Study Identifying Priority Fields for Research and Innovation Cooperation between the EU and India

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EXECUTIVE SUMMARY

While India is one of the most important emerging research and innovation (R&I) cooperation partners of the EU, information on the means and extent of the S&T collaboration between the EU and India is neither systematically nor readily available. To obtain better insights into current practices and future potentials in collaborative R&I activities vis-à-vis India the JRC-IPTS was asked to provide an evidence based strategic analysis in order to consistently reflect the dynamics of recent collaborative R&I activities of the EU with India. Based on bibliometric analysis and investigation of the scattered related information, this report aims to provide a short assessment of the current status of collaborative research and innovation activities of the EU with India. As agreed this report presents a simple straight forward analysis of bibiliometric information including co-publication and co-patenting data along with the analysis of some mapping and assessment exercises, but without introducing any input-output indicators for particular MS or their benchmarking. The main findings regarding research and innovation cooperation with India are summarised in a comparative perspective. Where possible, the main partners in the EU and India, as well as in the US were identified as well as the key modalities and instruments of their bilateral collaborative activities. The underlying reasons for successful practices in the competitor US-India cooperation in the selected priority fields were also pursued. Current report thus aims at providing a strategic scientific analysis in order to support and facilitate a sustained progress of the European collaborative undertakings in the evidence based identified priority fields for research and innovation cooperation with India. Furthermore, it aims to identify good practices in cooperation with India, which may serve as incentives for a better targeted transnational coordination of certain internationalisation policies of the EU vis-à-vis India.

1. INTRODUCTION

The emergence of India and China as major forces in the global economy constitutes one of the most significant economic developments of the past quarter century. India, ranked as the world's second most populated country (census population 1.21 billion; GoI – Ministry of Home Affairs, 2011) and the seventh largest country by geographical area, is a federal constitutional republic with a parliamentary democracy consisting of 28 states and seven union territories. International acknowledgment of India as a well-established political democracy and of its geopolitical role in the region's economic stability is increasing. At the same time, India continues to gain recognition as an emerging global knowledge-economy power and an important partner in international research and innovation.

Henceforth modest outsets in combating widespread poverty, malnutrition, illiteracy and the precarious health conditions of its population of over a billion people in the early 1980s, India experienced an astonishing surge. In the following two decades it has managed to propel an remarkable recovery with rapid socio-economic progress and impressive growth rates in all of the important sectors, from health, employment and education to industry, research, innovation and the overall economy. Since the introduction of market-based economic reforms in 1991, the country has become one of the fastest-growing major economies in the world. Agriculture's contribution to the national economy declined steadily (representing only 17.5 % of the national income in 2009), giving way to the rise of high added-value sectors such as industry, services and manufacturing. Industry accounts for 28 % of the Indian GDP and employs 14 % of the total workforce (CIA World Factbook, 2007a), rending India twelfth in the world in terms of absolute nominal factory output (CIA World Factbook, 2007b). As in developed economies, services and goods driven by rapid growth of high-value, knowledge-intensive activities (such as information and communication technologies [ICT], banking and consulting) have become the fastest-growing sectors in India and account for an important share of its GDP. India is ranked thirteenth in the world in services output. That sector has provided employment to 23 % of the work force and held the largest share of the GDP at 55 % in 2007 and more than 60 % in 2010. As a result of trade liberalisation worldwide, and rapid advances in technology giving way to transport and communications' cost reductions, the Indian share of traded goods and services as a percentage of global GDP was stable at around 20 % in 2009 (The World Bank, 2011).

Impressive economic performance and growth at staggering rates of over 8 % yearly during the past decade (9.1 % in pre-crisis period 2007–08), as well as national resilience in the face of the global economic crisis, have gained the respect of many established economic authorities. In 2010 the Indian economy was the tenth largest in the world by nominal GDP and the fourth largest by purchasing power parity (PPP) (IMF, 2011). India's key strengths are its large domestic market, its young and growing population, a strong private sector with experience in market institutions and its well-developed legal and financial system. In addition, from a knowledge-economy perspective, another strong point is its large critical mass of highly trained English-speaking researchers — 35.7 % in engineering and technology; 22.4 % in natural sciences (UNESCO Institute for Statistics, 2005). Skilled engineers, business people, scientists and other professionals have been the driving force behind the growth of the high value-added services sector. Country's stable entrepreneurial environment and its industrial sector's S&T capacities supported its ability to mitigate the sharp slowdown of the international financial situation and economy and the knock-on effects of the global financial crisis. During the peak crisis year 2009 India's industrial growth according to the industrial production index was at 2.4 % while most countries fell into a deep recession. India's huge domestic consumer market has also helped mitigate the effects of the global economy crisis since the country has a lower share of international trade of goods and services compared to other developing countries (The World Bank, 2011).

Nevertheless, India's remarkable rates of recent sustained economic growth and impressively rapid rise in global prominence are largely due to the country's increasingly important role in knowledge creation and dissemination, which was recognised as the major component of its sustained economic growth and competitiveness in the global context (The World Bank, 2011). Products and services are increasingly designed and developed for global markets in order to recover research and development investments. In addition, R&I itself is becoming increasingly globalised and cohesive in ways that reach far beyond mere increases in joint authorship of technical papers or joint patenting by teams from different countries. Thanks to reduced communications costs, there is an increasing tendency to source many knowledge-intensive services in lower-cost developing countries such as India. This is part of what drives global off shoring of knowledge-intensive services, such as back office functions, as well as engineering design and even contract innovation services (Dahlman & Utz, 2005).

A growing number of R&I activities are performed by multinationals in countries such as India, and the country is benefiting greatly from this trend at present, as it plays host to many R&D centres established by multinational companies. Innovation and high-level technology skills are therefore becoming the most important factors determining competitiveness. India has therefore developed more explicit strategies to take advantage of rapid creation and dissemination of knowledge and to develop stronger innovation capabilities of its own.

As one of the key BRICS countries, India's recent rapid increase in the number of SCI-cited publications and WIPO patents has been supported by a fast-growing well-educated work force of young engineers and doctors, a solid and business-friendly policy framework offering a flexible entrepreneurial environment and a powerful and highly competitive corporate sector able to search for niches in the competitive world economy successfully (The Royal Society, 2011). With 64 % of its population at working age (15-60 years) (Bound, 2007), a pool of 14 million young university graduates (1.5 that of CN and twice that of the US) and 2.5 million science, engineering and IT graduates each year (Farrell et al., 2005), an annual science budget of 4.5 billion USD and 229 universities, more than 400 government laboratories and approximately 1300 industrial R&D units (GoI, Department of Science and Technology, 2006) and a growing per capita revenue, India also represents major research, technology, innovation and market opportunities.

For these reasons, the EU and Member States (MS) launched the *India Pilot Initiative* in 2009 to coordinate cooperative efforts and identify how the MS and the EU could best work together to develop a coherent S&T agenda with India. The European partners are committed to establishing a common strategic roadmap for long-term comprehensive and coherent S&T cooperation with India and have agreed to a common set of criteria for developing priorities for their future work and collaborative links with regard to Indian partners for upcoming activities.

The aim of the current study is to provide a strategic scientific analysis in order to support and facilitate sustained progress by European cooperative undertakings in identified priority fields for research and innovation cooperation with India.

1.1. Aims

Despite reviewing substantial literature on the subject and extensive inventory data, and performing a complex and demanding analysis, the study is intended to provide a summary of factual information established through the evidence-based analysis and evaluation process focusing on the following:

- identify the top eight thematic areas for cooperative research and innovation, i.e. priority fields for EU and MS S&T cooperation with India;

- identify the main partners in the EU and India (institutes, universities, enterprises) which perform cooperative S&T activities in selected thematic areas; and
- identify the key modalities and instruments (including institutional cooperation) used in bilateral S&T cooperation in these thematic areas.

Priority fields for research and innovation cooperation of the EU with India as well as the main partners and key modalities of research and innovation (R&I) cooperation were selected on basis of scientific evidence. The top eight thematic areas represented the basis for a detailed study correlating the co-publication data with the co-patenting data between the EU and India (IN) in order to identify the most prolific technologies within each priority field of R&I co-operation and the reliable partners with huge technological cooperation potential between India and the EU. In addition, a comparison of advantages and challenges from successful US-IN R&I cooperation practices was performed based on the co-publications and co-patents, identifying where and why the US, a successful competitor of the EU vis-à-vis India, has got strategic advantages in technology and innovation cooperation with India.

1.2. Methodology

1.2.1. Combined bibliometric and patent analysis taking into account Grand Challenges

The initial analysis intended to identify core areas of EU–India S&T cooperation was based on the set of all cited Indian publications in the SCOPUS database. A total of 522 820 Indian publications from 2000–2010 were retrieved. Based on the total number of citable documents produced by India-based scientists (SCImago, 2011) the top eight subject areas were then identified from the set of all Indian publications in that period. A total of 39 446 articles co-published with the EU and 31 613 articles co-published with the US sorted by Frascati fields were also retrieved (New INDIGO, 2011). These top priority fields of cooperation were cross-referenced with the numbers corresponding to total EU–India co-publications for 2000–2010 in the SCOPUS and ISI Web of Science databases, taking into account sector competitiveness and emerging Grand Challenges. This complex setting served as a basis for identifying the top eight thematic areas for research cooperation between the EU and India, which were then compared to and cross-checked with numerous reports mapping EU–IN cooperation and various project assessment exercises. For comparison purposes, the US–IN co-publication and co-patent data were fitted into the same eight thematic areas of R&I cooperation to showcase the comparative strengths of both research communities working in partnership with India in the priority thematic areas (see **Figure 1a, 1b**).

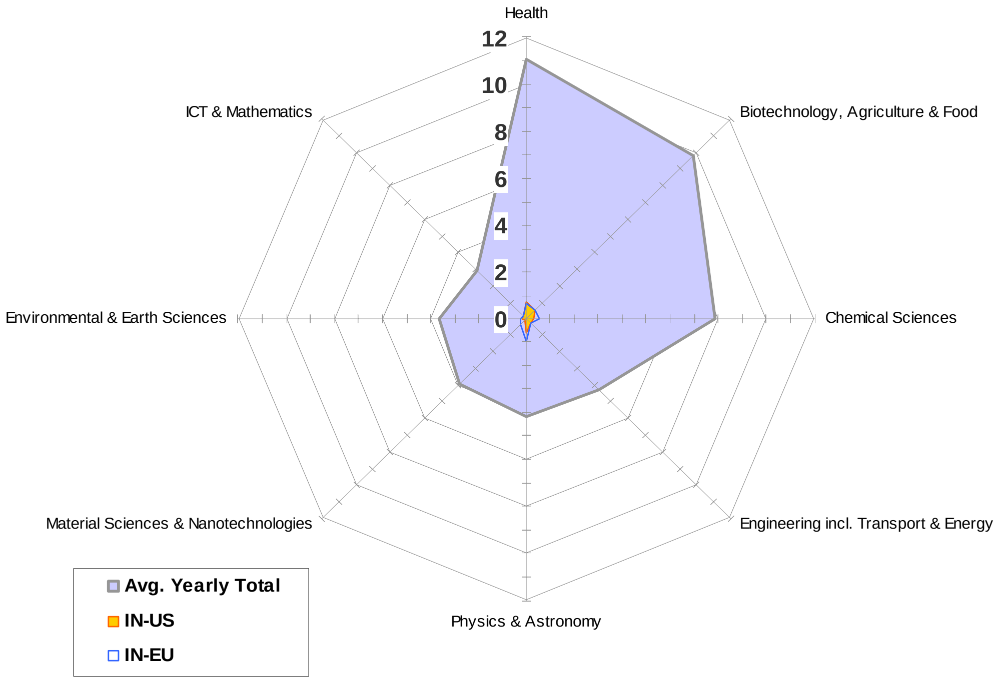
As examining the change dynamics and quality of EU–IN (or similarly US–IN) co-publications and co-patents for 2000–2010 would largely exceed the scope of this study, we only consider the total volume of co-publications and co-patents for that time period. While the change dynamics of the impact of EU–IN and US–IN co-publications could provide additional important information regarding evolution in publication quality, a future evidence-based study shall be conducted to address that issue. The impact and quality of co-publications, along with their sheer volumes could disclose promising emerging pioneer research fields which are not yet characterised by a large number of publications, but which could be of utmost importance for future scientific and technological cooperation with the emerging country. An interesting detailed study analysing collaborative output in the case of Indian and German co-publications, which addresses the abovementioned publication quality aspects, has just been released and may provide certain aspects to understanding of overall EU–IN collaborative activities (Gupta & Gupta, 2011).

The top eight thematic priority fields for EU and MS research cooperation with India, ranked by order of relevance expressed as the total number of Indian publications during 2000–2010, are as follows:

1. **Health, Medicine & Pharmaceutics;**
2. **Biotechnology & Bioengineering** including **Agriculture & Food;**
3. **Chemical Sciences;**
4. **Engineering** including **Transport & Energy;**
5. **Physics & Astronomy;**
6. **Advanced Materials & Nanotechnologies;**
7. **Environmental & Earth Sciences** including **Water-related Challenges;** and
8. **Information and Communication Technologies (ICT) & Mathematics.**

The distribution of the average yearly number of Indian publications in 2000–2010 and of the average yearly EU–IN and US–IN co-publications in the same period are shown in **Figure 1**.

a.)



b.)

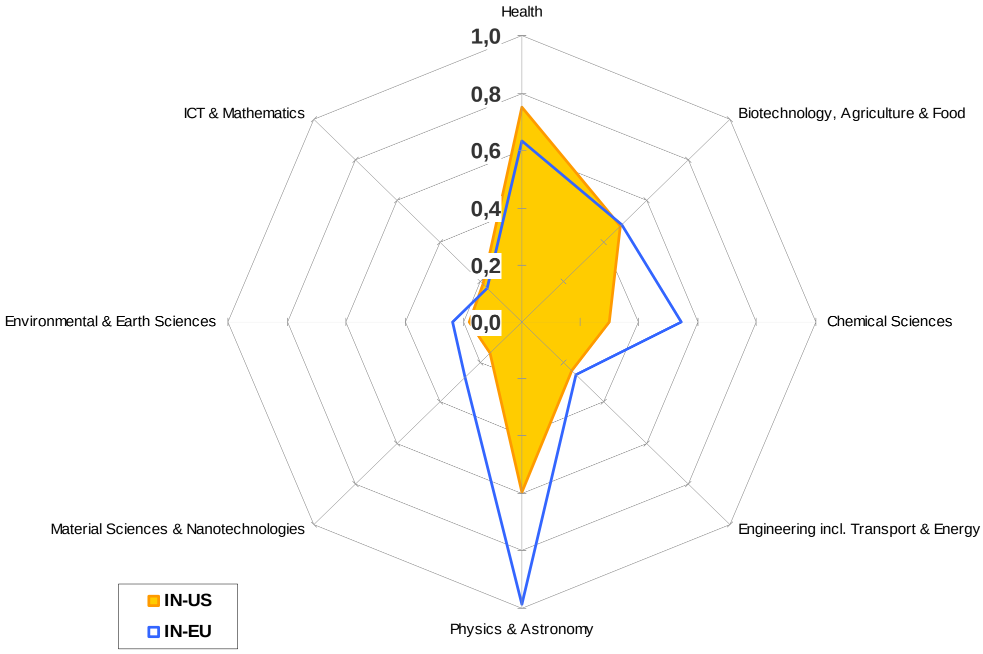


Figure 1: a) Distribution of the average yearly publications from India in 2000–2010;
b) Distribution of the average yearly EU–IN and US–IN co-publications in the same period. Note: all figures given in thousands.

The top eight thematic research areas identified using Indian scientific publications were then correlated with the standardised codified technology fields in the WIPO database for the codes of all Indian patent applications during 2000–2007[1], and with EU–IN and the US–IN co-patents in that period.

IPC classes were assigned to thematic research areas and technological fields based on the WIPO concordance table (WIPO 2010). However, some of the classification work was challenging due to having to harmonise the eight identified thematic priority fields of cooperation with the nomenclature used in established databases that report scientific research publications on one side and IPC classifications in the patent codes of the patent databases on the other. Outliers were classified on a case-by-case basis, after which all borderline IPC classes were cross-checked with the literature and WIPO database assessments. The IPC categories corresponding the closest to identified thematic areas were retained for the final analysis.

We retrieved a total of 12 601 patent applications with at least one Indian inventor during 2000–2007 from the PATSTAT database, and performed a qualitative identification of co-patents with the EU and the US. We located 3 655 Indian co-patent applications with at least one foreign inventor; of these, 735 involved partners from the EU and 2446 involved partners from the US were retrieved. Based on the numbers of Indian patents and co-patents, the top eight subject areas were then repositioned in order to gauge their importance in the Indian R&I system as well as their importance in R&I cooperation with India. Fractional counts applied when counting patent applications with multiple Indian and foreign applicants as well as when counting the affiliation of each patent application to the various priority fields of cooperation. More detailed information on the methodology used for patent data analysis is provided in the Annex.

1.3. Structure of the Report

Chapter 1 presents a short introduction with methodology and the description of the approach applied.

Chapter 2 presents the eight priority fields for research and innovation cooperation between the EU and India by descending order of importance. Each priority field of cooperation is presented as a brief fact sheet in decreasing order of the importance of scientific and innovation activities, that is, of the shares of the most prolific specific areas within each selected priority field in Indian scientific production and EU–IN S&T cooperation for 2000–2010 (including co-publications and co-patenting). The fact sheets also contain the top three R&I partners — institutes, universities, and enterprises in India, the EU and the US — which undertake cooperative research and innovation activities in the selected thematic areas, and the key modalities and instruments used in bilateral cooperation in these thematic areas. We provide comparative information on US–India research and innovation cooperation. A paragraph on a broader policy perspective providing possible reasons for certain S&T cooperation characteristics in the EU–IN or US–IN cooperation in the field is found at the end of each fact sheet.

Chapter 3 summarises the main findings and the lessons learned from a comparative perspective, addressing good practices in R&I cooperation with India and, where possible, giving underlying reasons for past successful practices. The Annex briefly describes the source and methodology for the patent data analysis used to identify the most prolific technology sectors in EU–IN and US–IN R&I cooperation.

[1] Due to the length of time required to process patent applications, 2008–2010 patent application data were too incomplete to be reliable at the time of data retrieval from PATSTAT.

2. PRIORITY FIELDS FOR RESEARCH AND INNOVATION COOPERATION BETWEEN THE EU AND INDIA

A comparative analysis framework based on bibliometrics (co-publications) and the analysis of co-patent applications has made it possible to identify and classify eight priority fields in research and innovation cooperation between the EU and India. The identified eight R&I priority fields also correspond reasonably well to those likely to be covered in the EU Common Strategic Framework.

The priority level assigned to each field of cooperation was cross-referenced with information on Indian researchers' involvement in international scientific and technological endeavours related to Grand Challenges, as well as with findings from various reports on specific fields of S&T cooperation between the EU and India. Information consistency was cross-checked against the analysis of official MS responses regarding S&T cooperation with India which were gathered using CREST WG Internationalisation[2] questionnaires to gauge countries' S&T cooperation with Brazil, India and Russia (Gnamus, 2009).

The distribution of the total patent applications from India in 2000–2007 and the fractional counts of EU–IN and US–IN co-patent applications in the same period are shown in **Figure 2.**

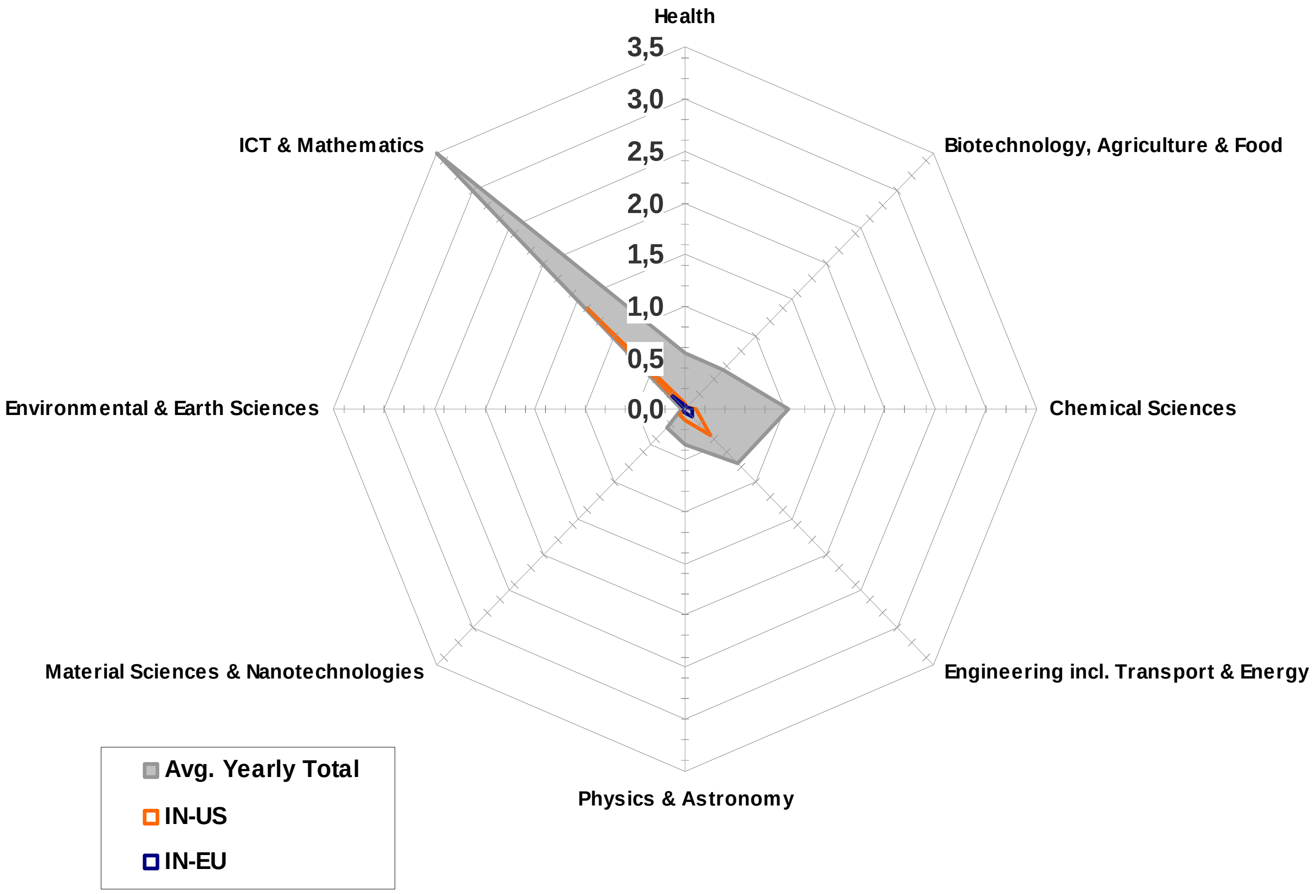


Figure 2: Distribution of total Indian, joint EU–IN and US–IN patent applications for 2000–2007 among the eight priority fields. (Note: All figures given in thousands).

[2] Now ERAC–SFIC (European Research Area Committee–Strategic Forum for International Cooperation)

The eight priority fields are consequently presented in decreasing order of Indian domestic and international (EU and US) innovation potential and this list therefore differs from the initial ranking based on the volume of Indian and EU–IN publications:

1. **Information and Communication Technologies (ICT) & Mathematics;**
2. **Engineering** including **Transport & Energy;**
3. **Chemical Sciences;**
4. **Physics & Astronomy;**
5. **Advanced Materials & Nanotechnologies;**
6. **Health, Medicine & Pharmaceutics;**
7. **Biotechnology & Bioengineering** including **Agriculture & Food;** and
8. **Environmental & Earth Sciences** including **Water-related Challenges.**

Due to the required brevity of this report, each priority field is summarised on a condensed one-page fact sheet. A short recap at the end of each sheet provides an assessment of EU and US R&I cooperation modalities with India based on a graphic comparison of co-publications vs fractional counts of joint patent applications by field, taking into account the total number of researchers (FTE) per 100 000 vs total EU/US population respectively.

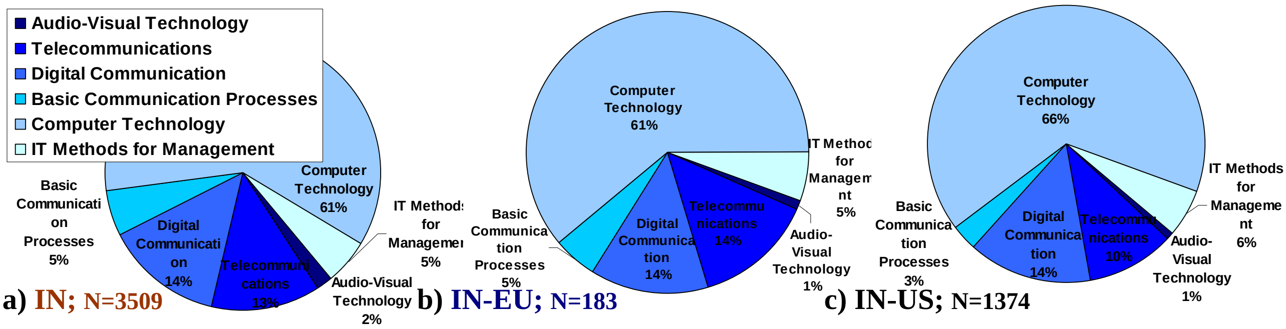
The assessments of EU and US R&I cooperation with India by sector demonstrate research and invention performance, that is, the dynamics of cooperative bilateral S&T activities, while also indicating researcher pool sizes and the economic/market potential of established cooperation practices (see Figures 4, 6, 8, 10, 12, 14, 16 and 18). The references also include additional documentation and background argumentation used to supplement purported inventive performance and support the rationale for identifying the most prolific specific technologies within each priority field. Source and methodology information for the patent data analysis is given in the Annex.

2.1. Information and Communication Technologies (ICT) & Mathematics

2.1.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US invention dynamics during 2000–2007 with potential for further high value-added cooperative R&I activities with India are shown in **Figure 3 a–c**.

Figure 3: Key specific technology areas in the priority field "ICT & Mathematics" ranked by the total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in 2000–2007.



2.1.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 1: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative research and innovation activities in the priority field "ICT & Mathematics".

India	EU	US
Honeywell International Inc. India	SAP AG (DE)	International Business Machines Corporation (IBM)
STMicroelectronics Pvt. Ltd.	Infineon Technologies AG (DE) / Siemens AG (DE)	Texas Instruments Incorporated
Indian Institute of Technology	Nagra Thomson Licensing S.A. (FR)	Microsoft Corporation

2.1.3. Key instruments used in R&I cooperation

Table 2: Key instruments supporting R&I cooperation of the EU and the US vis-à-vis India.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint mobility schemes & grants	Joint mobility schemes & grants
Joint research programmes	Business cooperation & knowledge-innovation clusters

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus, 2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.1.4. Research/invention performance in bilateral collaborative activities

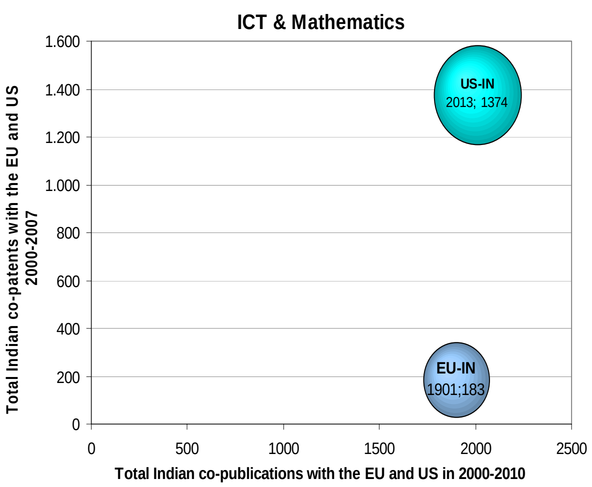


Figure 4: The research and invention performance of the EU and the US with India in "ICT & Mathematics" based on cooperative R&I activities in 2000-2007[4].

Analysis of the R&I performance benchmark indicates that US–IN innovation cooperation for ICT is more productive and efficient (co-patents IN–US ≈ 7.5×EU–IN). While the distribution of EU–IN patent applications among specific ICT sectors does not differ much from those of IN alone and US–IN, EU cooperative partners should focus more on the instruments supporting technology-oriented cooperation, explore IN and US potentials **(Computer Tech.)**, overcome R&I cooperation shortcomings and identify any gaps in the innovation process in each sector in India **(Telecommunications)** which could be filled by innovative EU partners. Besides specific traditional areas of Indian technological expertise, it could be interesting to examine **AV-Technology;** here, IN patent activities are stronger than those of the EU–IN and US–IN.

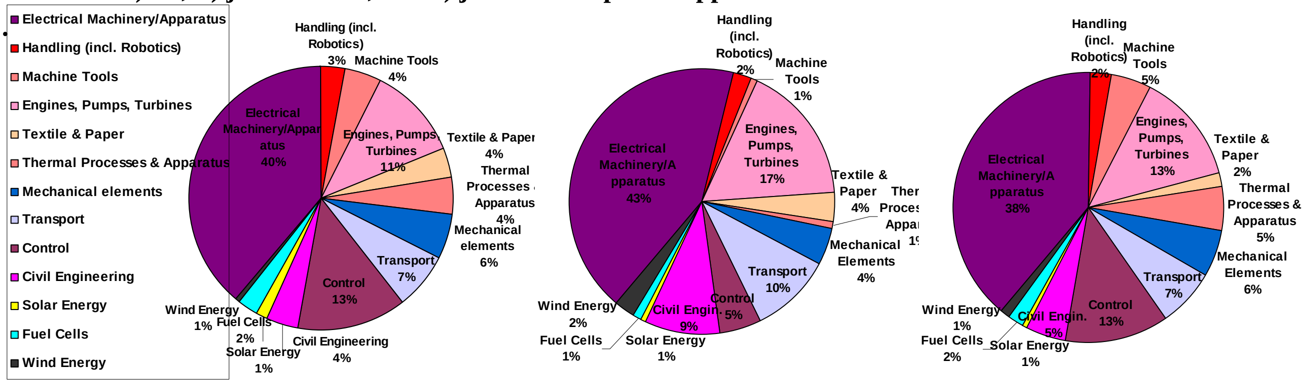
[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

2.2. Engineering including Transport & Energy

2.2.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with potential for further high value-added cooperative R&I activities with India are shown in **Figure 5 a–c**.

Figure 5: Key specific technology areas in "Engineering including Transport & Energy" by total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in 2000–2007.



a) IN; N=742 b) IN-EU; N=95 c) IN-US; N=364

2.2.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 3: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative R&I activities in the priority field "Engineering including Transport & Energy".

India	EU	US
Council of Scientific & Industrial Research	Robert Bosch GmbH (DE)	General Electric Company
Exide Industries, Ltd.	Forschungszentrum Jülich GmbH (DE)	Honeywell International Inc.
General Electric Company	NM Spintronics AB (SE)	GE Medical Systems Global Technology Company, LLC

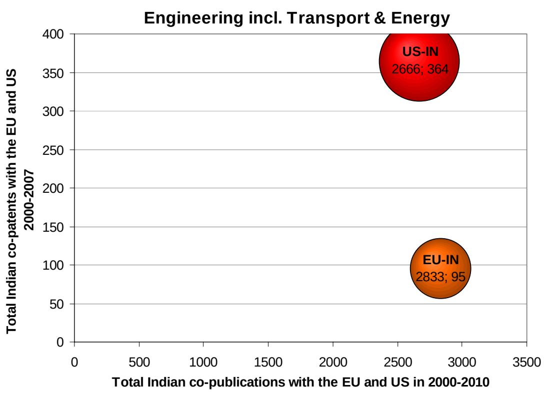
2.2.3. Key instruments used in S&T cooperation

Table 4: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Business cooperation & knowledge-innovation clusters
Business cooperation & knowledge-innovation clusters	Comprehensive R&I cross-sector partnerships

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus, 2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.2.4. Research/invention performance in bilateral collaborative activities



[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 6: Research/invention performance of the EU and the US in partnership with India in "Engineering" based on collaborative R&I activities in 2000–2007.

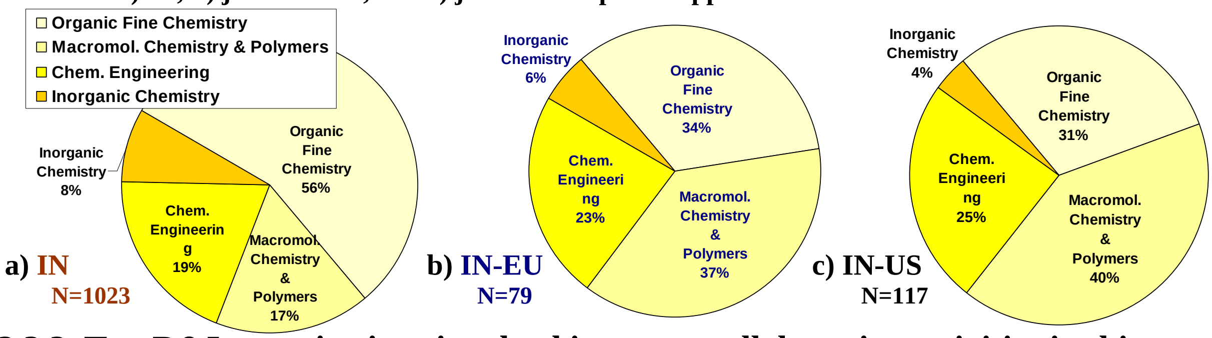
While the EU has a slight advantage in co-publications, the R&I performance benchmark indicates that IN–US innovation cooperation is more efficient (co-patents IN–US ≈ 4× EU–IN). The palettes of specific technology areas (Fig. 5) show that the EU could use its competitive advantage in sectors such as Machine Tools, Thermal Processes & Apparatus, Mechanical Elements and Control. Also it should better use its excellence in specific high-tech frontier engineering technologies: Transport (e.g. high speed trains) and RES Energy Technologies (Wind & Solar). Similarly, the EU should focus on instruments supporting technology-oriented cooperation, examine its competitor's potentials/shortcomings and identify gaps in innovation processes in specific sectors in India which could be complemented by innovative EU activities.

2.3. Chemical Sciences

2.3.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with a potential for further prolific high value-added collaborative R&I activities with India are shown in **Figure 7 a–c**.

Figure 7: Key specific technology areas in the priority field "Chemical sciences" ranked by total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in 2000–2007.



2.3.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 5: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative research and innovation activities in the priority field "Chemical sciences".

India	EU	US
Council of Scientific & Industrial Research	SABIC Innovative Plastics IP B.V. (NL-US)	General Electric Company
Torrent Pharmaceuticals, Ltd.	Creavis Gesellschaft für Technologie und Innovation mbH (DE)	Momentive Performance Materials Inc.
Indian Oil Corporation, Ltd.	Universidad Politècnica de Valencia (ES)	Exxon Mobil Chemical Patents Inc.

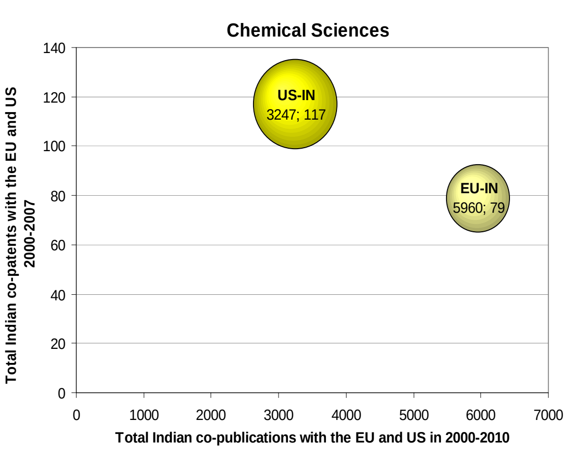
2.3.3. Key instruments used in R&I cooperation

Table 6: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Business cooperation & knowledge-innovation clusters
Joint large-scale research infrastructures and facilities	Comprehensive R&I cross-sector partnerships

[2] Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus, 2009) and CREST WG-Internationalisation questionnaires on countries' cooperation in science & technology with BR, IN and RU.
[3] Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.3.4. Research/invention performance in bilateral collaborative activities



[4] Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 8: The research/invention performance of the EU and the US with India in "Chemical sciences" based on collaborative R&I activities in 2000–2007.

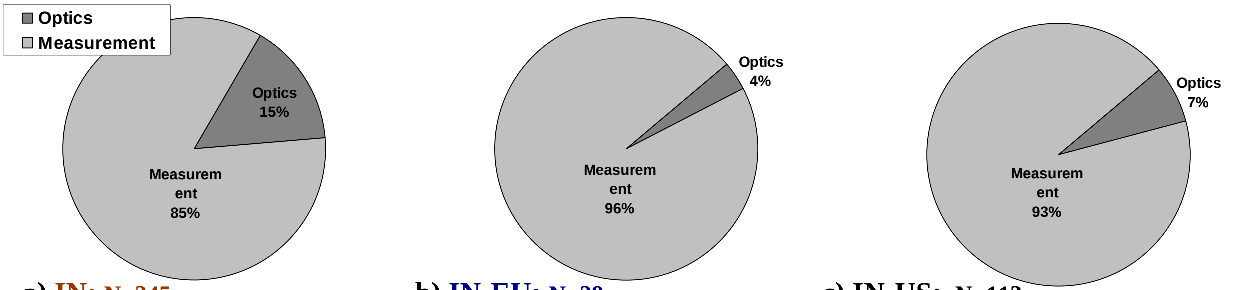
The EU holds a strong advantage in research performance (co-publications EU–IN ≈ 2×US–IN); however, the R&I performance benchmark indicates that IN–US innovation cooperation is more productive (co-patents IN–US ≈ 1.5× EU–IN). While the palettes of specific technology areas of the EU and the US are comparable (Fig.7), the EU could venture more actively into some sectors where IN shows a comparably high inventive capacity (Organic Fine Chemistry and Inorganic Chemistry). Also, the EU should use its competitive advantage in many pioneer technologies (e.g. fullerenes and carbon technologies and other high-tech fields of chemistry). Similarly, the EU should focus more on instruments supporting technology-oriented cooperation, explore its competitor's potentials and shortcomings and identify any gaps in innovation processes in specific sectors in India which could be complemented by innovative EU activities.

2.4. Physics & Astronomy

2.4.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with a potential for further prolific high value-added collaborative R&I activities with India are shown in **Figure 9 a–c**.

Figure 9: Key specific technology areas in the priority field "Physics & Astronomy" by total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in 2000–2007.



a) IN; N=345 b) IN-EU; N=28 c) IN-US; N=113

2.4.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 7: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative research and innovation activities in the priority field "Physics & Astronomy".

India	EU	US
Council of Scientific & Industrial Research	Robert Bosch GmbH (DE)	General Electric Company
Bose Institute, Kolkata	Polymeters Response International Ltd (UK)	Honeywell International Inc.
Honeywell International Inc.	Daimler Chrysler AG (DE)	Texas Instruments Incorporated

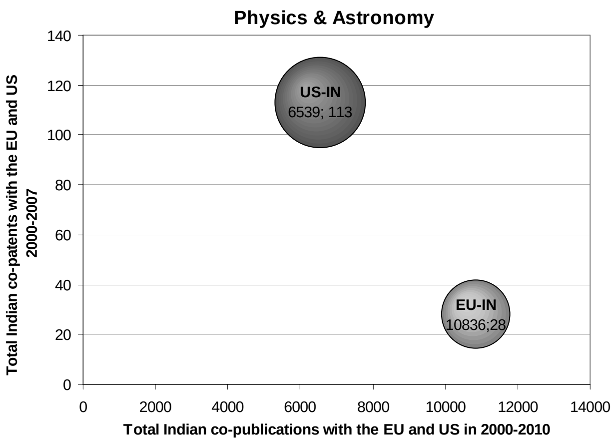
2.4.3. Key instruments used in S&T cooperation

Table 8: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Joint large scale research infrastructures
Joint science & academic networks	Comprehensive R&I cross-sector partnerships

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus,2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.4.4. Research/invention performance in bilateral collaborative activities



[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 10: The research/invention performance of the EU and the US with India in "Physics & Astronomy" based on collaborative R&I activities in 2000–2007.

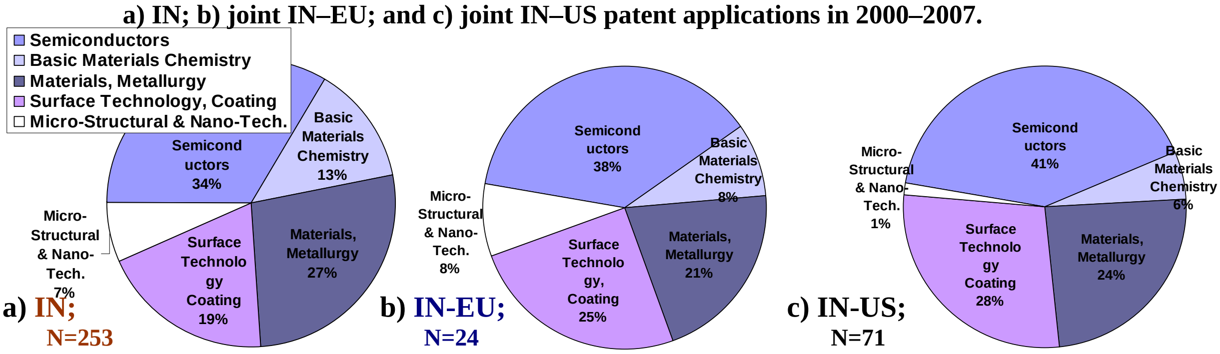
While the EU holds a considerable advantage in research performance (co-publications EU–IN ≈ 2×US–IN), the R&I performance benchmark indicates that IN–US innovation cooperation is more efficient (co-patents IN–US ≈ 4×EU–IN). Despite palettes for specific technology areas in the EU and US being similar (Fig. 9), the EU could venture more actively into the field of Optics where IN shows a comparably high inventive capacity. In addition, the EU could use the competitive advantage from its extensive knowledge in the field as demonstrated by its co-publications and focus on the instruments supporting technology-oriented cooperation. It should also identify any gaps in innovation processes in specific sectors in India that could be complemented by innovative EU activities.

2.5. Advanced Materials & Nanotechnologies

2.5.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with potential for further prolific high value-added collaborative R&I activities with India are shown in **Figure 11 a–c.**

Figure 11: Key specific technology areas in "Advanced Materials & Nanotechnologies" by total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in 2000–2007.



2.5.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 9: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative R&I activities in the priority field "Advanced Materials & Nanotechnologies".

India	EU	US
Council of Scientific & Industrial Research	NM Spintronics AB (SE)	General Electric Company
Jindal Steel & Power, Ltd. / Nalwa Sons Investments, Ltd.	ENEA (IT)	Texas Instruments Incorporated
India Iron & Steel Administrative Co., Ltd.	Saint-Gobain Glass (FR) / Hahn-Meitner-Institut Berlin GmbH (DE)	Hewlett-Packard Development Company, L.P. / IBM Corporation

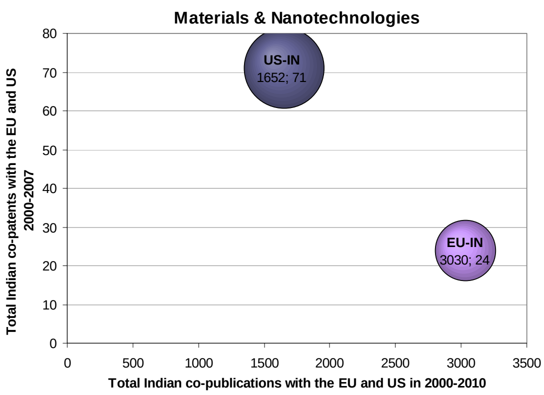
2.5.3. Key instruments used in S&T cooperation

Table 10: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Business cooperation & knowledge-innovation clusters
Joint science & academic networks	Comprehensive R&I cross-sector partnerships

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus,2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.5.4. Research/invention performance in bilateral collaborative activities



[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 12: The research-inventive performance of the EU and the US vis-à-vis India in "Advanced Materials & Nanotechnologies" based on the collaborative R&I activities in 2000-2007.

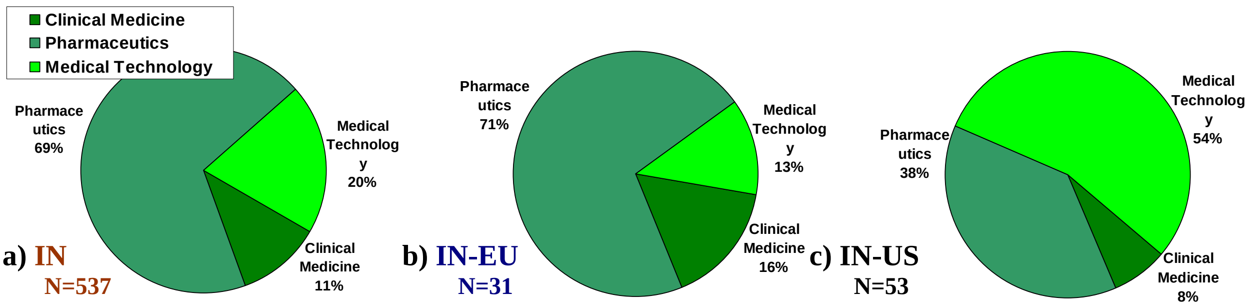
While the EU holds a substantial advantage in research performance (co-publications EU–IN ≈ 2×US–IN), the R&I performance benchmark indicates that IN–US innovation cooperation is more efficient (co-patents IN–US ≈ 3×EU–IN). Whereas EU–IN distribution of patent applications among specific sectors does not differ much from those of IN alone and US–IN (Fig. 11), EU collaborative partners should use the competitive advantage of their extensive knowledge in this field as shown by their co-publications, and focus on instruments supporting technology-oriented cooperation. They should also identify any gaps in innovation processes in specific sectors in India that could be complemented by innovative EU activities.

2.6. Health, Medicine & Pharmaceutics

2.6.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with potential for further prolific high value-added collaborative R&I activities with India are shown in **Figure 13 a–c.**

Figure 13: Key specific technology areas in "Health, Medicine & Pharmaceutics" by the total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in the period 2000–2007.



2.6.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 11: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative R&I activities in the priority field "Health, Medicine & Pharmaceutics".

India	EU	US
Council of Scientific & Industrial Research	Niche Generics, Ltd. (UK)	General Electric Company
Ranbaxy Laboratories, Ltd.	Röhm GmbH & Co KG (DE)	GE Medical Systems Global Technology Company, LLC
CIPLA Ltd.	ETHYPHARM (Société Anonyme) (FR)	Vyteris, Inc.

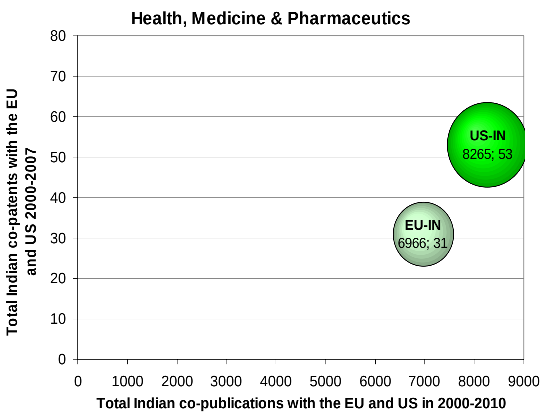
2.6.3. Key instruments used in S&T cooperation

Table 12: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Business cooperation & knowledge-innovation clusters
Joint mobility schemes & grants	Comprehensive R&I cross-sector partnerships

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus, 2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US-IN co-patent applications in PATSTAT.

2.6.4. Research/invention performance in bilateral collaborative activities



[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 14: Research/inventive performance of the EU and the US with India in "Health, Medicine & Pharmaceutics" based on collaborative R&I activities in 2000–2007[4].

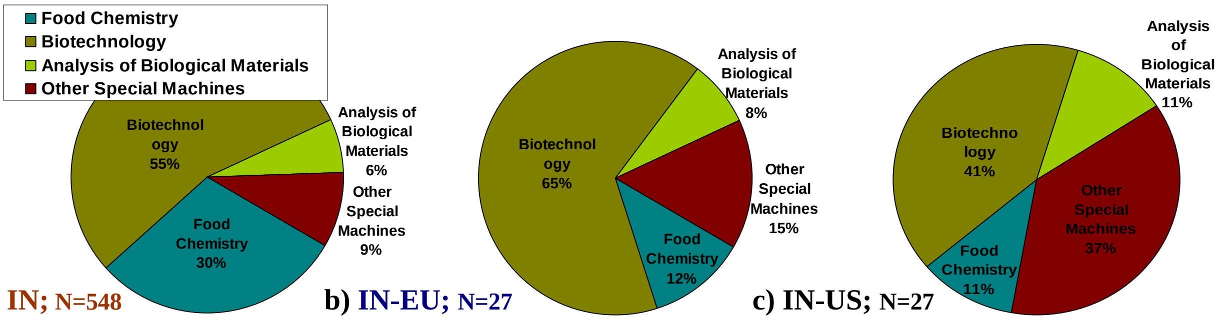
Comparison of both R&I co-publication and co-patent numbers indicates that the EU is trailing the US in R&I cooperation with India in this sector. Despite palettes for specific technology areas being similar between the EU and IN (Fig.13), the EU could venture more actively into the field of Medical Technology, which appears to be dominated by the US, and where IN shows a comparably high inventive capacity. There could be several reasons explaining EU underperformance in comparison to the US: use of less adequate S&T cooperation instruments, poor coordination of targeted R&I policies and possibly having a less favourable percentage of SMEs actively involved in innovative activities. A more specific analysis is needed to identify the underlying reasons.

2.7. Biotechnology & Bioengineering including Agriculture & Food

2.7.1. Important technologies in this priority field in India

The key technologies in this priority field, based on the Indian, joint IN-EU and IN-US inventive dynamics during 2000-2007 with potential for further high value added collaborative R&I activities with India are shown in **Figure 15 a-c.**

Figure 15: Key specific technology areas in "Biotechnology & Bioengineering" by the total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in the period 2000–2007.



a) IN; N=548 b) IN-EU; N=27 c) IN-US; N=27

2.7.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 13: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative research and innovation activities in the priority field "Biotechnology".

India	EU	US
Council of Scientific & Industrial Research	Evonik Industries / Degussa AG (DE)	International Business Machines Corporation (IBM)
Reliance Life Sciences Pvt. Ltd.	Forschungszentrum Jülich GmbH (DE)	NEC Research Institute, Inc.
Dabur Research Foundation	CNRS / INSERM (FR)	General Electric Company

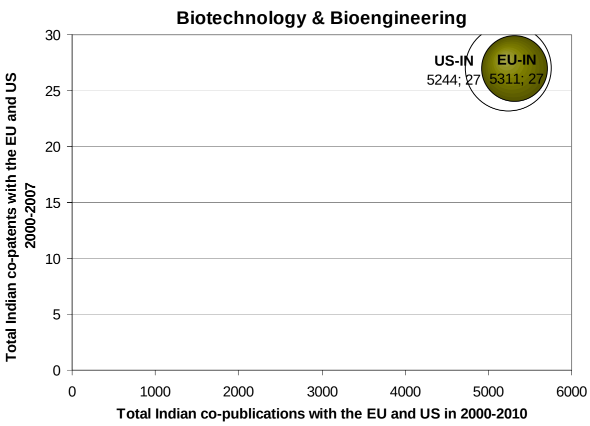
2.7.3. Key instruments used in R&I cooperation

Table 14: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Technology-oriented cooperation
Joint research programmes	Business cooperation & knowledge-innovation clusters
Business cooperation & knowledge-innovation clusters	Comprehensive R&I cross sector partnerships

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus,2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.7.4. Research/invention performance in bilateral collaborative activities



[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

Figure 16: The research/inventive performance of the EU and the US with India in "Biotechnology" based on collaborative R&I activities in 2000–2007.

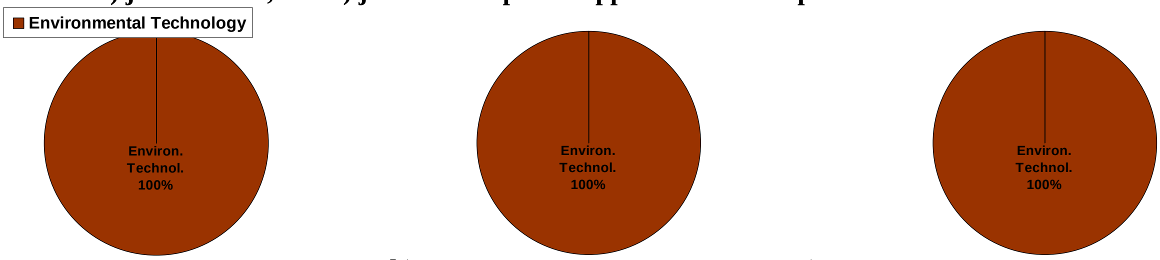
R&I performance in terms of both co-publications and co-patents for both the EU and US in partnership with India in this priority area are comparable. Since the palettes of the specific technology areas in the EU and US are quite different (Fig. 15), the EU should venture more actively into the sector of Food Chemistry where IN shows a comparably high inventive capacity and where the US competitiveness does not appear to be dominant. Measured by overall co-patenting activity in this area, the EU's competitiveness remains comparable with that of the US; however, the low number of patent applications does not correspond to the potential that this sector offers for future R&I cooperation with India. Considering the pressing needs in that heavily populated country, this sector represents the greatest potential for the future.

2.8. Environment & Earth Sciences including Water-related Challenges

2.8.1. Important technologies in this priority field in India

The key technologies in this priority field, based on Indian, joint IN–EU and IN–US inventive dynamics during 2000–2007 with potential for further prolific high value-added collaborative R&I activities with India are shown in **Figure 17 a–c.**

Figure 17: Key specific technology areas in "Environment & Earth Sciences" by the total number of a) IN; b) joint IN–EU; and c) joint IN–US patent applications in the period 2000–2007.



a) IN; N=43 **b) IN-EU; N=7** **c) IN-US; N=9**

2.8.2. Top R&I organisations involved in recent collaborative activities in this priority field

Table 15: Top three applicant legal entities in India, the EU and the US holding IPRs to the most prolific cooperative R&I activities in the priority field "Environment & Earth Sciences".

India	EU	US
Council of Scientific & Industrial Research	Robert Bosch GmbH (DE)	General Electric Company
National Institute for Interdisciplinary Science and Technology (NIIST)	Institut National de la Recherche Agronomique (INRA) (FR)	Nalco Holding Company (formerly Ondeo Nalco)
General Electric Company	Biothane Systems International B.V. (NL)	-

2.8.3. Key instruments used in S&T cooperation

Table 16: Key instruments supporting R&I cooperation between India and the EU or US.

EU vs India[2]	US vs India[3]
Joint research projects	Joint research projects
Joint research programmes	Business cooperation & knowledge-innovation clusters
Joint mobility schemes & grants	Joint mobility schemes & grants

[2]Based on the Comparative report on S&T cooperation of ERA countries with Brazil, India and Russia (Gnamus,2009) and CREST WG-Internationalisation questionnaire on countries' cooperation in science & technology with BR, IN and RU.
[3]Assessment based on the NSF (2010), available literature data and analysis of US–IN co-patent applications in PATSTAT.

2.8.4. Research/invention performance in bilateral collaborative activities

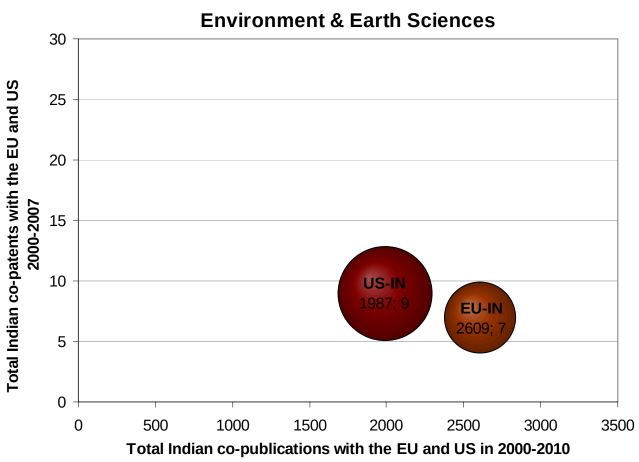


Figure 18: The research/inventive performance of the EU and the US with India in "Environment & Earth Sciences" based on collaborative R&I activities in 2000–2007.

While the EU holds a substantial advantage in research performance (co-publications EU–IN ≈ 2×US–IN), the R&I performance benchmark indicates that innovation cooperation in this priority area is very low but comparable to India's. The EU could fortify established cooperative links for water-related challenges and use its competitive advantage of extensive knowledge in the field as shown by its co-publications. The low level of co-inventive activities indicates substantial potential for future cooperation in this field.

[4]Note: Circle size equal to ratio: total number of researchers (FTE) per 100 000 vs total EU / US population respectively (EC, 2011).

3. SUMMARY OF MAIN FINDINGS

The main findings are summarised in accordance with the three main aims of this study:

- to identify key thematic areas or priority fields for EU and MS research and innovation in cooperation with India;
- to identify major partners in India, the EU and the US (institutes, universities, enterprises) that undertake cooperative S&T activities in the selected thematic areas;
- to identify key modalities and instruments (including institutional cooperation) used in bilateral cooperation with India in these thematic areas.

In addition, benchmarking of successful US–India R&I cooperation practices was performed based on co-publications in 2000–2010 and co-patents in 2000-2008. We attempted to identify challenges affecting EU–India R&I cooperation versus those present in US–India cooperation in order to pinpoint where and why the US enjoys certain strategic advantages in research and innovation cooperation with India.

3.1. Key priority fields of the EU–India collaborative R&I activities

The top priority fields for collaborative R&I activities with India, based on the strengths of the Indian research and innovation system in 2000–2010, are as follows:

1. **Information and Communication Technologies (ICT) & Mathematics;**
2. **Engineering** including **Transport & Energy;**
3. **Chemical Sciences;**
4. **Physics & Astronomy;**
5. **Advanced Materials & Nanotechnologies;**
6. **Health, Medicine & Pharmaceutics;**
7. **Biotechnology & Bioengineering** including **Agriculture & Food;** and
8. **Environmental & Earth Sciences** including **Water-related Challenges.**

According to the analysis of the EU–India co-publication and co-patenting information, R&I cooperation intensity did not always correspond to the strongest thematic priority areas for Indian partners and the Indian R&I system. It appears that the EU's cooperative R&I activities with India often adhere to the structure of the EU Framework programme and its calls for projects rather than playing to Indian partners' strengths in priority areas. Nevertheless, the analysis of EU–India co-publications and co-patents mostly followed the priority areas of S&T cooperation most frequently indicated by the MS in the CREST WG Internationalisation questionnaires (Gnamus, 2009), which demonstrated emphasis on ICT, Biotechnology & Bioengineering, Health, Medicine & Pharmaceutics, followed by Environment, Life Sciences & Genetics, Engineering including Energy and Advanced Materials.

While the true strength of EU–IN collaborative activities in research can be assessed through numbers of co-publications, their strength in technology and innovative competitiveness is best reflected by co-patent figures, although patenting may be a less favoured way of protecting intellectual property in certain priority fields. Nevertheless, comparative analysis of R&I collaborative activities for the EU and India in 2000–2007 showed the following figures: ICT (183), Engineering (95), Chemical Sciences (79), Health, Medicine & Pharmaceutics (31), Physics & Astronomy (28), Biotechnology & Bioengineering (27), Advanced Materials & Nanotechnologies (24), and Environment & Earth Sciences (7). Note that the numbers are rounded fractional counts of patent applications' authors and the listed coverage of technology fields.

3.2. Main partners undertaking collaborative R&I activities in India, the EU and the US

Top three partners by priority fields for R&I cooperation between India and the EU or the US

On the Indian side, the institution holding IPR royalties and involved in most collaborative R&D activities is the Council of Scientific and Industrial Research, which appeared among the top three to five patent applicant legal entities in all of the priority fields, followed by a few India-based multinational companies and corporations. To a certain extent, some Indian national institutes and foundations are also among those closely involved in international R&I activities.

While individual patent applicants were not considered in this count, EU legal entities undertaking collaborative R&D activities with India mostly consisted of large corporations; the top three legal entities for each priority field were occupied by large multinational companies headquartered in DE, FR, UK, SE and NL. In a few priority fields (materials, biotech and the environment), national research institutes and universities were among the top three partners (IT, ES and FR).

As regards top US partners for R&I cooperation with India, large multinational corporations headquartered in the US were the only legal entities receiving IP royalties for patents during 2000–2007 (see Chapters 2.1–2.9).

3.3. Key collaborative activity instruments/modalities used by the EU in bilateral R&I cooperation with India

The main modalities/instruments identified for collaborative activities between the EU and India varied somewhat among different priority R&I cooperation areas. However, **joint research projects** and **joint research programmes** represented the main part of the collaborative instruments in all priority fields. **Joint mobility schemes and grants** for scientist exchange programmes made the top three instruments in the priority fields of ICT, Health and Environmental/Earth Sciences. **Joint science and academic networks** appeared among the important instruments in the fields of Physics & Astronomy and Advanced Materials & Nanotechnologies. **Business cooperation and knowledge-innovation clusters** were mentioned in the fields of Engineering including Transport & Energy and in Biotechnology. **Joint large-scale research infrastructures and facilities** appeared as an important instrument in the field of Chemical Sciences and Physics & Astronomy.

For comparison purposes, we also identified the main modalities/instruments used in US–IN cooperation. Here, regardless of the priority field, the main instruments for collaborative activities were **technology-oriented cooperation**, **business cooperation and knowledge-innovation clusters** and comprehensive **R&I cross-sector partnerships**. All of these instruments demonstrate that innovation is a very active component of in R&D cooperation, and one that corresponds to the US' leading position in cooperative invention with India.

3.4. Research/inventive performance in collaborative activities with India

Research/inventive performance in bilateral collaborative activities undertaken by the EU in partnership with India was assessed using the US benchmark. The top eight priority fields are compared in **Figure 19**.

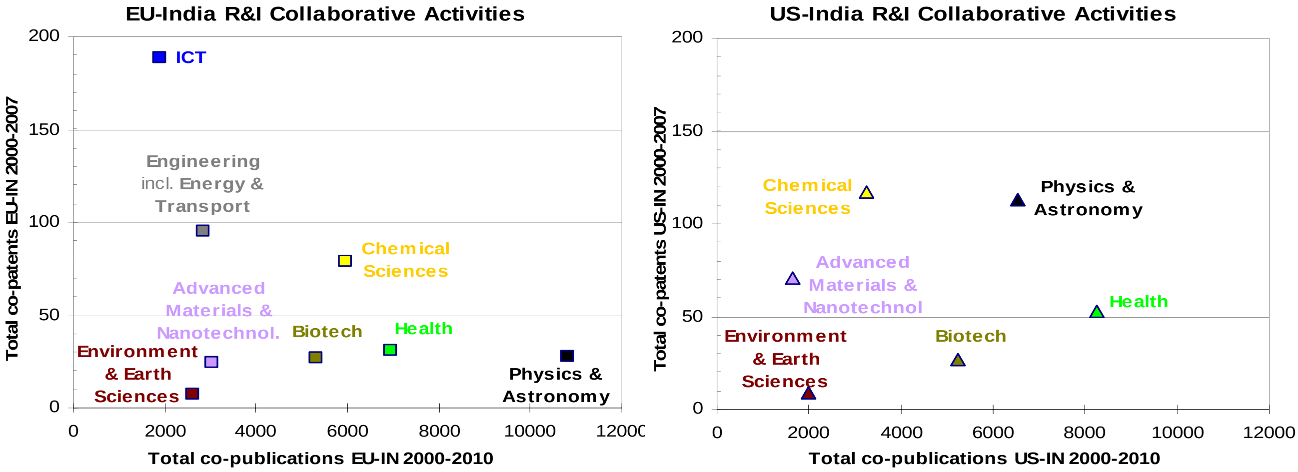


Figure 19: Benchmark of research/inventive performance of collaborative activities undertaken by India with the EU or the US by priority fields. Note: The US–IN figures for co-patent applications in the ICT (N=1374) and Engineering (N=364) are too high to be shown on the comparative scale.

While the EU has remarkable comparative advantages in terms of total numbers of co-publications with India in all selected priority fields except "Health, Medicine & Pharmaceutics" and "Biotechnology", the US is clearly predominant in the area of innovative performance of activities undertaken in partnership with India in most of the R&I priority cooperation fields. Invention activity, demonstrated by co-patenting performance benchmarks, clearly shows that US–IN cooperation was more efficient than that of the EU–IN in most of the top priority fields except for "Biotechnology" and "Environment & Earth Sciences", where the EU remained competitive. However, in the examined period 2000–2007 these two R&I fields were characterised by a rather low overall number of joint patent applications for both research communities in partnership with India (e.g. Biotechnology: 27 joint EU–IN vs 27 joint US–IN patent applications; Environment & Earth Sciences: 7 vs 9 joint patent applications respectively — see also Figures 16, 18 and 19). The low number of joint patent applications could also point to the existence of other means of intellectual property protection or different market strategies. Nevertheless, the situation appears to be the result of the EU and its MS having a more fragmented and less market-oriented R&I environment, unsuitable instruments for supporting R&I cooperation with India, the different structure of R&I enterprises and other stakeholders in the EU with respect to the US and lower involvement of SMEs and spin-offs in the EU's activities with India compared to that in US-IN collaborative activities. One of the possible scenarios for improving the competitiveness of EU and MS R&I activities in partnership with India would be improving support for the innovation part of the R&I cycle through launching targeted support measures for SMEs and high-tech spin-offs in the priority fields of R&I cooperation, as they are more flexible and better able to compete in the global market. Further dedicated studies will be needed in order to address specific problems and identify proportionate and adequate measures to improve EU competitiveness in its collaborative R&I activities with India.

Research/inventive performance in EU-India bilateral collaborative activities was assessed using the US as a benchmark. While the EU has remarkable comparative advantages in research performance as measured by total numbers of co-publications in all selected priority fields except "Health, Medicine & Pharmaceutics" and "Biotechnology", the US is clearly predominant in innovation performance as measured by collaborative patent activities with India. The exceptions were two fields: "Biotechnology" and "Environment & Earth Sciences".

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ANNEX - Source and methodology for patent data

The PATSTAT database

The results presented in the section 2 of this report are based on analysis performed on a subset of the PATSTAT database. The PATSTAT database is the European Patent Office (EPO) Worldwide Patent Statistical Database; it provides a snapshot of the data available in the EPO's 'master bibliographic database DocDB' at a specific point in time, and it is updated twice a year. Data extracted from the source database cover nearly 90 national Patent Offices, the World Intellectual Property Organisation (WIPO) and the EPO.

A brief description of the main methodological aspects is given below. However, for a more complete and detailed description of the methodology followed, please refer to Predict 2011 Report (Turlea et al., 2011), to ICT Internationalisation Report (Nepelski et al., 2011), and to Picci (2009).

Priority applications

A number of steps have to be taken in the process of patenting an invention. When the application is first filed at a patent office by an applicant seeking patent protection, it is assigned a priority date (in the case of a first filing in the world) and a filing date. The filed application could become a granted patent, being then assigned a grant date, if no reasons for refusing the application have been raised during the process of analysis of the subject, novelty, non-obviousness and industrial applicability of the invention.

The indicators proposed in this study aim to provide the best measure of the inventive capability of countries, rather than of the productivity of patent offices. To achieve this objective, patent applications are taken into account, rather than granted patents. The reasons behind this choice are manifold and documented in the scientific literature on patent statistics. In the present report, therefore, references made to 'patents' always mean 'patent applications'. Moreover, the considered subset of data includes only 'priority patent applications'; this means that only the first filing of an invention is considered and all the possible successive filings of the same invention to different patent offices are not counted again. An invention is therefore counted only once. 'Priority patent applications' are considered a more suitable proxy measure of inventing capability, even though a number of shortcomings have been pointed out by the literature (OECD, 2009; De Rassenfosse et al., 2009).

Data set considered: patent offices and years covered

The analysis proposed in the present report is based upon the April 2010 release of the PATSTAT database. The subset of data considered included all priority applications filed in any of the Patent Offices taken into account: the EPO, USPTO, JPO; national patent offices of the 27 EU Member States; the national patent offices of Arab Emirates, Australia, Brazil, Canada, Chile, China, Columbia, Croatia, Hong Kong (Hong Kong SAR), Iceland, India, Indonesia, Israel, Korea, Malaysia, Mexico, New Zealand, Norway, Pakistan, Philippines, Puerto Rico, Russia, Singapore, South Africa, Switzerland, Taiwan (Taiwan Province of China), Thailand, Turkey, and Vietnam. To avoid taking into account data affected by delays in the updating procedure of the database, the analysis considers only the period between 2000 and 2007, even though more recent data is available.

Assigning patents to countries and regions

The literature commonly refers to the possibility of adopting two alternative criteria in order to assign patents to countries: it is possible to refer to either the declared country of residence of the inventor(s) ('inventor criterion') of a patent, or to that of the applicant(s) ('applicant

criterion')[3]. According to patenting rules, the applicant is "the holder of the legal rights and obligations on a patent application", i.e., the patent owner (see OECD 2009). The applicant is in many cases a company or a university, but it could also be an individual.
Several applicants could hold rights on a patent application, and they would have legal title to the patent once (and if) it is granted. In the same way, several inventors could have taken part in the development process of the invention, and be listed in the patent application. A *fractional count* is applied in order to assign patents to countries in cases where several inventors (or applicants) with different countries of residence have to be considered for the same application.

In this study, the adoption of the inventor criterion has been chosen. In general, the choice of the criterion depends on the perspective from which innovative capability is being investigated. As mentioned above, the dataset includes all priority applications filed at selected 59 Patent Offices. It must however be made clear that, in the cases where the inventor criterion is used, we call 'EU applications', those applications in which EU-based inventors are involved, and not all applications to EU patent offices (which can involve EU-based or non-EU-based inventors). In the same way, 'US applications' are those involving US-based inventors rather than those filed to USPTO (which can involve US-based or non-US-based inventors). Moreover, the application of the fractional count implies that, in the case where an application has several inventors with different countries of residence, for that specific application a value lower than a unit will be assigned to each of the respective countries. The use of fractional count of patent applications, by assigning 'fractions' of a patent application to different countries depending on the country of residence of each of the inventors (or applicants), produces, as a consequence, decimal figures in the number of patent applications per country.

Patent-based measures of internationalisation

Methodology of constructing measures of internationalisation based on information included in patent applications is described in OECD (2008). This methodology is based on the fact that each patent application has a list of inventors, i.e., the people who developed a particular invention; and a list of applicants, i.e., the people who own the property rights over this invention. The analysis uses measures of internationalisation that are based on the presence of inventors and/or applicants residing in different regions of the world among the list of people who file a patent application. An international patent application is defined in the analysis presented here as a patent application with people and organizations residing or located in different countries or regions, for example, in the US and the EU. It is, however, important to note that, intra-EU patent applications are not considered here as international patents. For

[3] 'EU-based' inventors are inventors (persons or companies, as declared in the patent applications) whose country of residence (or that of registration for companies) is one of the 27 EU Member States. Please note that, notwithstanding the effort by European Patent Office (EPO) for a constant and effective improvement of the quality and coverage of data provided, only 50% of country codes are present in the database (European Patent Office, 2010). The missing countries of residence are attributed by means of several procedures, continuously updated and discussed in literature (OECD, 2009; Picci, 2010; De Rassenfosse et al., 2010). This fact stands as one of the main reasons behind some differences in figures in the time series of each annual report (other reasons have to be found in the constant updating and refining of data provided by Patent Offices to EPO and in turn by EPO by means of PATSTAT, and in the minor intrinsic effect of applying a different software tool). EPO works on reducing the amount of missing country information (by filling the missing codes with the country of publication in the next editions), but at present time the attribution of country codes by means of a set of subsequent procedural steps is the only alternative commonly adopted worldwide. It must be noticed that the lack of information about the country of inventors (and applicants) has noticeable consequences in the case of Japan, as EPO does not receive this information on Japanese data and therefore for Japanese documents PATSTAT does not explicitly indicate the country (European Patent Office, 2010), which is then assigned in all possible cases by means of procedures. Thus, the huge number of Japan-based inventors could hide a share of inventors resident in countries different from Japan, but which it is not possible presently to identify. Finally, the country does not necessarily hold a reference to the 'nationality' of inventor or applicant (European Patent Office, 2010).

example, a patent application having only a German inventor and/or applicant and a French inventor and/or applicant, is not considered here as international.

The measure of innovation internationalization used in this report is based on the concept of co-invention. A co-invention concerns a patent with at least two inventors residing in different countries or regions, e.g., a patent with an EU and a non-EU inventor. This concept captures international co-inventions and is used to construct a relative measure of international collaboration between inventors.

Technology fields - classes

With regard to the identification of technology fields - classes, Based on the bibliometric analysis of the EU-India co-publications there were 8 priority fields identified. Consequently, the IPC classes of patent applications were grouped into the corresponding groups. The assignment of IPC classes to technological field was made based on the WIPO concordance table (WIPO 2010) and all the outliers were grouped into the 8 classes by best matching principle. The fractional counts approach has also been applied in case of applications referring to more than one technology class.