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A Systematic Review of Science, Technology, and Innovation Impact of Scientific Diasporas and the role of Foreign Missions

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Abstract
The quest for international talents contributes to the rise of brain drain, hence, the existence of the scientific diaspora. Skilled immigrants possess the capacity to contribute solutions to national and global crises. This systematic review aims to show the empirical evidence of scientific diaspora impact, indicators to measure impact, the sustainability model(s), and the role of foreign missions and embassies in harnessing the potential of the scientific diaspora. A total of 31 publications retrieved from PubMed, Web of Science, International Bibliography of the Social Sciences (IBSS), ScienceDirect and Scopus were included in the literature review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses methodology was used in the study. The findings show that the scientific diasporas have made significant contributions to the revolutionizing of STI development in the nations that were able to develop strategic approaches to harnessing their skills. The empirical evidence and the role of the embassies were categorized into five different themes. The formation of the scientific diaspora is bottom-up or top-down which has some deduced implications for their sustainability after analysing it from five different models of government engagement. No established indicator exists in measuring the STI impact delivered by the scientific diaspora.
Keywords; Scientific diaspora, embassy, science, technology, innovation, sustainability

Introduction
Developing nations are severely distressed by challenges that Science, Technology, and Innovation (STI) could directly or indirectly provide solutions to. There is a need to develop STI capability both in terms of human resources and infrastructural development. Unfortunately, about 30 to 50% of those trained in STI-related professions in developing countries immigrate to developed countries (Samet 2013). Many authors have regarded this as a brain drain (Echeverría-King et al. 2022; Samet 2013; Nedelcu 2019; Ciumasu 2010). This class of skilled immigrants constitute the scientific diaspora. It is a network of skilled professionals who are residents abroad with work or study experience, and they seek to connect with their home country to contribute their STI expertise (Seguin et al. 2006). Some other authors have similarly defined the scientific diaspora but with some emphasis on their "self-organized" nature (Barré et al., 2003). Therefore, they are a significant pool of very useful knowledge that could support the STI drive in developing nations (Singh et al. 2020; Yurevich et.al., 2019; Horvat 2005).

There are suggestions as to the strategies that could be adopted in transforming such brain drain into brain gain. Some authors discuss the "return option" which requires the return of skilled professionals to their home country, or the "diaspora option" which enables the diaspora to contribute their expertise without necessarily returning home (Samet 2013). Exploring the diaspora option seems to be more viable since most of the factors that caused immigration from developing countries appear to persist (Anand et.al., 2009; Amagoh and Rahman 2016). Many developing countries are now aware of the potential of the scientific diaspora (Samet 2013; Bonilla et.al, 2022; Pandey et.al., 2022; Bonilla et. al. 2022; Echeverría-King et. al.

2022; Georges-Ivo Ekosse 2011). The African Union has recognized the African Diaspora as a critical mass of skills and expertise that is required for advancing developments in the continent (Georges-Ivo Ekosse 2011). Some other countries from different continents have developed some policies to attract the scientific diaspora. Examples include China, Taiwan, and South Korea (Samet 2013).

The foreign missions of a country can be a strong channel to support and coordinate the activities of the scientific diaspora for national STI development. How foreign missions operate to support the scientific diaspora has not been well researched. Besides, some literature discusses the potential that could be derived from the scientific diaspora without much empirical evidence (Lopez-Verges et. al. 2021; Pandey et.al., 2022; Echeverría-King et. al. 2022). This review aims to contribute to the discourse of harnessing the potential of the scientific diaspora by reviewing the activities and role of the embassies in the host country. It is a systematic review that seeks to answer the following questions: RQ1: What empirical evidence exists of the scientific diasporas' contribution to STI development in their home countries? RQ2: What is the role of the home foreign missions and embassies in the host countries? RQ3: What sustainability model(s) of the activities of the scientific diaspora can be deduced? RQ4: Are there indicators to measure the impact of the scientific diaspora in the development of Science, Technology, and Innovation in their home countries? A study on the answers to these questions is scarce. This review is limited to reviewed papers. Grey literature was not considered. Therefore, there could be the possibility of gathering more evidence and responses to the research questions.

Methods

The systematic review followed three steps. The first involved the framing of relevant keywords used as search terms for retrieving reviewed articles from five different scientific databases. To address the research questions, the keywords were selected to capture scientific diaspora, evidence of impact, indicators, the sustainability of their activities and the role of their country's foreign missions. In the second stage, the keywords were combined to search for publications in the databases. Table 1 shows the combination of the keywords and the search queries from the five databases: PubMed, Web of Science, International Bibliography of the Social Sciences (IBSS), ScienceDirect and Scopus. The search on the ScienceDirect database was conducted using two strings in conjunction with the primary keyword "scientific diaspora" because the database does not allow more than eight "OR" terms per search under the "Title, abstract or author-specified keywords". The investigation was restricted to reviewed articles published only in English, spanning from the inception of the databases to July 2023, when the review was done.

Table 1. Keywords and search queries from five different scientific databases in the current review.

PubMed	(contribution OR support OR assist OR science OR technology OR sustainability OR indicators OR "science attaché" OR "science envoy" OR "embassy" OR "foreign mission" OR "foreign affairs") AND ("scientific diaspora")
Web of Science (WoS)	"scientific diasporas" (All Fields) and "contribution" OR "support" OR "assist" OR "science" OR "technology" OR "innovation" OR "engineering" OR "sustainable" OR "sustainability" OR "indicators" OR "science attaché" OR "science envoy" OR "embassy" OR "foreign mission" OR "foreign affairs"
International Bibliography of the Social Sciences (IBSS)	"scientific diasporas" AND ("contribution" OR "support" OR "assist" OR "science" OR "technology" OR "innovation" OR "engineering" OR "sustainable" OR "sustainability" OR "indicators" OR "science attaché" OR "science envoy" OR "embassy" OR "foreign mission" OR "foreign affairs")
ScienceDirect	1st string
	"scientific diaspora" AND "contribution" OR "support" OR "assist" OR "science" OR "technology" OR "innovation" OR "engineering" OR "sustainable" OR "sustainability"
	2nd string
	"scientific diaspora" AND "indicators" OR "science attaché" OR "science envoy" OR "embassy" OR "foreign mission" OR "foreign affairs"
Scopus	(TITLE-ABS-KEY ("scientific diaspora") AND TITLE-ABS-KEY ("contribution" OR "support" OR "assist" OR "science" OR "technology" OR "innovation" OR "engineering" OR "sustainable" OR "sustainability" OR "indicators" OR "science attaché" OR "science envoy" OR "embassy" OR "foreign mission" OR "foreign affairs"))

Finally, the third step deployed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology (Moher et al. 2009) for the retrieval and evaluation of reviewed publications. The PRISMA flow chart is shown in Fig. 1. It followed a series of processes of "identification", "screening", "eligibility" and "included" stages. Some publications were excluded at every stage with the reasons for exclusion given. The titles and abstracts were initially reviewed for relevance to the current study and some of the publications did not pass this stage. The full-text publications of those that passed were further reviewed and subjected to assessment to ascertain that they meet at least two or more of the eligibility criteria such as evidence of STI-related contributions by the scientific diaspora to their country of origin, the role of their country's foreign missions, the sustainability strategies, and the indicators to measure the impact of their STI-related activities.

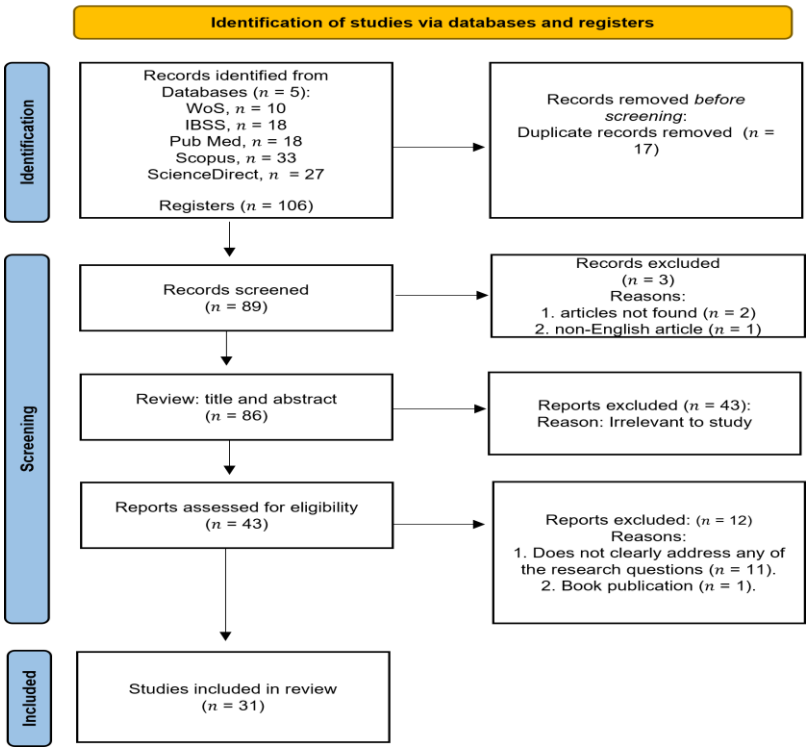

Figure 1. PRISMA (Moher et al. 2009) flow chart from five databases.

Results

The search queries on the databases retrieved 106 publications. The number of publications decreased to 89 after the removal of 17 duplicates. After a thorough review of the publications through the eligibility criteria, a total of 31 publications were included in the review as shown in Fig. 1. Figure 2 shows the percentage distribution of the included publications as sourced from the five databases. About 39% (12) of the publications that represented the highest in this study were retrieved from the PubMed database followed by the International Bibliography of the Social Sciences (IBSS) database of about 23% (7). Scopus, ScienceDirect, and Web of Science have about 16% (5), 13% (4) and 10% (3) respectively. The reason why more publications were found in the PubMed database could be that most published areas of STI-related interventions of the scientific diaspora are health-related. PubMed is well known to be suitable for health-related scholarly articles (White 2020). More relevant reviewed literature was published in 2022 as shown in Fig. 3 compared to other years except for 2023 which is barely halfway at the time of this review. The increase in the number of publications beginning around 2019-2021 might not be unconnected with the renewed international partnership offered by the scientific diaspora after the COVID-19 pandemic outbreak in 2019 and early 2020. A list of the publications, authors, country of first author's affiliation and citation is presented in Table 2. Figure 4 shows the number of publications based on the country affiliation of the first authors. Guatemala, the United States, Canada, India, Israel, and Colombia top the results and it

appears they seem to show more scholarly interest in understanding the impact of the scientific diaspora and the involvement of foreign missions in supporting their objectives. This does not, however, suggest a lesser interest in the other countries that have just one related publication.

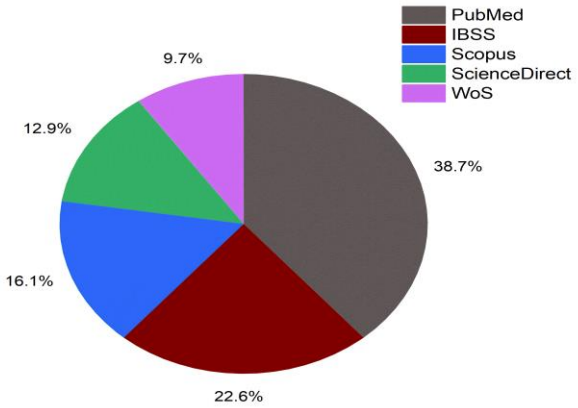

Figure 2: Percentage distribution of the included publications from five databases.

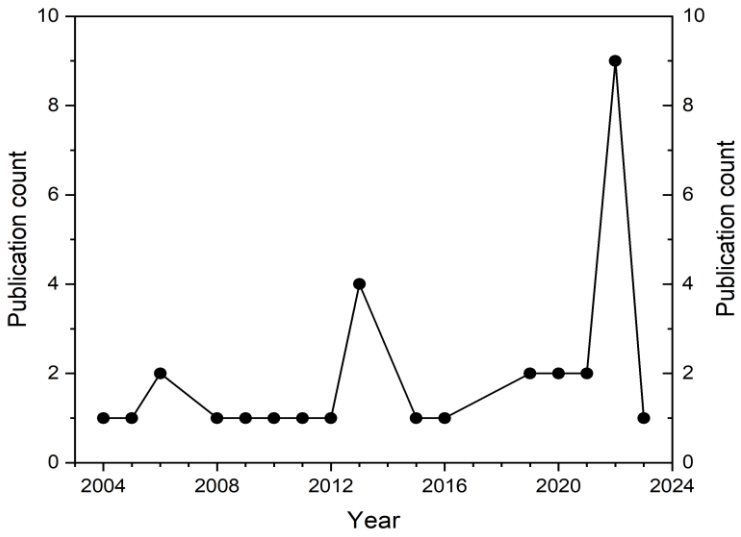

Figure 3: Yearly distribution of publications included in the review

Table 2. Title, authors, first author's country of affiliation, and citations of the included publications.

SN	Title	Authors	Country	Citation
	Tapping into the Potential of Academic Diaspora for Homeland Development: The Case of Nigeria	Amagoh, Francis;Rahman, Taiabur	Kazakhstan	21
	Skilled flows and selectivity of Chinese scientists at global leading universities between 1998 and 2006	Tian, Fangmeng	China	14
	Recruiting "Super Talent": The New World of Selective Migration Regimes	Shachar, Ayelet;Hirschl, Ran	Canada	80
	Diaspora Engagement Strategies and Policies	Filipovic, Jovan;Devjak, Srecko;Ferfila, Bogomil	Serbia	10

	Turning brain drain into brain networking	Ciumasu, Ioan M	Romania	85
	Higher Education and Global Talent Flows: Brain Drain, Overseas Chinese Intellectuals, and Diasporic Knowledge Networks	Welch, Anthony R;Zhen, Zhang	Australia	161
	Plumbing the brain drain	Nancy Gore Saravia;Miranda, Juan Francisco	Colombia	197
	Scientific diasporas	Seguin, Beatrice; Singer, Peter A.; Daar, Abdallah S.	Canada	29
	Global Experience in Interaction with Compatriot Scientists: Lessons for Russia	Yurevich, M. A.; Malakhov, V. A.; Aushkap, D. S.	Russia	4
	International visibility of Armenian domestic journals: the role of scientific diaspora	Gzoyan, Edita; Mirzoyan, Aram; Sargsyan, Anush; Yeghikyan, Mariam; Maisano, Domenico A.; Sargsyan, Shushanik	Italy	0
	Advances in controlled release pesticide formulations: Prospects to safer integrated pest management and sustainable agriculture	Amrita Singh, Nitesh Dhiman, Aditya Kumar Kar, Divya Singh, Mahaveer Prasad Purohit, Debabrata Ghosh, Satyakam Patnaik	India	226
	Ethology and animal behaviour in Latin America	Klaus Jaffe, Juan Carlos Correa, Zuleyma Tang-Martínez	Venezuela	10
	From nation to profession: Israeli state strategy toward highly-skilled return migration, 1949–2012	Nir Cohen	Israel	26
	Circular Migration between the North and the South: Effects on the Source Southern Economies	Kaies Samet	Tunisia	21
	Engaging the Guatemala Scientific Diaspora: The Power of Networking and Shared Learning	Bonilla K, Romero-Oliva CS, Arrechea S, Ortiz Osejo NY, Mazariegos S, Alonzo M, Orellana-Corrales G, Del Valle AC, Montenegro-Bethancourt G.	Brazil	2
	Emerging Technologies, STI Diaspora and Science Diplomacy in India: Towards a New Approach	Pandey N, Srinivas KR, Deepthi TR.	India	0
	RAICEX: A Successful Story of the Spanish Scientific Diaspora	Ortega-Paino E, Oliver E.	Spain	2
	Organized Scientific Diaspora and Its Contributions to Science Diplomacy in Emerging Economies: The Case of Latin America and the Caribbean	Echeverría-King LF, Camacho Toro R, Figueroa P, Galvis LA, González A, Suárez VR, Torres Atencio I, Widmaier Müller CN.	Colombia	5
	Scientific diasporas and the advancement of science diplomacy: The InFEWS US-China program in the face of confrontational "America First" diplomacy	Prieto J, Scott CA.	United States	1
	Imagining a 'Jewish atom bomb', constructing a scientific diaspora	Rabinowitz O, Abramson Y.	Israel	6
	Developing a Digital Technology System to Address COVID-19 Health Needs in Guatemala: A Scientific Diaspora Case Study	Alvarado JR, Lainfiesta X, Paniagua-Avila A, Asturias G.	Guatemala	0
	Voices of the Costa Rican scientific diaspora: Policy lessons from a decade of	Jarquin-Solis ME, Lin-Shiao E, Guerra M, Calderón Zúñiga K,	Costa Rica	0

	experiences from our scientists abroad	Mora Solórzano D, Gutiérrez JM.		
	Connecting Scientists Residing Abroad: A Review of Converciencia as a Practice to Engage the Guatemalan Scientific Diaspora From 2005-2020	Bonilla K, Arrechea S, Velásquez Pérez LG.	Guatemala	2
	Participation in Communities of Women Scientists in Central America: Implications From the Science Diplomacy Perspective	Bonilla K, Cabrera J, Calles-Minero C, Torres-Atencio I, Aquino K, Renderos D, Alonzo M.	Guatemala	4
	The globalization of health research: harnessing the scientific diaspora	Anand NP, Hofman KJ, Glass RI.	United States	32
	Call to Action: Supporting Latin American Early Career Researchers on the Quest for Sustainable Development in the Region	Lopez-Verges S, Valiente-Echeverría F, Godoy-Faúndez A, Fernandez Rivas D, Urbani B, Berger JJ, Carmona-Mora P.	Panama	10
	Networking of intellectual capital in Southeast Europe: Boosting the transition to meritocratic societies	Vedran Horvat	Croatia	1
	The Romanian scientific e-diaspora: Online mobilization, transnational agency, and globalization of domestic policies	Mihaela Nedelcu		6
	Scientific diasporas as an option for brain drain: Re-circulating knowledge for development	Beatrice Seguin, Leah State, Peter A. Singer and Abdallah S. Daar	Canada	83
	Scientific Diaspora: Stay plans of Indian faculty in the United States	Sabharwal M.; Varma R.	United States	9
	Reflections on Cameroonian scientists in diaspora	Georges-Ivo Ekosse	South Africa	0

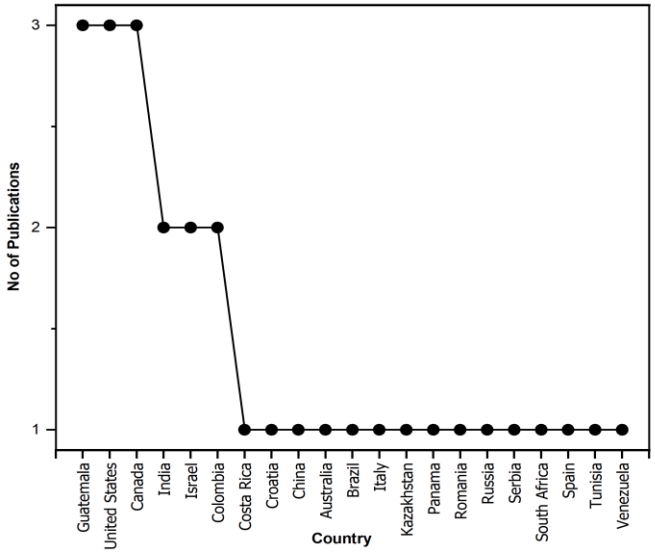

Figure 4. Number of publications based on first author's country of affiliation.

Discussion

The study aimed to synthesize empirical evidence of the contribution of the scientific diaspora towards the development of Science, Technology, and Innovation (STI) in their home country, the indicators in measuring this impact, the interventions of foreign missions towards this drive and the sustainability

model(s) of the activities of the scientific diaspora. Therefore, the results are analyzed based on the following research questions:

RQ1: What empirical evidence exists of the scientific diasporas' contribution to STI development in their home countries? For simplicity and comprehension, the response to this research question is discussed by organizing the answers into themes. Five major themes were identified:

Capacity building and education: This involves the contributions from the scientific diaspora in STEM-innovation-related capacity-building programs and collaborations with home country educational institutions to provide mentorship and to improve research capability and scientific scholarly publications. For example, China's prominence and success in STI-related research enjoyed significant contributions from the scientific diaspora (Shachar and Hirschl 2013). The country moved from the 38th to the 5th position on the international ranking of academic output between 1979 and 2003 (Welch and Zhen, 2008; Li 2008). It was found that domestic paper citations by diaspora researchers increased tremendously (Pandey, et al., 2022; Xie and Freeman, 2020). Such academic international collaboration for scientific publications by the scientific diaspora and home country researchers was also seen in the InFEWS-US-China program where Chinese scholars led some of the projects in the program (Prieto and Scott 2022). In terms of capacity building in STI, an example was found for some Chinese scientific diaspora based in the United States who collaborate with the Chinese Academy of Science and Shanghai Institute for Biological Science to build capacity for 200 students in molecular and cell biology (Saravia and Miranda, 2004). This program is usually offered for one year in Chinese.

Many countries in Latin America are also benefiting from the STI activities of their scientific diaspora. The Centro Virtual de Altos Estudios de Altas Energías (CEVALE2VE) initiative of the Venezuelan scientific diaspora is strengthening the academic community training in Physics, and this has been extended to include countries like Colombia, Ecuador, and Peru (Echeverría-King et al. 2022). They are now engaged in the Latin American Alliance for Capacity Building in Advanced Physics (LA-CoNGA), which aims at building and enhancing capability and capacity in advanced physics research and development. An example of an individual scientist (Alejandro Alex Kacelnik), a fellow of the Royal Society of London and one that can be considered of the scientific diaspora community, was recorded for Argentina in providing mentorship for Latin American scientists and helping to build international cooperation. He received a national award from Argentina's Ministry of Science, Technology, and Innovation for his contribution to national STI development (Jaffe et.al., 2020).

Other countries found in the study within the theme of capacity building and education for STI-related interventions include Armenia, Spain, Cameroon, Kenya, and Iran. The Armenian diaspora researchers gave international visibility to Armenian domestic journals by academically proliferating the scientific knowledge of their publications. This enlisted the domestic journals in international scientific databases (Gzoyan et al. 2023). The Iran scientific diaspora contributed to improving the scientific publications from domestic scientists from 374 in 2000 to 9000 in 2017 (Yurevich et.al, 2019). The Spanish Network of Associations of Spanish Researchers and Scientists Abroad, RAICEX (Red de Asociaciones de Investigadores y Científicos Españoles en el Exterior) are participating in the EURAXESS Spain program in providing mentorship for scholars interested in careers outside academe (Ortega-Paino and Oliver 2022).

Building science-based international partnerships: This includes the initiatives taken by the scientific diaspora in establishing international partnerships or cooperation for STI development. The Spanish scientific diaspora organizes a series of meetings tagged "Bridging European Science". They are also actively involved in cancer research through their collaborations with the Cancer Research Innovation in Science Foundation, CRIS (Ortega-Paino and Oliver 2022). CRIS is an international non-profit organization that invests in cutting-edge research, providing improved treatments for people with cancer. The Foundation provides grants to Spanish researchers who carry out some of their research in Spain for some months. This is perceived as a framework to favour talent attraction. The Network of Chilean Researchers in Germany (Red INVECA e.V.) participated actively in strengthening the scientific

relationships between Chile and Germany. Several annual conferences took place in Germany such as those held in Berlin, 2012; Heidelberg, 2013; Bamberg, 2014; Frankfurt, 2015; Berlin, 2016; Hamburg, 2017; Karlsruhe, 2018; Freiberg, 2019. It was a platform for Chilean Researchers in Germany to brainstorm strategies to address the development of science in Chile, science policies and academic issues. These conferences have helped develop and strengthen state actors' relationships in both countries (Echeverría-King et al. 2022). The Colombian scientific diasporas were also reported to have organized similar conferences on the scientific cooperation between the European Union and Colombia (Samet 2013).

Beyond the organized scientific diaspora initiating science-based international partnerships, there are examples of individual scientific diaspora that initiated STI-related cooperation between host and home institutions. This is the case with an example from Costa Rica where a scientist at the Institut Pasteur in France promoted a cooperation agreement between the University of Costa Rica and the Institut. This has enhanced research in the field of Microbiology at the University. Some other scientists initiated and promoted the internship programs for Costa Rican students, and the development of cooperation agreements, and memorandums of understanding between foreign STI-related institutions and those of the home country (Jarquin-Solis et al. 2022). A similar international collaboration was fostered by an Argentinian scientist in the United Kingdom (Jaffe et.al., 2020).

Technology transfer, STI infrastructure and institutional capacity development: This theme covers empirical evidence of STI-related contributions of the scientific diaspora in building technological infrastructure and STI capacity either in the public or private sector (Sabharwal and Varma 2015). Evidence shows that the contribution of the scientific diaspora is historic. For example, China's research and development in nuclear and missile technology benefitted from the scientific diaspora. When a political decision was taken to develop a nuclear capability in China in 1955, there was a mobilization of the returnees of Chinese scientists who were well-connected internationally (Rabinowitz and Abramson 2022). In China's private sector example, there is a significant impact on technology development start-ups and established companies. Shanghai hosts more than 1,700 firms that are established by the contribution of the scientific diaspora. Among these companies are health and biotechnology-related firms (Seguin et al. 2006). The revolution in Taiwan's information and communication technology (ICT) sector between the 1980s and 1990s was attributed to the Asian-American scientific diaspora. This group of skilled immigrants linked the economies of Silicon Valley in the United States and Hsinchu Park in Taiwan. By 2000, 113 of the 289 STI-related companies in Hsinchu were launched by the Taiwanese scientific diaspora from the US (Samet 2013). In 1972, the Pakistani scientific diaspora demonstrated a commitment to developing Pakistan's nuclear program. Some scientific diaspora members travelled to Pakistan to join the nuclear program and used personal resources in the development of the program (Rabinowitz and Abramson 2022).

Similarly, India's ICT sector experienced a significant transformation because of the knowledge exchange and technology transfer between the Indian scientific diaspora and the home country (Pandey et.al., 2022). The Indian-American scientific diaspora was instrumental in the development and improvement of Indian health sectors such as engaging in sabbatical residencies in Indian hospitals (Seguin et al. 2006). Guatemala's scientific diaspora similarly leverages ICT to contribute to the nation's health sector, especially during the COVID-19 pandemic. They created a digital platform called ALMA (Asistente de Logística Médica Automatizada in Spanish), creating an interactive website that is a free national multilingual call center, associated with an artificial intelligence-based chatbot for improved access to healthcare (Alvarado et al. 2022). Some other countries were found in the study to have benefitted from the scientific diaspora in the industrialization of their economies such as South Korea which engaged in reverse brain drain efforts between the 1960s and 1980s (Yurevich, et al. 2019). In the case of Slovenia, skilled Slovenian engineers and technicians played a major role in technology transfer by establishing a new group of high-technology industries after World War II (Welch and Zhen 2008).

Science advice: This is a consideration of the scientific diaspora in their capacity as a transnational body in providing or making input to national STI-related policies. The Spanish Network of Associations of Spanish Researchers and Scientists Abroad, RAICEX was found to be among the few published active scientific

diaspora in this regard. Specifically, RAICEX was actively involved in the Spanish Science Act 14/2011 amendment (Ortega-Paino and Oliver 2022). The Spanish Association for Biotechnology is working with state actors such as the Ministries of Science, Technology, and Innovation, Foreign Affairs, Migrations, and some private stakeholders such as Instituto Cervantes, and the Royal Academy of Sciences in developing STI policies that will attract and retain domestic and international talents in STI (Ortega-Paino and Oliver 2022). The Romanian scientific diaspora in collaboration with the Ministry of Education and Research have contributed to the new procedure for research evaluation in Romania. This policy on Institute for Scientific Information -based classifications of universities and scientists' performance has formed the main criteria of evaluation, even for the domestic general scientific community (Nedelcu 2019). The current study shows that Costa Rica benefits from expert advice from the scientific diaspora. A scientist resident in Europe has provided such expert advice to support the work of a Costa Rican diplomatic delegation at the United Nations Framework Convention on Climate Change (Jarquin-Solis et al. 2022).

Donation of scientific and related equipment: This theme covers the work and activities of the scientific diaspora in supporting STI development in their home countries by providing or supporting home institutions with STI-related scholarly articles, equipment, and infrastructure. A case of Colombia was recorded where the Colombian intellectual community in New York sent scientific works and equipment to Colombia (Samet 2013).

RQ2: What is the role of the home foreign missions and embassies in the host country? The reviewed findings to this question are also grouped into five main themes:

Connecting scientific diasporas: The role of the embassies or foreign missions in supporting the activities of the scientific diaspora in the host country can be discussed in two folds:

- Identification of the scientific diasporas – The embassies of some countries play the role of helping the scientific diasporas in the host country to easily identify themselves and strengthen their network. Also, they play the role of connecting the scientific diaspora with the scientific community of the home country. For example, the Colombian scientific diaspora organization, Red Colombiana de Investigadores en el Exterior (Colombian Network of Researchers Abroad; R-Caldas). R-Caldas depends on Colombian diplomatic missions to help identify and connect with their potential members in the host country (Bonilla et al., 2022). Spanish embassies, for example, recruit knowledgeable scientists with an excellent understanding of the scientific landscapes of the host and home country to coordinate outreach programs and build cooperation between the two communities (Moreno et al., 2017; Pandey et al., 2022). The Israeli Prime Minister through the Ministry of Foreign Affairs in 1955 pushed to establish links with the educated European-born Israeli Jews (Cohen 2013).
- Identification and promotion of STI-related startups and companies – The study revealed evidence of embassies identifying and supporting the internationalization of STI-related startups and companies of home countries by connecting with the scientific diaspora. An example is the Brazilian Consulate General in the United helping to connect with its diaspora for the promotion and internalization of Brazilian startups and companies (Jarquin-Solis et al. 2022).

Negotiating the return of the scientific diaspora: Although, many countries have opted for the option of brain circulation instead of the return option, however, the study shows that some countries engage their embassies abroad to negotiate with the scientific diaspora for their return home. Israel has explored the role of their embassies in this regard. Specific examples include the request for Israeli State ambassadors to negotiate with Israeli scientists studying or working in British and American universities. The respective ambassadors from consulates in London and New York were requested to use their immigration database system to carry out contact tracing of the scientific diaspora (Cohen 2013). The case of China was not different when expert knowledge of the scientific diaspora was required. The leadership of China's strategic weapons program contacted the Chinese ambassadors in Europe with a plea to convince the scientific diaspora to return home (Rabinowitz and Abramson 2022).

Intergovernmental negotiation: This is a unique role observed at an intergovernmental level between the host and the home country. It presents a case where the government of the home country negotiates with that of the host country to facilitate the return of scientific diasporas who face some forms of discrimination or are under prohibition in the host country. Some Chinese scientific diasporas in the United States featured prominently as an example. The Chinese government asked the Director General of the General Office of the Ministry of Foreign Affairs to rely on the 1954 Geneva Convention to negotiate for the return of this selected group of Chinese scholars. This negotiation was a success as it saw the return of about 100 Chinese to China. The returnees formed a critical mass in the advancement of China's nuclear and missile technology program (Rabinowitz and Abramson 2022).

Taking initiatives targeted at general and specific STI interventions: Some studies show that a few countries engage their embassies in harnessing the potentials of their scientific diasporas to drive foreign policies on science, technology, and innovation in line with national STI priorities. Most of the embassies engage in organizing routine discussion forums and it appears to be the easiest objective. An example is the outreach activities organized by Spanish embassies (Pandey et al., 2022). The Uruguay Advisory Councils and the General Directorate of Consular Affairs and Liaison of the Ministry of Foreign Affairs organize the "active citizenship for development" aimed at bringing together the scientific diaspora with the interest in contributing their scientific knowledge for national development, especially in national priority areas like biotechnology, pharmaceuticals, information technologies, energy, food, and forestry (Echeverría-King et al. 2022).

Engaging the scientific diaspora in an advisory role: The review study also shows that the embassies could engage the scientific diaspora in profiling developments in the thriving STI ecosystems of the host country to keep the home country abreast of the latest developments. Mexico showed a good example of this when about 25 experts were recruited from the Mexican diaspora by the Consulate General of Mexico in Boston to provide advice on STI development (Jarquin-Solis et al. 2022). Such capacity to optimally gather updated knowledge on STI matters in the host country was a requirement for being appointed as a scientist diplomat at the Spanish embassies to help foster cooperation between the scientific communities from the host and home countries (Moreno et al. 2017; Pandey et.al., 2022).

RQ3: What sustainability model(s) of the activities of the scientific diaspora can be deduced? No master model defines the operations of the scientific diaspora or guarantees the sustainability of their activities. However, there are stakeholders' participation and approaches that are believed could help in sustaining the scientific diaspora and their activities depending on the level of engagement. Some identified stakeholders and approaches in the review are as follows:

A national multi-stakeholder and -project approach: Some case studies in the review show that adopting a multi-stakeholder and -project approach could help sustain the scientific diaspora and promise a sustainable means of funding. The Columbian Caldas initiative is an example where they lost their relevance, momentum, and funding due to their strict focus on university-based collaborative projects which eventually turned out to be a bad decision (Ciumasu 2010). The Guatemalan scientific diaspora had a slightly wider approach in its contribution to the health sector in Guatemala. They created a digital system called ALMA (Asistente de Logística Médica Automatizada in Spanish) to support health development. Even though their intervention was health-based, they expanded their stakeholder consideration to include students, government institutions, non-profit organizations, indigenous communities, and the media (Alvarado et al. 2022).

A strong diaspora policy: Some authors have argued that the absence of a diaspora network policy does not mean that scientific diaspora organizations cannot succeed (Seguin et al. 2006). However, many other authors have attributed the success of some scientific diaspora to the strong national diaspora policy. China and India are presented as examples of countries with strong diaspora policy which has significantly helped in the self-organizing of the scientific diaspora and sustainability (Prieto and Scott 2022; Seguin et al. 2006).

Engagement with the scientific communities of host and home countries: The scientific diaspora community

must see the home country's scientific community as an important stakeholder in sustaining their activities and making an impact. Examples of the suggested approach include frequent visits facilitated by the scientific diaspora to help the local scientific community build global networks and collaborations for strong local rooting, with consideration for the individual interests of members (Tian 2013). Also, building concerted efforts to strengthen the scientific diaspora force of negotiation in the host countries and strengthen their visibility in the home countries. And finally, the use of ICT to support their mode of communication is suggested to be quite effective in sustaining both communities (Nedelcu 2019; Samet 2013). Some other sustainability approaches found in the study include decentralized leadership of the scientific diaspora (Ciumasu 2010), and partnership with international organizations (Seguin et al. 2006).

Formation and level of government engagement with the scientific diaspora: The formation of the scientific diaspora organization can be categorized into two: bottom-up and top-down. The bottom-up approach in the formation of the scientific diaspora involves the individualistic and organic constitution of the organization by the scientific diasporas themselves. Examples of this category include the Network of Mexican Talents Abroad which was started in 2000 by individuals, although it later received support from the Mexican Government (Bonilla et al., 2022). The Iranian Academic Association of North America (Yurevich et al., 2019) and the Spanish RAICEX (Ortega-Paino and Oliver 2022) are similar examples of scientific diaspora organizations formed by the bottom-up approach. On the other hand, the top-down approach refers to scientific diaspora organization formation that is initiated by the government. Examples of countries that have used this approach include the Colombian Red Caldas which was established in 1991 with the assistance of the government (Samet 2013), the South African Network of Skills Abroad (SANSA) established by the South African Government (Samet 2013), and the Argentina Programa Raices, a network of Argentine researchers and scientists abroad, designed by the Ministry of Science, Technology, and Productive Innovation in 2003 (Bonilla et.al., 2022). Available evidence suggests that SANSA is not as active compared to when the initiative was started (Seguin et al. 2006).

It is not clear which model for scientific formation is more sustainable as there is no detailed empirical research to conclude. Nonetheless, from the review, it appears that the bottom-up has a stronger tendency to be more sustainable (Bonilla et al. 2021; Filipovic et al., 2014). Government ownership of the scientific diaspora could mean more sustainable funding for the organization but could also significantly dampen the interests of the scientific diaspora members as they may not be in control of the policies. Extrapolating an understanding of this from diaspora organizations in general, Fig. 5 defines 5 different levels of state (government) engagement and diaspora ownership (Filipovic et al., 2014). (1.) “Absent” describes a low level of state engagement where ownership is in the hands of the diaspora organization, and the linkage between the home country and the diaspora is left to the market or self-directed social, cultural, and political movements. (2.) “Custodian” is the situation where the state provides guardians, and regulations and sets the policy directions for existing and emerging diaspora networks. The diaspora ownership is slightly lower

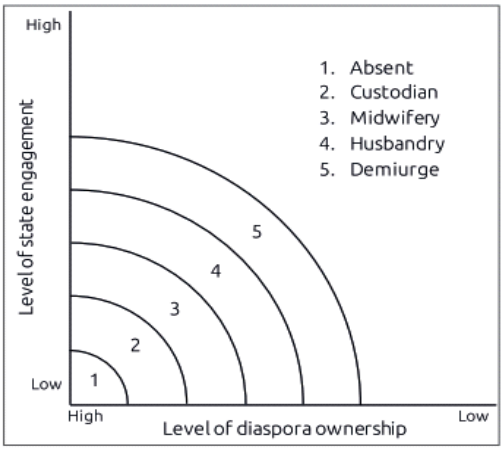

Figure 5. Different levels of state engagement and diaspora ownership (Filipovic et al., 2014).

compared to the "Absent". (3.) "Midwifery" is when the state plays the identification role of prospective engagements and potential primary stakeholders while mobilizing and promoting them, yet the ownership still stays strongly with the diaspora. (4.) "Husbandry" is when the state works in partnership with existing diaspora organizations and facilitates their activities. However, the diaspora ownership gradually fades. (5.) "Demiurge": the state builds and takes control of the diasporic initiatives and networks, letting variable forces subsequently take over. The level of diaspora ownership is significantly reduced.

These five models for the creation and ownership of the diaspora are well applicable in explaining the sustainability concept of the scientific diaspora in different contexts depending on national governance style, culture, and socio-economic conditions. Based on this review, the characteristics of the bottom-up approach could align with the "Absent" model. This type of model may suffer legitimacy and funding challenges. On the other extreme, a top-down approach is observed for the "Demiurge" model, which may enjoy sustained funding but might fail in successfully holding the scientific diaspora together. A better model seems to be Midwifery, which has the potential to combine the positives of both the top-down and bottom-up approaches.

Conclusion

This systematic review aimed to ascertain the empirical evidence of the impact of the scientific diaspora in the development of Science, Technology, and Innovation (STI) in their home countries, and the sustainability models used by the scientific diaspora. It also explores the role played by foreign missions. A total of 31 papers were reviewed and the findings for their STI contributions towards national development were grouped under 5 different themes. Similarly, the role of embassies in working with the scientific diaspora was also summarized in 5 different themes. The sustainability of the scientific diasporas and their activities seems to depend on the formation approach of the organizations. Two approaches were identified: the bottom-up which is organic in nature, and the top-down which is initiated by the government. The level of government involvement and engagement in the formation, ownership and operations of the scientific diaspora were explained based on 5 different models: Absent, Custodian, Midwifery, Husbandry and Demiurge. The Midwifery model is suggested to have a mix of the characteristics of the bottom-up and top-down approach and is recommended to fairly guarantee funding and sustainability of the scientific diaspora activities. No clear and established indicator seems to exist to measure the impact of the STI interventions carried out by the scientific diaspora. More research will be needed for data that will be required for a comprehensive characterization of the indicator. Although the Midwifery model of diaspora ownership is suggested in the review for scientific diaspora formation, an empirical study on the scientific diaspora organizations formed by the bottom-up and top-down approach will be valuable in understanding their sustainability. Evidence from the grey literature will also be valuable.

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