals.

Journal	1965– 1974	1975– 1984	1985– 1994	1995– 2004	2005– 2014	>=2015	Total	Contribution% Over 406	WoS Categories
1. Int. Migr.	0	5	4	13	22	13	57	14.04	Demography
2. J. Dev. Econ.	0	0	2	2	22	4	30	7.39	Economics
3. Scientometrics	0	0	1	5	9	9	24	5.92	Computer Science, Interdisciplinary Applications; Information Science and Library Science
4. Hum. Resour. Health	0	0	0	0	13	11	24	5.92	Health Policy and Services; Industrial Relations and Labor
5. J. Popul. Econ.	0	0	1	2	4	7	14	3.45	Demography; Economics
6. Soc. Sci. Med.	1	1	1	2	5	3	13	3.21	Public, Environmental and Occupational Health; Social Sciences, Biomedical
7. World Dev.	0	0	0	1	8	4	13	3.21	Development Studies; Economics
8. Econ. Lett.	0	0	2	2	9	0	13	3.21	Economics
9. Popul. Space Place	0	0	0	0	3	9	12	2.96	Demography; Geography
10. Int. Migr. Rev.	1	2	0	1	4	3	11	2.71	Demography
11. High. Educ.	0	0	3	1	2	5	11	2.71	Education and Educational Research
12. Appl. Econ.	0	0	1	1	5	4	11	2.71	Economics
13. World Bank Econ. Rev.	0	0	0	0	7	3	10	2.47	Business, Finance; Development Studies; Economics
14. World Econ.	0	0	0	0	4	6	10	2.47	Business, Finance; Economics; International Relations
15. Res. Policy	0	0	0	1	5	4	10	2.47	Management
16. J. Dev. Stud.	1	0	0	0	3	6	10	2.47	Development Studies; Economics
17. Int. J. Hum. Resour. Man.	0	0	0	0	6	4	10	2.47	Management
18. J. Ethn. Migr. Stud.	0	0	0	0	5	4	9	2.22	Demography; Ethnic Studies

Table 4. Cont.

Journal	1965– 1974	1975– 1984	1985– 1994	1995– 2004	2005– 2014	>=2015	Total	Contribution% Over 406	WoS Categories
19. Reg. Stud.	0	0	0	0	7	2	9	2.22	Economics; Environmental Studies; Geography; Regional and Urban Planning
20. Stud. Comp. Int. Dev.	1	1	4	1	1	0	8	1.98	Development Studies; International Relations; Political Science
21. Sotsiol. Issled+	0	0	0	4	1	3	8	1.98	Sociology
22. J. Int. Econ.	0	0	0	0	5	3	8	1.98	Economics
23. Pap. Reg. Sci.	0	0	0	0	3	5	8	1.98	Economics; Environmental Studies; Geography; Regional and Urban Planning
24. Int. J. Manpower	0	0	0	0	4	4	8	1.98	Industrial Relations and Labor; Management
25. Econ. Dev. Q.	0	0	0	3	3	2	8	1.98	Development Studies; Economics; Urban Studies
26. BMC Health Serv. Res.	0	0	0	0	6	2	8	1.98	Health Care Sciences and Services
27. Se. Eur. Black Sea. Stu.	0	0	0	0	6	1	7	1.73	Area Studies
28. Reg. Sci. Urban Econ.	0	0	0	0	5	2	7	1.73	Economics; Environmental Studies; Urban Studies
29. Minerva	4	2	0	0	1	0	7	1.73	Education and Educational Research; History and Philosophy of Science; Social Sciences, Interdisciplinary
30. J. Stud. Int. Educ.	0	0	0	0	4	3	7	1.73	Education and Educational Research
31. Econ. Model.	0	0	0	0	3	4	7	1.73	Economics
32. Health Policy Plann.	0	0	1	0	5	1	7	1.73	Health Care Sciences and Services; Health Policy and Services
33. Health Policy	0	0	0	2	4	1	7	1.73	Health Care Sciences and Services; Health Policy and Services
Total Nucleus	8	11	20	41	194	132	406	100	



**Figure 3.** Graph of keywords plus<sup>®</sup> in co-occurrence.

Figure 4 presents 1041 a word cloud for the contemporary semi-period (2013–2020). The research process extracts those words from the set of keywords plus®-KWP-metadata related to the articles published in our current period.



**Figure 4.** Wordcloud of keywords plus<sup>®</sup>.

Figure 4 it is a first step in the analysis of KWP. This very broad view permits a first impression of the complex network of concepts that are connected in the brain drain phenomenon. In this first reading, it is possible to foresee the nomadic political ontology nature of people mobility where nationalism, transnationalism, and migration are interrelated.

### 3.2. Actors and Terms Trend Analysis

Figures 5 and 6 expands the idea of concept renewal, recognizing new actors (organizations) involucres in the knowledge production network about brain drain. The analysis

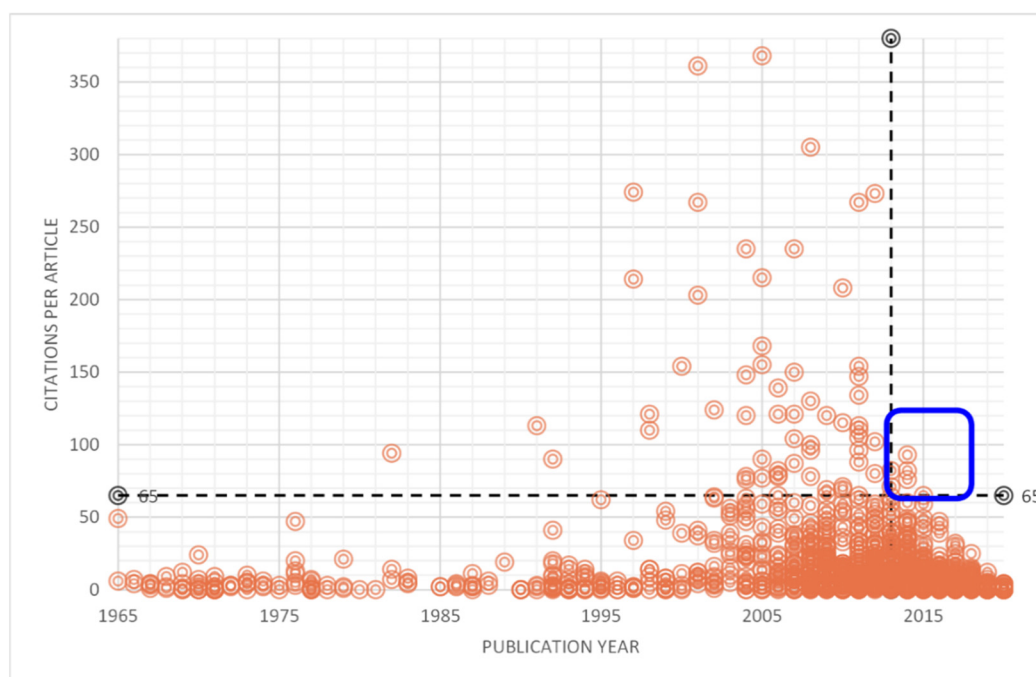






202 articles with at least one author with organizational multi-affiliation (see Appendix D), the analysis shows 949 remain organizations. From this set, 280 are part of the relational graph. Even when the analysis withdraws authors' multiple affiliations, results still show that new actors continue to appear in the network of organizations and co-authorship in the most recent studies. Consequently, by cleaning up multiple institutional affiliations, the idea of concept renewal recognizes new actors (organizations) involved in the knowledge production network about brain drain—see Figure 6—is maintained.

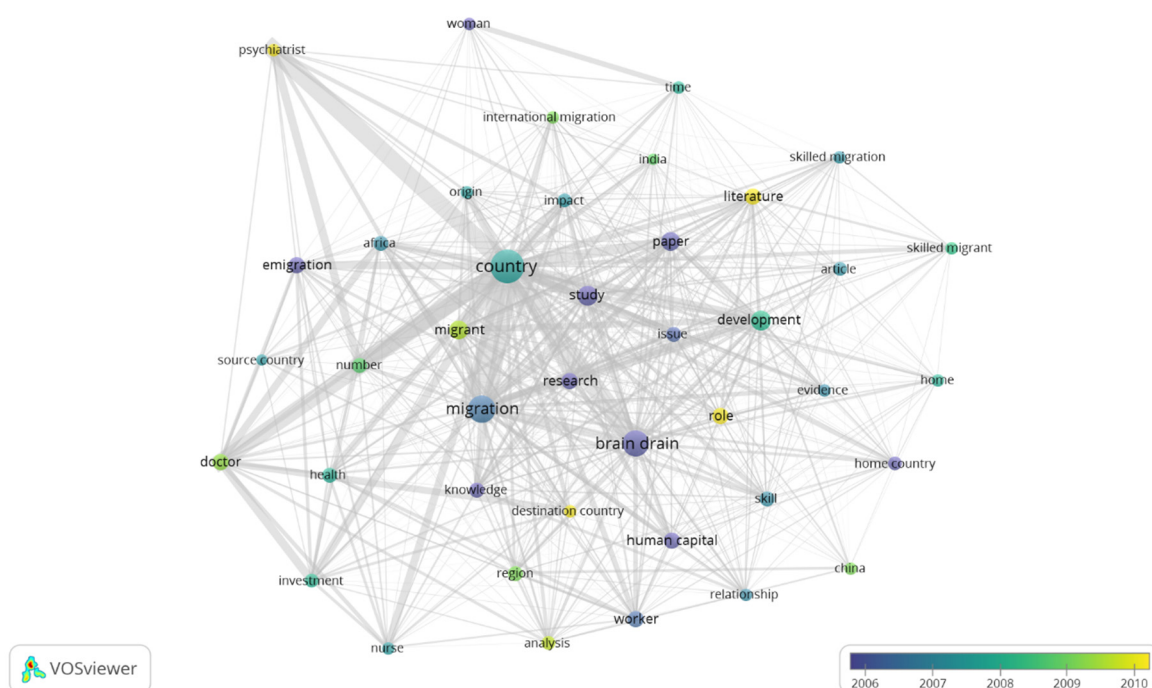
However, new authors—connected or not—do not necessarily imply preferent authors in the whole knowledge production system. The analysis proceeds using the data set of 1212 articles and establishing the Hirsch index (h-index) as limits—in this case, 65 articles cited at least 65 times—see Appendix C, plus the year 2013 as the beginning of the contemporary semi-period of publications. Furthermore, analysis shows that articles from the first 30 years are not the most cited in the corpus. In the opposite, the major citation volume is concentrated from the year 1996 onwards—See Figure 8. All in all, only a reduced number of six recent articles (in the blue box) would be achieving a number equal to or greater than 65 citations—see Figure 8. These six-6-articles are: Artuc et al. (in co-authoring with Docquier) [98], Baruch et al. [99], Beine et al. [100], Cerdin et al. [101], Gamlen [102], and Kenney et al. [103]. In contrast, there are 59 articles with the connotation of being classics, being part of the h-index and being published within the obsolescence period. These 65 articles receive contributions from 180 authors cooperating in a network of 50 countries. Those 65 articles represent less than 10% of the authors and less than 50% of the countries that participate in the complete database.



**Figure 8.** Relationship publication year and citations per article.

These 65 articles that present a higher citation refer to 1694 terms (square root ( $1694 = 41$ )) with 41 terms of high frequency equivalent to nine or more repetitions. Figure 9 presents a detailed representation of the conceptual network. In Figure 9, yellow spheres highlight the most recent and recurring average terms: destination country, literature, role, analysis, and psychiatrist. Additionally, note that these 27 articles are associated with the WoS Economics category (42%), and therefore, the thematic segment Economics and Politics (including Business) achieves great notoriety with a total of 41 highly cited articles on the subject Brain Drain (63%). Furthermore, among the 11 journals that publish two or more economic category articles, eight correspond to journals identified in Table 3 as part of the

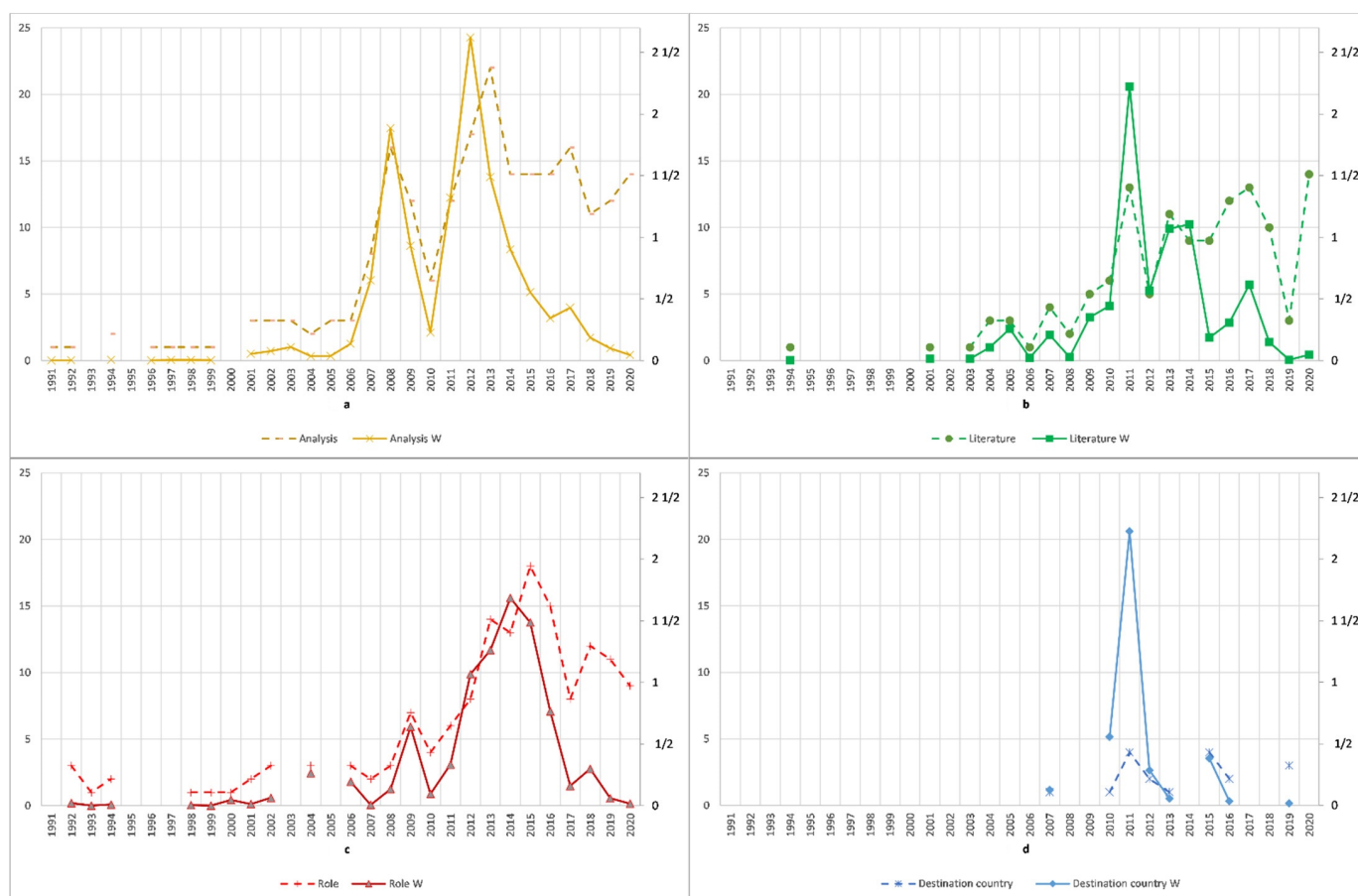
Bradford nuclear zone: J. Dev. Econ. (7 articles), Int. Migr. (4 articles), Int. J. Hum. Resour. Man. (3 articles), Soc. Sci. Med. (3 articles), Econ. Lett. (2 articles), Hum. Resour. Health (2 articles), World Bank Econ. Rev. (2 articles), and World Dev. (2 articles), achieving an overall concentration of 25 articles (38%). Likewise, co-authors are concentrated territorially in the USA (29; 45%), England (19, 29%), and France (11, 17%), which after subtracting the repetitions give as a result 47 of 65 articles (72%). Such a concentration marks a clear delimitation between center and periphery in the global contribution to the Brain Drain knowledge production. Finally, those three featured authors mentioned above maintain their presence in documents among a total of 156 authors: Docquier F. (6 articles), Rapoport H. (4 articles), and Hagopian A. (2 articles).



**Figure 9.** Relationship average publication year and occurrences per terms.

Regarding the six recent articles with high citation, they consider some of these terms with at least one repetition: article (4 occurrences), country (3 occurrences), international migration (3 occurrences), literature (3 occurrences), research (3 occurrences), role (3 occurrences), home (2 occurrences), migration (2 occurrences), and time (2 occurrences). Due to their past historical weight, some terms are not in use after 2010; therefore, the network does not color it in yellow, with literature and role being the exceptions.

When the analysis went deep into the five terms in yellow spheres, the term “psychiatrist” its mention in only seven articles [104–110]. The rest of the subset-destination country, literacy, role, and analysis are presented and jointly in a total of 429 articles published for 30 years, between 1991 and 2020. Figure 10 shows the usage trends of these 429 articles.



**Figure 10.** (a–d) Trends of publication year and occurrences per terms.

Terms such as “analysis”—light orange—seem to be of a much more general order with a presence practically throughout the period and even with two previous articles [111,112], but they also question the development of middle cognitive levels [113–115]. The term “literature”—in green—in the sense of antecedents and documentary evidence of non-literary scientific production or documented scientific production in the words of Vega and Salinas [50] is widely present in the subject studied. The word “role” calls to assume a role in the brain drain phenomenon by Institutions—countries, states, politics and public policy, trade agreements, academic centers, immigration agencies, university—industry relationships, scientific foundations, and firms; Individual capacities—language, cultural and economic capital, social cooperation networks; Psychological factors—career satisfaction, affect for knowledge sharing, environmental perceptions, personality traits, and motivations; and the answer role of intellectual capital on all the above.

Finally, for the term “destination country,” there is an emergency from 2007 onwards in the articles reviewed. Destination country is a variant of “country” identified in Figure 9 and more contemporary than the home country, home, and source country. However, research is still limited to destinations in OECD countries with high-income: European countries (United Kingdom, Austria, and Belgium), Canada, United States, New Zealand, and Australia. There are a few exceptions in the case of the study of brain drains flows from Malaysia to Singapore [116] or from sub-Saharan African to Botswana and South Africa [117] included.

Citations have weighted the term’s occurrence, and the behavior pattern over time does not show variations, except in the last five years—see Figure 10a–d. Patterns do not change when citations are weighted because these publications are still in the process of disseminating their knowledge. It is easy to see a typical example of this effect with the example of ‘impact factor’ index measured by journals. To understand the impact factor of

a journal, a responsible analyst needs to measure it in years one and five. That is how any person can see the knowledge dissemination processes.

#### 4. Discussion

The article contributes to the study about the conceptualization of elites' migratory phenomenon defined as brain drain, in a broader disciplinary scope that are 99 WoS categories with a focus and more detail on 24 of them. Instead, the article does not just focus on a single category of knowledge production. The specialties delimitations are recognized as a relevant problem in the study of the mobility of elites at the micro-level [39]; thus, this article manages to differentiate itself from other contemporary studies that give coverage of specific disciplines, either in economics [118], in artificial intelligence [119], or communication [120]. The present article contributes to the literature presenting a general and updated analysis of the brain drain concept usage and its expansion in the last 55 years. The study is reliable because using the database -see supplements- any researcher can replicate the study. Researchers need to use the software and the agreed-upon measures to obtain a robust replication. Furthermore, considering the defined search vector, the results can even be updated for future studies. Consequently, it is reliable and contributes to the literature analyzing the massive metadata of previous research about brain drain. However, considering the brain drain concept in a panoramic and non-specific way. Such panoramic perspective understands brain drain as a social phenomenon mainly related to sustainable technological development, a sustainability type that has recently been studied within the SDGs framework [121–130].

In the same sense, from the study of data spatiality, contributions from authors from 102 countries are covered, which are reduced to 50 when applying the h-index and narrowing it down to the elite of researchers. This approach gives ground coverage by adding countries on the periphery of world knowledge generation [47]. Such coverage allows departing from contemporary studies that cover the phenomenon of brain drain with a focus on a classic and limited nucleus of countries, mainly: Australia, Canada, China, New Zealand, the United States, and the United Kingdom [42,44,46]. Finally, this study contributes to providing temporary coverage of 55 years (1965–2020). The various international scientific collaborations, resulting from the intellectual human capital mobility [12,131–133], constitutes a partnership that allows progress in global sustainability (17th SDG) [134–138].

Regarding the thematic segments defined—Economics and Politics, Territory and Environment, Science and Education Studies and Health—some of these are consistent even with the first identified articles in this study Oteiza [7] and Perkins [9] from Economics and Politics journal, and Johnson [6] and Grubel [8] from Science and Education Studies journal. In the case of Health, the focus of the phenomenon from its inception on physicians makes the development of this specialized theme natural, even more so in the current global health situation. About Territory and Environment, and in terms of migration, coverage of the brain drain in demography and geography, though later, it is thematically natural [92,139]. Among all these themes, Economics and Politics, as in other social phenomena, is preponderant due to thematic economization, consistent with the recognition of the economy as the main engine of mobility of advanced human capital [140]. Such WoS category alone represents participation in practically a third of the registered articles. Such thematic is how the two most prominent authors account for the economization of studies since they have an academic trajectory in this field in European Universities that are part of UNA-Europe, added an academic in Health in a North American -USA- University. She obtained her Ph.D. in the USA, while the other male authors obtained their Ph.D. in France. Both countries are among those with the highest concentration in the knowledge production indexed articles in brain drain studies. In short, a lag in Brain Drain studies and its effects on the sustainability of the economy and technological development, which has been widely surpassed by studies focused

on Environmental SDGs (Resources and Environment) and economics for life, promptly GoodHealth and Well-being (3rd SDG) [141,142].

Results show that a set of studies focused on destination countries [143–145] raises the necessity of a change of approach since these types of studies were initially raised based on the loss of advanced intellectual capital in the countries of origin. However, studies are currently rethinking their orientation to brain gain [12,145–149], and to ideas of migratory dynamics presented in the brain circulation [12,47,146,147,150–154]. Results emphasize that policies and efforts need to change if policymakers look at researchers' brain drain concept use. Researchers moved away from brain leakage and retention and now emphasize brain drain attraction and gain. Even more, researchers recently focused on the study of circulation by individuals' decisions, even at the cost of objective well-being; that is now known as brain circulation.

## 5. Conclusions

The main objective of the present article is to systematically study the current theoretical approaches to the Brain Drain phenomenon. The study offers an answer to questions regarding critical mass existence of scientific research on the brain drain phenomenon, how has the brain drain study evolved thematically and conceptually, and if it is possible to identify classic and new reference authors on this topic. We operationalize the study through the next research questions:

- RQ1. Is there a critical mass of scientific research regarding the brain drain phenomenon?
- RQ2. How has the study of the brain drain phenomenon evolved thematically and conceptually?
- RQ3. Is it possible to identify classic authors on this topic? Are we facing the emergence of new reference authors?

Results show that there were 1212 articles produced by 2400 authors that present an exponential growth knowledge generation process. That process adjusts by approximately 70%, achieving a critical research mass in an exponential density-independent growth form, with a nucleus of 33 journals that discuss deeply brain drain studies, conforming to Bradford's law with a margin of error equal 1.1% that is considered not significant. Therefore, this study gives an account of the 'territory' where the global epistemic community is built on brain drain studies, from its various approaches, delimiting their products (articles), actors (authors) and spaces (journals). Furthermore, the study recognizes 65 articles with a high citation -according to the Hirsch index, *h-index*- by the full 156 authors' knowledge production. These 65 high citation articles belong to a researcher's group that would be the contemporary research front of this knowledge global community. Among these community, there are three distinguished authors through the whole dataset. Additionally, there are 59 historical articles (classic pieces) from those 65 highly cited articles. These classic pieces are located by age temporarily under the median or semi-period of obsolescence. Finally, the remained six papers could give way to potential new relevant references in the brain drain phenomenon.

From a thematic point of view, the research distinguishes four study segments that manage to delimit the focus of the discussion. Table 4 shows those themes based on the 33 journals of the Bradford nucleus and their contributions in percentage. There are two original themes. The first is Science and Education Studies, and the second is Economics and Politics. The latter of these themes has a great preponderance in the volume of discussion. Another segment, Health, is heavily studied. This sector has a significant impact on brain drain. Another paradoxical theme that presents a later start is Territory and Environment, which among others, comprises the WoS categories of Demography and Geography. Additionally, to these segments, scholars widely use five terms in recent literature. The theme that raises the highest interest in brain drain discussion is "destination country" and its local effects on research and the strengthening of innovation and industry, in terms of the 9th SDG. The brain drain studies and their effects on the sustainability



dimensions, present a global imbalance that is evident and must be overcome, especially in the social sustainability dimension terms, which is mainly absent, despite various social pressure movements in the last decade, which demand greater equity (SDGs: 4 Education, 5 Gender and 10 Inequality) and social development (SDGs: 11 Cities and communities, 16 Peace, Justice and Strong institutions, and 17 Global partnerships), in different latitudes of the globe.

Finally, and as a precautionary note, scholars need to be aware that beyond the change of direction in the national effects, they need to extend their analysis to other countries when countries consider themselves destination countries. For example, scholars must focus their analysis beyond countries with a high level of development, which constitutes a new challenge in this line of research toward the study of the effects of the brain drain in the peripheral areas of knowledge production, contributing to a better understanding of the phenomenon in those geographic areas and design new public policies, in the economic dimension of sustainability [17], to strengthen innovation and local industry [32,47,140,155–157]. Likewise, public policies should be approached from a logic of adaptation to the global mobility of advanced intellectual human capital (brain circulation) and not only from a drain perspective [12,158] and with a greater emphasis on the intellectual human capital attraction policies and not principally focused on brains retention or forced return [45], avoiding the research groups break [159] and promoting geographically distributed research [160–163].

As a limitation, despite the large number of JCR-WoS articles analyzed (1212), privileging the quality in the journal's selection [52] generates coverage limitations and an opportunity to access information to studies in the working phase, please see the discussion in the methodology section. Thus, in future research, the authors plan to increase the opportunity for early access to information by also incorporating proceeding documents (conferences) and pre-prints available in specialized repositories, as well as expanding the studies coverage by incorporating data from journals indexed in Scopus (non-WoS journals) and Emerging WoS journals, which do not have an impact index (Emerging Sources Citation Index, ESCI), but allow recovering more studies developed in the periphery and semi-periphery of global knowledge production.

Regarding future research lines, it is relevant to advance brain drain studies on less studied geographical areas. Studying less researched locations, researchers can offer new light about the effects of this phenomenon on the sustainability of those countries and territories. Other study areas include the destination country concept incorporation and brain circulation optics, the attraction and permanence forces in those destinations, the mobility motivations, and the subsequent effects, both personal and national. The social researcher's role in the brain drain is also interesting for the social sustainability effects, a product of their contributions to social sciences. Finally, the SARS CoV 2 pandemic scenario increases the tension due to the health personnel brain drain, making them another interest group to be studied today, which may even be of interest in national security and geopolitics.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/2071-1050/13/6/3195/s1>, Table S1: brain\_drain\_dataset.xlsx.

**Author Contributions:** Conceptualization, A.V.-M.; methodology, A.V.-M.; software, A.V.-M.; validation, J.F.E.-C.; formal analysis, A.V.-M.; data curation, A.V.-M. and J.F.E.-C.; writing—original draft preparation, A.V.-M. and J.F.E.-C.; writing—review and editing, A.V.-M. and P.G.-G.d.M.; supervision, P.G.-G.d.M.; project administration, J.F.E.-C. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

The appendix shows the Web of Science Core Collection Field Tags:

PT: Publication Type (J = Journal; B = Book; S = Series; P = Patent); AU: Authors; BA: Book Authors; BE: Editors; GP: Book Group Authors; AF: Author Full Name; BF: Book Authors Full Name; CA: Group Authors; TI: Document Title; SO: Publication Name; SE: Book Series Title; BS: Book Series Subtitle; LA: Language; DT: Document Type; CT: Conference Title; CY: Conference Date; CL: Conference Location; SP: Conference Sponsors; HO: Conference Host; DE: Author Keywords; ID: Keywords Plus<sup>®</sup>; AB: Abstract; C1: Author Address; RP: Reprint Address; EM: E-mail Address; RI: ResearcherID Number; OI: ORCID Identifier (Open Researcher and Contributor ID); FU: Funding Agency and Grant Number; FX: Funding Text; CR: Cited References; NR: Cited Reference Count; TC: Web of Science Core Collection Times Cited Count; Z9: Total Times Cited Count (Web of Science Core Collection. Arabic Citation Index. BIOSIS Citation Index. Chinese Science Citation Database. Data Citation Index. Russian Science Citation Index. SciELO Citation Index); U1: Usage Count (Last 180 Days); U2: Usage Count (Since 2013); PU: Publisher; PI: Publisher City; PA: Publisher Address; SN: International Standard Serial Number (ISSN); EI: Electronic International Standard Number (eISSN); BN: International Standard Book Number (ISBN); J9: 29-Character Source Abbreviation; JI: ISO Source Abbreviation; PD: Publication Date; PY: Year Published; VL: Volume; IS: Issue; PN: Part Number; SU: Supplement; SI: Special Issue; MA: Meeting Abstract; BP: Beginning Page; EP: Ending Page; AR: Article Number; DI: Digital Object Identifier (DOI); D2: Book Digital Object Identifier (DOI); EA: Early access date; PG: Page Count; WC: Web of Science Categories; SC: Research Areas; GA: Document Delivery Number; UT: Accession Number; PM: PubMed ID; OA: Open Access Indicator; HC: ESI Highly Cited Paper. Please note that this field is valued only for ESI subscribers.; HP: ESI Hot Paper. Please note that this field is valued only for ESI subscribers.; DA: Date this report was generated.

## Appendix B

The appendix shows the countries and territories details where the affiliation institutions of the 2400 authors are located between 1965 to 2020 (in parentheses number of articles in which it contributes): Albania 3; Argentina 2; Australia 66; Austria 31; Bahrain 1; Belgium 50; Bosnia and Herzegovina 1; Botswana 3; Brazil 5; Cambodia 2; Canada 72; Chile 5; Colombia 1; Cote Ivoire 1; Croatia 4; Cyprus 4; Czech Republic 8; Denmark 13; Dominica 1; Egypt 1; England 142; Estonia 2; Ethiopia 3; Fed Rep Ger 1; Finland 8; France 77; Georgia 1; Germany 105; Ghana 5; Greece 11; Guyana 1; Haiti 1; Hungary 2; Iceland 2; India 16; Indonesia 1; Iran 4; Ireland 14; Israel 33; Italy 66; Japan 18; Jordan 1; Kazakhstan 2; Kenya 10; Kuwait 1; Laos 1; Latvia 2; Lebanon 6; Lithuania 11; Luxembourg 15; Malawi 2; Malaysia 9; Malta 1; Mexico 7; Moldova 1; Mozambique 2; Myanmar 1; Nepal 1; Netherlands 25; New Zealand 23; Nigeria 7; North Ireland 1; Norway 14; Pakistan 10; Palestine 1; Peoples R China 77; Peru 3; Philippines 5; Poland 18; Portugal 13; Rep Congo 1; Romania 14; Russia 16; Saudi Arabia 2; Scotland 10; Serbia 6; Singapore 8; Slovakia 6; Slovenia 3; South Africa 42; South Korea 7; Spain 43; Sri Lanka 3; Sudan 1; Suriname 1; Sweden 13; Switzerland 31; Syria 1; Taiwan 13; Tanzania 1; Thailand 3; Tunisia 1; Turkey 13; U Arab Emirates 4; Uganda 4; Uruguay 1; USA 345; Venezuela 1; Vietnam 4; Wales 8; Zambia 1; Zimbabwe 4.

### Appendix C

The appendix shows the WoS identifiers (UT) for the 65 articles belonging and 6 contemporaneous articles to the h-index of the studied search vector:

(WOS:000234146500004;	WOS:000166022000012;	WOS:000254272900004;
WOS:000071167600003;	WOS:000309000200002;	WOS:000172825700002;
WOS:000288642600005;	WOS:000224485300033;	WOS:000244394800003;
WOS:000233182800006;	WOS:A1997XZ77600012;	WOS:000273110500039;
WOS:000172825700006;	WOS:000233665800005;	WOS:000227167900018;
WOS:000085041200002;	WOS:000294111300005;	WOS:000245718300010;
WOS:000187517000002;	WOS:000287946000034;	WOS:000237827600002;
WOS:000285215000008;	WOS:000260472100007;	WOS:000175968700009;
WOS:000078262000008;	WOS:000240042900004;	WOS:000244400600007;
WOS:000188094700002;	WOS:000266981200004;	WOS:000208405300002;
WOS:A1991FZ02600013;	WOS:000290580600007;	WOS:000076715600017;
WOS:000288642600003;	WOS:000284673700004;	WOS:000250686900003;
WOS:000304032100003;	WOS:000264980600001;	WOS:000258799000006;
WOS:000299015400005;	WOS:A1982NK73000007;	WOS:000329962500006;
WOS:A1992JZ95900009;	WOS:000233498800003;	WOS:000288642600006;
WOS:000250686900002;	WOS:000239666000001;	WOS:000316530400008;
WOS:000340978200004;	WOS:000311608300004;	WOS:000240492800002;
WOS:000188509300003;	WOS:000243108000001;	WOS:000261309500008;
WOS:000227089400004;	WOS:000223696300001;	WOS:000342754300006;
WOS:000274474400008;	WOS:000319106200006;	WOS:000261194400002;
WOS:000285269700011;	WOS:000243085300006;	WOS:000265205100001;
WOS:000294111300006;	WOS:000345730400002).	
	AND	
(WOS:000329962500006;	WOS:000316530400008;	WOS:000340978200004;
WOS:000342754300006;	WOS:000319106200006;	WOS:000345730400002).

### Appendix D

The appendix shows the WoS identifiers (UT) for the 202 eliminated articles that shows at least one author with organizational multi-affiliation.

UT = (WOS:A1992HB74200007 OR	WOS:000078262000008 OR	WOS:000188094700002 OR
WOS:000284673700004 OR	WOS:000264980600001 OR	WOS:000286783500004 OR
WOS:000288642600005 OR	WOS:000320573500007 OR	WOS:000331431900020 OR
WOS:000249748300001 OR	WOS:000281715300011 OR	WOS:000297230300004 OR
WOS:000271358200001 OR	WOS:000295151100013 OR	WOS:000252975900002 OR
WOS:000308685300007 OR	WOS:000310022600003 OR	WOS:000340080600013 OR
WOS:000260472100007 OR	WOS:000280919900004 OR	WOS:000288381200009 OR
WOS:000267623900010 OR	WOS:000342246100009 OR	WOS:000261381100008 OR
WOS:000291316900010 OR	WOS:000285215000008 OR	WOS:000254735000005 OR
WOS:000291545200006 OR	WOS:000267655100023 OR	WOS:000300343200001 OR
WOS:000259545500004 OR	WOS:000334324800004 OR	WOS:000281491500003 OR
WOS:000263716700003 OR	WOS:000258427700002 OR	WOS:000265690100001 OR
WOS:000276131700032 OR	WOS:00033237500010 OR	WOS:000310448600001 OR
WOS:A1993KJ94700010 OR	WOS:000261636400003 OR	WOS:000273514100007 OR
WOS:000312808400003 OR	WOS:000264173000003 OR	WOS:000297818800014 OR
WOS:000405669300001 OR	WOS:000267375000003 OR	WOS:000309000200002 OR
WOS:000320182100004 OR	WOS:000320780800003 OR	WOS:000327726700005 OR
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 WOS:000311008500006 OR  
 WOS:000280679100016 OR  
 WOS:000340978200004 OR  
 WOS:000337870200003 OR  
 WOS:000345730400002 OR  
 WOS:000338695700012 OR  
 WOS:000357326600005 OR  
 WOS:000313706300001 OR  
 WOS:000339959300004 OR  
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 WOS:000302864600009 OR  
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 WOS:000372023800003 OR  
 WOS:000300825700005 OR  
 WOS:000386061000006 OR  
 WOS:000355341200003 OR  
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 WOS:000461972700001 OR  
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 WOS:000533653600001 OR  
 WOS:000539518600001 OR  
 WOS:000547804200006)

WOS:000449242400011 OR  
 WOS:000345180700010 OR  
 WOS:000308243600006 OR  
 WOS:000401389900014 OR  
 WOS:000312919300002 OR  
 WOS:000385335100010 OR  
 WOS:000329796800001 OR  
 WOS:000256778400005 OR  
 WOS:000329373300001 OR  
 WOS:000368075800007 OR  
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 WOS:000342279400008 OR  
 WOS:000360861600009 OR  
 WOS:000308091700001 OR  
 WOS:000390105300004 OR  
 WOS:000361129200002 OR  
 WOS:000387115500002 OR  
 WOS:000307363500001 OR  
 WOS:000351785500030 OR  
 WOS:000374258700004 OR  
 WOS:000395202800008 OR  
 WOS:000441116700003 OR  
 WOS:000306009100012 OR  
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 WOS:000413253700005 OR  
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 WOS:000500954400015 OR  
 WOS:000261623300001 OR  
 WOS:000280393900004 OR  
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 WOS:000419577100003 OR  
 WOS:000457127100016 OR  
 WOS:000470967500087 OR  
 WOS:000460550800004 OR  
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 WOS:000511153700004 OR  
 WOS:000500924400016 OR  
 WOS:000519945800005 OR  
 WOS:000542629600037 OR  
 WOS:000549611900001 OR

WOS:000452955800015 OR  
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 WOS:000308449600001 OR  
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 WOS:000347762000009 OR  
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