# Migration of highly skilled workers from India
## What is their contribution to global scientific research?

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Every year large numbers of highly educated students, engineers, doctors, management professionals and others migrate from India to other countries to pursue higher education or for employment. In the present study we use scientometric methods to chart the contribution of migrant Indian scientists to global scientific research in the last decade, through their publications (journal articles) listed in the Science Citation Index. We estimate that the number of papers contributed annually by the diaspora is of the same order as that by Indian scientists. However, there are major differences in the quality of journals where the papers by these two groups are published, the diaspora publishing in more reputed journals. There are also significant differences in the research areas addressed, Indian scientists publishing more basic research and the diaspora publishing more in applied and technologically advanced areas. We also chart the participation of migrant Indian scientists in highly visible research by examining papers by Nobel prize winning scientists. Policy changes that can lead to increasing benefits for India from the large presence of diaspora scientists are discussed.

### Introduction

The situation on migration of highly educated and skilled migration is rapidly changing all over the world (Lan et al., 2015). India is currently sending large numbers of students, engineers and scientists to many countries,

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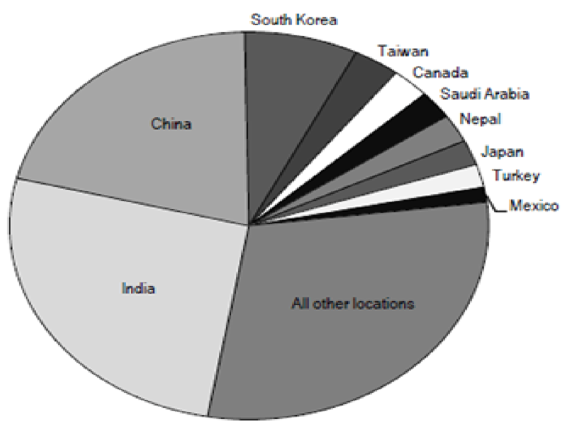
but chiefly to the U.S. In fact, the latest figures show that India now is the single largest sender of engineers and scientists to US (Statesman, Jan. 14, 2016). The total number of scientists and engineers residing in the US rose from 21.6 million in 2003 to 29 million in 2013. In the same year, a total of 950,000 immigrant scientists and engineers came from India. The equivalent number in 2003 was about 512,000, which represents an almost 85 per cent increase from 3.4 million to 5.2 million in 10 years (Lan et al., 2015). Among students also, Indians form the largest single group of foreign students in USA (Fig. 1).

FIGURE 1. Foreign S&E students enrolled in U.S. higher education institutions, by country of citizenship: Fall 2009




S&E = science and engineering.

SOURCE: Department of Homeland Security, U.S. Immigration and Customs Enforcement, Student and Exchange Visitor Information System database, special tabulations: 2010.

For many years now, the exodus of highly educated and trained personnel has been a matter of concern for the sending nations, a phenomenon referred to as the "brain drain" (for the Indian context, see Kapur, 2005, Khadria, 1999, 2003, 20012a, 20012b). It is well known that educated and skilled workers contribute to the knowledge pool of a country, which in turn can be used for economic gain and development. Loss of these individuals implies a loss for the home country[1] . Brain drain was followed by theories of 'brain gain' and 'brain circulation' where scientists either return permanently or periodically to the home country[2] . In the case of China, modern science and technology received a tremendous boost from Chinese diaspora scientists. Chinese scientists living and working in the best laboratories in the world were able to contribute to China's phenomenal scientific growth. Our hypothesis is that a similar benefit may accrue to India with suitable policy steps.

## Gains to the Host Country

In what way do receiving countries gain from the large influx of foreign students whom they are training at a considerable expense? There is some evidence to show that countries admitting a large flow of foreign talent have benefitted, as seen by Levin and Stephan (1999) who noted that a disproportionate number of awards and distinctions had gone to persons of foreign origin in the US. Of the world's most highly cited scientists from 1981 to 2003, one in eight was born in a developing country, but 80% of them had moved to a developed country (Noorden, 2012). Three Nobel laureates of Indian origin were US citizens - Dr. Hargobind Khorana in life sciences, Dr. V. Ramakrishnan in chemistry and Prof. Chandrasekhar in astrophysics.

Foreign-born residents not only contributed to the U.S. high-tech workforce but helped start new businesses. These have generated billions in revenue and hired tens of thousands of workers. Foreign-born entrepreneurs helped start one-fourth of all new U.S. engineering and technology business established between 1995 and 2005, including Google and eBay. In high-tech Silicon Valley, California, more than one-half of business startups over that period involved a foreign-born scientist or engineer; and one-fourth included a person of Indian or Chinese origin (Wadhwa, 2007; Kent, 2011). Economic impact of migration for the US is estimated to raise GDP through lowered wages due to migrant workers[3] by one-tenth of 1 percent in 1996, increasing the GDP of $8 trillion by an additional $8 billion. In 2010, this effect contributed $15 billion to the U.S. GDP of $15 trillion (Martin and Midgley, 2010). However, estimated immigrant impacts de-

[1]An incidental benefit observed in India is that the possibility of gainful employment overseas has increased the demand for higher education in the country (Kapur, 2012).

[2]This has now been followed by 'transnationalism', a feature of globalization, where individuals move between countries in response to international labour demands and opportunities.

pend largely on assumptions, and economic studies have not reached definitive conclusions.

## Scientometric Analysis of papers published by the Indian Diaspora

Our approach in this paper will be to examine the scientific or research contribution of Indian immigrant[4] scientists[5] via an enumeration of their published papers or publication records, using a methodology known as scientometrics[6] (see, Hood and Wilson, 2001). Scientometrics is the study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities, including, among others, publication (Tague-Sutcliff, 1992). Earlier work on the Indian diaspora using scientometric methods may be found in Basu (2006a, 2006b, 2009a, 2009b, 2012, 2014) and Basu and Lewison (2006).

We take our data from the Science Citation Index[7] , in which Eugene Garfield first began listing bibliographic details of papers published in scientific journals in the 1970's. From the publication records we will try to deduce i) the country wise distribution of Indian diaspora papers ii) main disciplines in which diaspora papers are published iii) journals in which the research is published. We will also make a comparison with the characteristics of research publications from India. Finally, to test for the presence of immigrant or non-resident Indians in high profile research, we have looked for Indian names among the co-authors of Nobel Prize winners.

## Data and Methodology

To identify Indians living in foreign locations, we have to look for Indian author names in Web of Science publication database, with a foreign address. The Science Citation Index is a comprehensive database in the Web of Science covering about 8000+ journals in all fields of science. It is the

3 Average wages in the US were lowered 3% because of migration.

4 By 'immigrant' we mean those Indians who can be identified by ethnic names and whose address is outside India. Analogous terms would be Non-resident Indian or Person of Indian Origin. No assumptions are made about country of birth or nationality.

5 The term 'scientists' includes engineers, social scientists and medical doctors

6 The term 'scientometrics' was coined in the 1960s, being used to describe the study of science: growth, structure, interrelationships and productivity

7 The Science Citation Index-Expanded database is currently marketed by Thomson Reuters via their platform, the Web of Science. The edition available to us dates back to 1987.

database of choice in scientometric studies due to its longer history, quality of journals covered and relatively low errors. It also affords facilities for online analytics[8] . The databases cover information on author names, title of paper, abstract, addresses, journal details and citations.

Collecting data for the diaspora is not simple due to the existence of many thousand ethnic Indian names. Unfortunately, only uniquely Indian names can be considered. As a result, names that are common in many countries such as Muslim or Christian names cannot be included for reasons of data integrity. There is also scope for errors arising from similar author names from neighbouring countries. We have collected data using some frequently occurring surnames. In the case of India, these names were successful in capturing 50% of the data. We have taken this to be an estimated percentage in the diaspora case as well. This is used as a sample data and analyzed for characteristics relating to geographical spread of authors, disciplinary distribution, and. growth trends in time[9] .

## Growth trends in Indian publications and Diaspora Publications

As stated earlier, publications are used here as a proxy measure of scientific activity. The diaspora data on published papers is retrieved from the Web of Science using a set of common Indian names for the years 1987-2011. Indian data, for comparison, is retrieved from the same database using the same set of names (Table 1). Both sets of sample data show growth in time, partly due to an intrinsic increase in productivity, but also a database effect that arises because of increase in coverage of journals in the database. The first thing we note from Fig. 2 is that the number of scientific papers authored by diaspora scientists and students is comparable in quantity to publications from India. It is not a negligible amount, being close to 27 thousand papers in the last year. Secondly, the growth rates are comparable, but toward the end of the period the Indian data appears to grow faster. (This is an artefact, as a large number of Indian journals were added to the database around this time)

8 The other important bibliographic database is SCOPUS by Elsevier, which has greater coverage but a shorter history as compared to Web of Science.

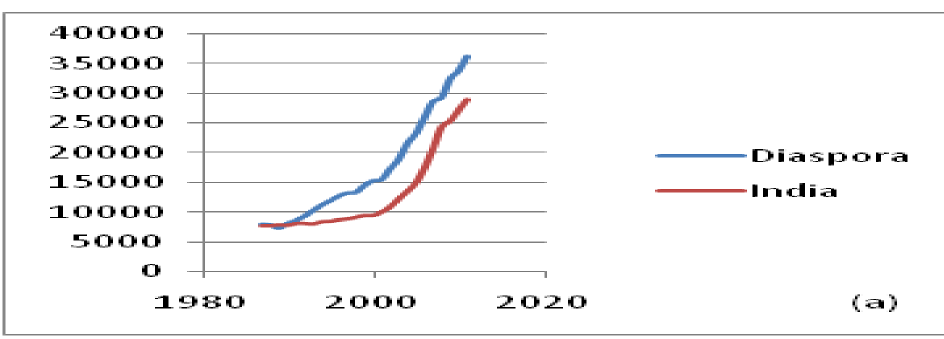
9 Definitions: Indian output= Papers where at least one address is from India; Diaspora output = Papers where one author is of Indian origin, but no address is from India.

**Table 1.**Sample Publications for India and the Diaspora (1987-2011): Articles and Reviews

| **Publication Years** | **Diaspora** | **India** | 1999 | 10283 | 8922 |
|---|---|---|---|---|---|
| 2011 | 26296 | 26482 | 1998 | 9853 | 8587 |
| 2010 | 24135 | 24510 | 1997 | 9623 | 8312 |
| 2009 | 22595 | 22634 | 1996 | 9237 | 8294 |
| 2008 | 20690 | 21464 | 1995 | 7951 | 6663 |
| 2007 | 19378 | 18680 | 1994 | 7561 | 6523 |
| 2006 | 17595 | 15628 | 1993 | 6948 | 6514 |
| 2005 | 15426 | 13539 | 1992 | 6837 | 6375 |
| 2004 | 14306 | 12360 | 1991 | 6366 | 6348 |
| 2003 | 12695 | 11320 | 1990 | 6126 | 6072 |
| 2002 | 11571 | 10153 | 1989 | 5592 | 6017 |
| 2001 | 10977 | 9426 | 1988 | 5256 | 5954 |
| 2000 | 10715 | 8939 | 1987 | 5173 | 5903 |

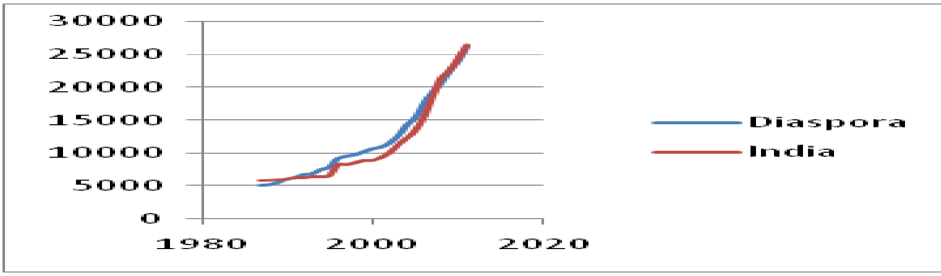
Data Source: Science Citation Index, Web of Science, Thomson Reuters

**Fig. 2.** Trends in the growth of diaspora and Indian publications a) All publications b) Only Articles and Reviews




(Other types of publication include Meeting Abstracts and Conference Proceedings papers.)

**Fig. 2**




Trends show that the diaspora publishes considerably more proceedings papers and meeting abstracts, apart from an equivalent number of articles and reviews as India does. Meeting abstracts constitute close to 22% of the diaspora output while it is only 3% of the Indian output. There are twice as many meeting abstracts and reviews by the diaspora. The high values of proceedings papers and meeting abstracts shows more work in current areas in science, and greater participation in conferences by the diaspora.

## Geographical Spread of the Indian Diaspora in Science

To obtain the geographical spread of Indian diaspora papers we have adopted the full counting approach where each country in the address field of a paper gets a full count (This is when authors come from more than one country). For comparison we give the number of papers from India written with foreign collaboration, and percentage with respect to all Indian papers. Again, all countries in the address field get a full count. By definition, no addresses from India are in the data.

America is the largest source of diaspora papers (~ 70%) followed by the UK (~10%) (Table 2). Compared to diaspora papers from a given country, foreign collaborative papers with the same country are far fewer. There is thus a scope of bridging the gap by initiating more collaboration with the diaspora. While Indians work and publish from several countries, our earlier studies have also found that the US accounts for the largest share of over 60% of published scientific papers by Indians abroad, pointing to the large number of active students and scientists in the Indian diaspora (Basu, 2014).

**Table 2.** Geographical distribution of diaspora sample publications and foreign collaboration (1991-2000)

| | | | Foreign Collaboration | |
|---|---|---|---|---|
| **DIASPORA** | | | | |
| **Countries/ Territories** | **Papers** | **%** | **Papers** | **%** |
| USA | 64183 | 69.915 | 3329 | 4.479 |
| England | 9346 | 10.181 | 805 | 1.083 |
| Canada | 8376 | 9.124 | 539 | 0.725 |
| Germany | 3745 | 4.079 | 1238 | 1.666 |
| Australia | 2465 | 2.685 | NA | |
| Japan | 2355 | 2.565 | 617 | 0.830 |
| France | 2092 | 2.279 | 816 | 1.098 |
| Italy | 1693 | 1.844 | 513 | 0.690 |
| Netherlands | 1333 | 1.452 | NA | |
| Sweden | 1261 | 1.374 | NA | |
| Scotland | 1203 | 1.310 | NA | |

## Subject wise distribution of Diaspora papers and distribution in Journals

Frequently occurring subject areas of research are shown in Table 3 indicating the subjects in which the diaspora publishes. The subject categories are given by Web of Science by classifying journals into categories. All papers in a given journal then belong to the same category. For comparison the subject areas of Indian papers is also shown.

**Table 3.** Subject areas in which the diaspora and Indian scientists publish

(2001-2010)

| | DIASPORA | | | INDIA | |
|---|---|---|---|---|---|
| **Web of Science Categories** | **Papers** | **% of 160273** | **Web of Science Categories** | **Papers** | **% of 159644** |
| Biochemistry Molecular Biology | 12950 | 8.08 | Materials Science Multidisciplinary | 11756 | 7.364 |
| Materials Science Multidisciplinary | 8089 | 5.047 | Chemistry Multidisciplinary | 10041 | 6.29 |
| Physics Applied | 7594 | 4.738 | Chemistry Organic | 8952 | 5.607 |
| Engineering Electrical Electronic | 7556 | 4.714 | Chemistry Physical | 8608 | 5.392 |
| Oncology | 7355 | 4.589 | Biochemistry Molecular Biology | 7283 | 4.562 |
| Surgery | 6401 | 3.994 | Physics Applied | 7157 | 4.483 |
| Cell Biology | 5774 | 3.603 | Physics Condensed Matter | 6453 | 4.042 |
| Chemistry Physical | 5189 | 3.238 | Pharmacology Pharmacy | 5561 | 3.483 |
| Pharmacology Pharmacy | 5143 | 3.209 | Physics Multidisciplinary | 5219 | 3.269 |
| Immunology | 4978 | 3.106 | Environmental Sciences | 4906 | 3.073 |

Data Source: Science Citation Index, Web of Science, Thomson Reuters

Biochemistry and molecular Biology have the largest share among the diaspora papers, the Indian share being considerably less. On the other hand there are many more Materials Science papers in the Indian output. Areas that do not appear in India's 'most- frequent' list are Oncology, Surgery, Cell Biology and Immunology. In fact the majority of Indian research papers in this period are in the basic sciences. Again this suggests complementarities which can be explored in forging links with the diaspora.

Most frequently used journals for India and the diaspora show a completely non-overlapping set, with the diaspora publishing in reputed international journals and India publishing most frequently in Indian journals (Table 4)

**Table 4.** Journals most frequently publishing Diaspora papers and Indian papers (2001-2010)

| | **DIASPORA** | | | **INDIA** | |
|---|---|---|---|---|---|
| **Source Titles** | **Papers** | **% of 160273** | **Source Titles** | **Papers** | **% of 159644** |
| Journal of biological chemistry | 2354 | 1.469 | Indian Journal of Animal Sciences | 2164 | 1.356 |
| Proceedings Of The National Academy Of Sciences Of The United States Of America | 1465 | 0.914 | Current Science | 2113 | 1.324 |
| Applied Physics Letters | 1460 | 0.911 | Asian Journal of Chemistry | 1727 | 1.082 |
| Lecture notes in computer science | 1349 | 0.842 | Tetrahedron Letters | 1509 | 0.945 |
| Physical Review B | 1312 | 0.819 | Indian Journal of Agricultural Sciences | 1383 | 0.866 |
| Physical Review Letters | 1311 | 0.818 | Journal of The Indian Chemical Society | 1354 | 0.848 |
| Journal of Applied Physics | 1020 | 0.636 | Indian Veterinary Journal | 1294 | 0.811 |

| | | | | | |
|---|---|---|---|---|---|
| Journal of the American Chemical Society | 906 | 0.565 | Indian Journal Of Chemistry Section B Organic Chemistry Including Medicinal Chemistry | 1081 | 0.677 |
| Cancer research | 902 | 0.563 | Journal of Applied Polymer Science | 927 | 0.581 |
| Journal of Immunology | 792 | 0.494 | Indian journal of chemistry Section a inorganic bio inorganic physical theoretical analytical chemistry | 906 | 0.568 |
| Physical Review D | 787 | 0.491 | | | |

In summary, scientometrics enables us to get an overview of the scientific output of a country or a group, in this case the Indian Diaspora, from which inferences can be made to shape or otherwise implement policy. We also deduce that the diaspora produces more high quality papers (judging from the journal set). The papers are also in more specialized subject areas. (Table 3)

## Nobel Prize winners and Migrant Indians: A sample study

To test for the presence of Indians in very high profile science, we looked for Indian co-authors of Nobel Prize winners. We collected data of all publications of Nobel Laureates in the fields of Physics and Chemistry for a sample period 2012-2014. For each laureate in a given year, we collected details of papers published from the Web of Science for a period of at least 10 years ending with the year of winning the award. If in a particular year the Nobel Prize was awarded to more than one person, the publication records for each of them were collected separately. The list of all the Nobel laureates for whom data is collected along with the year of winning, subject and period for which data is collected is given in Table 5, together with the number of papers with Indian co-authors for each awardee. For calculating the contribution of Indian authors, we needed to first identify Indians from the list of authors. Here, we have manually identified Indian names from the list of author names. Though this method has its limitations, we had to use it as there is no information available in the WoS records about the nationality or country of birth of the authors. Since the initial data excluded any Indian locations, collaborative work with any Indian scientist located in India was automatically eliminated.

**Table 5.** Nobel Prize winners in Physics and Chemistry (2012-14) and percentage of papers with Non-Resident Indian co-authors

| Name of Awardee | Year of Award | Subject | Data Period* | Country of birth | Total Papers | Papers with (at least one) Indian Co-author | Percentage of papers with an Indian |
|---|---|---|---|---|---|---|---|
| co- author | | | | | | | |
| David J. Wineland | 2012 | Physics | 2003 - 2012 | USA | 61 | 0 | 0 |
| Serge Haroche | 2012 | Physics | 2003 - 2012 | France | 34 | 0 | 0 |
| Brian K. Kobilka | 2012 | Chemistry | 2003 - 2012 | USA | 59 | 17 | 28.8 |
| Robert J. Lefkowitz | 2012 | Chemistry | 2003 - 2012 | USA | 141 | 57 | 40.4 |
| Peter Higgs | 2013 | Physics | 2000 - 2013 | UK | 5 | 0 | 0 |
| François Englert | 2013 | Physics | 2004 - 2013 | Belgium | 9 | 1 | 11.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Michael Levitt | 2013 | Chemistry | 2004 - 2013 | American-British-Israeli (born South Africa) | 61 | 8 | 13.1 |
| Martin Karplus | 2013 | Chemistry | 2004 - 2013 | Austria | 122 | 8 | 6.6 |
| AriehWarshel | 2013 | Chemistry | 2003 - 2013 | Israel | 163 | 31 | 19.0 |
| Hiroshi Amano | 2014 | Physics | 2005 - 2014 | Japan | 105 | 1 | 1.0 |
| Isamu Akasaki | 2014 | Physics | 2005 - 2014 | Japan | 122 | 17 | 13.9 |
| Shuji Nakamura | 2014 | Physics | 2005 - 2014 | Japanese born American | 283 | 100 | 35.3 |
| Eric Betzig | 2014 | Chemistry | 2005 - 2014 | USA | 55 | 9 | 16.3 |
| William E. Moerner | 2014 | Chemistry | 2005 - 2014 | USA | 163 | 15 | 9.2 |
| Stefan W. Hell | 2014 | Chemistry | 2005 - 2014 | Romanian-born German | 225 | 7 | 3.1 |

*Publication data is for a 10 years period including the year of award; Data Source: Science Citation Index, Web of Science; Official website of the Nobel Foundation http://www.nobelprize.org/

We note that the percentage contribution of the Indian diaspora to the publications of Nobel prize awardees (i.e. the percentage of papers that had an Indian co-author) could be as high as 40%. Aggregating the values gives the percentage contribution in Physics and Chemistry in the years 2012-2014 (Table 6).

**Table 6.** Percentage of Nobel Prize winners' papers with an Indian co-author

| Diaspora Contribution to Publications over a decade prior to Nobel Award | | |
|---|---|---|
| **Award Year** | **Chemistry** | **Physics** |
| 2012 | 46% | 0% |
| 2013 | 14.08% | 6.67% |
| 2014 | 10.18% | 30.00% |

The figures in Table 6 are likely to be overestimates as there is some degree of overlap between the papers authored by the awardees, for instance, in the case of a joint award, leading to multiple counting. This is just an approximate quantitative measure of the likely contribution made over the decade prior to the award, and no claims are being made about the qualitative nature of that contribution as it is well-known that co-authors of a paper have varied tasks ranging from significant to mechanical or technical. Table 7 gives the number of Indian co-authors in either the groups or teams working with the Nobel awardees, or among their collaborators.

**Table 7.** Number of Indian co-authors of Nobel Prize winners in Physics and Chemistry (2012-2014)

| Name of the Awardee | Total Co-authors | Indian Co-authors | percentage of Indian Co-authors |
|---|---|---|---|
| David J. Wineland | 124 | 0 | 0 |
| Serge Haroche | 107 | 0 | 0 |
| Brian K. Kobilka | 197 | 14 | 7.1 |
| Robert J. Lefkowitz | 388 | 20 | 5.2 |
| Peter Higgs | 5 | 0 | 0 |
| François Englert | 15 | 1 | 6.7 |
| Michael Levitt | 128 | 5 | 3.9 |

| | | | |
|---|---|---|---|
| Martin Karplus | 262 | 4 | 1.5 |
| AriehWarshel | 103 | 7 | 6.8 |
| Hiroshi Amano | 310 | 1 | 0.3 |
| Isamu Akasaki | 302 | 8 | 2.6 |
| Shuji Nakamura | 490 | 26 | 5.3 |
| Eric Betzig | 198 | 4 | 2.0 |
| William E. Moerner | 277 | 7 | 2.5 |
| Stefan W. Hell | 589 | 7 | 1.2 |

*Publication data is for a 10 years period including the year of award; Data Source: Science Citation Index, Web of Science

The results show that all but three out of 15 Nobel Prize winners in the immediate past had Indian co-authors (Table 7) contributing to a fairly large proportion of papers (Table 5) (Only two of these papers had an author in India, the rest were non-resident Indians). If this appears surprising, one should consider that when looking at the level of qualifications, higher the diploma the bigger the proportion of the foreign-born population. 23% of those having a doctorate in the US in the 1990's were foreign-born, and in some key areas such as engineering and computer sciences it was as high as 40% (NSF 1998, p. 3-19). It is "obvious that the first country in terms of S&T capacity, of academic knowledge production and of technological innovation in the world, relies significantly and sometimes heavily on non-native skill holders."(Cohen, 1997)

## Policy Alternatives

Attempts have been made in different countries to utilize diaspora members through attractive policy options and some of the success stories are in Israel, South Korea and Taiwan. In the early 20th century Chinese students from US Universities returned and played important roles in Chinese intellectual life. In the 21st century, the re-emergence of Chinese science has been attributed to the return of overseas scholars; 81% of the Chinese Academy of Sciences and 54% of the Academy of Engineering are returned overseas scholars (Jin, 2007). Similar programs to attract foreign talent of Indian origin have also been initiated in India (Ref.) , though they can only be said to have had a limited impact. While diaspora members can form important bridges between skill levels in developed countries and local conditions in their home countries, either on return or through collaborative efforts, the prior level of advancement in the latter determines what can be termed the 'absorptive capacity'. The pre-existence of such absorptive capacity also appears to be a necessary condition for significant reverse migration (Parthasarathi, 2006). In brief, it is a debatable point to what extent the losses to the sending country are offset by the benefits of migration.

Be that as it may, the fresh opportunities offered by the internet and communication technology for long distance engagement and collaboration should certainly be aggressively explored. Adjunct positions could be initiated in universities and colleges, or research institutes. The comparatively affordable rates of travel and airfare should make this a workable option with regular visits. Indian faculty in foreign universities could be involved in the informal training of Indian students on their campus. This is already being implemented by the Chinese in Australia with funds being set aside for the purpose (Graeme, 2009). It is important to recognize that while it may be unrealistic to expect diaspora members to return, it may certainly be possible to engage them academically in fruitful ways. Mutual exchange of information will lead not only to the Indian counterpart gaining direct exposure to a distant set-up, but also make the diaspora scientist aware of research problems that need to be addressed in India's social, economic and environmental context.

The Prime Minister has taken sufficient interest in engaging the diaspora on his foreign visits. Apart from government initiative, the involvement of alumni of Indian IITs and IIMs in initiating start-ups in the software industry is well known and has put India on the software map of the world today. Since the 1990's, India has seen the effect of 'diaspora knowledge networks' particularly in the IT sector, where professional associations of highly skilled diaspora scientists and engineers used their reputation and skills to bring up the IT industry in India. Diaspora knowledge networks can be defined as self-organised communities of expatriate scientists and engineers working for the development of their home country or region, mainly in the areas of science, technology and higher education (Barre, 2006). Such associations are officially recognized in China by the Chinese government, though they are independent of the government. The legal framework has been changed to include dual nationality and dual job-holding, and offers economic incentives to returnees. In India the same degree of official recognition is not there, even though there are a large number of expatriate organizations with critical mass and recognized skills the world over, particularly in IT, and a huge potential to make a change. The achievement of high professional status by a large number of Indian expatriates, which occurred in the 1980s and 1990s, seems to have been a precondition for them to contribute to India's development (Pandey, 2006; Kuznetsov, 2006).

It remains for realistic policy instruments to be put in place to facilitate exchange at the academic and research levels. It is important to emphasize that a policy to engage the diaspora scientist does not necessarily equate only with offering pecuniary benefits. It requires a detailed knowledge of existing knowledge pools within the diaspora to make an effective match with competency on the Indian side. It is well known that for skill transfer to be successful, the skill sets must be well matched (Parthasarathi, 2006). An intensive program of workshops, summer schools, MOOCs (Massive Open Online Courses)[10] and even volunteer tutoring can be planned taking advantage of visits and distance communication, after suitably matching research interests.

## Conclusions

This, then, is what we are offering with our methodology of tracking knowledge pools among the Indian diaspora using data on published papers and scientometric techniques. Not only does it give an idea of the geographical spread of the scientific diaspora, and the status of research especially in contrast to India, as shown in this paper, it offers the possibility of generating actionable information by tracking diaspora knowledge pools and corresponding or complementary Indian matches. For example we find that the number of collaborative papers written with foreign scientists is miniscule when compared to the number of diaspora papers which are of the same order as the total number of Indian papers. The immediate implication is that there is a definite scope for additional collaborative work with the Indian diaspora. China had large numbers of students and scientists in American and Australian universities who collaborated extensively with scientists in mainland China before the surge in scientific activity that has taken China to the second position in scientific productivity (for a concise description of the Chinese case, see Jin, 2007). China had arrangements such as dual job appointments with the host country.

To conclude, in addition to its own scientific manpower, the diaspora of a country is undoubtedly a significant potential resource. One of the most important steps is to create databases of expatriates and talents (Kshitij, 2009). This can be done, partially, for publishing scientists by using scientometric methods, as demonstrated in this paper. Another more recent route is to use diaspora scientific or intellectual networks by giving them official recognition and facilitating interaction (Meyer and Brown, 1999). To engage the diaspora, it may be necessary to provide flexible options as well as appeal to their sense of duty or obligation, to be fulfilled without unduly curtailing their own aspirations or commitments. A case in point is the Chinese policy, which was changed from 'Return: and Serve the motherland' to simply 'Serve the motherland' (Graeme, 2009).

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