Application of patent statistics for cross-country comparison of innovation activity/technological change: A case study of China and India

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Abstract

Indian and Chinese patenting activity in US patent system are analysed from different perspectives. Two types of patenting activity are analysed — patents assigned (PA), and patents invented but not assigned (PNA). Within each of these two types, patents are further segregated in terms of their categories of patents — utility, design, and plant patents. Based on these delineations, the characteristics of their patenting activity are uncovered. Patents are further matched to technology sector to uncover their relative strengths and weakness' in various technology sectors/sub-sectors.

PA and PNA patents of both the countries show differences in terms of different types of institutions involved in patenting and the collaborative linkages among institutions. In case of China, patents addressing technology sectors do not exhibit major difference within the two types of patents. On the otherhand India's PA and PNA patents exhibit major difference in the technology sectors being addressed. Cross-national comparisons show marked difference among PA patents of India and China. However, PNA patents of both these countries exhibit similarity. The difference is only in the categories of their patents. The study suggests that the various distinctions explored in this paper can be useful for policy analysis.

Introduction

Patent document provides rich source of details for looking at various aspects of inventive/innovative activity of firms, industries, and countries (Griliches, 1990; OECD, 1994). The various attributes which comprises a patent document have been exploited in number of studies with different research questions under examination. Researchers have also questioned going too far in applying patent statistics due to inherent limitations and variations in different industries/firms regarding patenting activity (see for instance Wakelin, 1997). These studies at-least brings forth the point that researchers must keep these aspects in consideration while drawing conclusions based on patent statistics. However, one does find most patent based studies use simple patent counts to reflect technological activity or tend to correlate with export data, r&d and the like without highlighting the drawbacks (Pavitt, 1985; Tong and Frame, 1994). Further most of the studies based on patent statistics to investigate technological issues and the like have largely focused on developed countries and less developed and developing countries have remained unrepresented.

The present study investigates the patent activity of two developing countries — China and India, in the US patent system. These two countries provide an interesting case for applying patent statistics as both are engaged in technology based economics growth, and compete with each other in many sectors. It is difficult to appropriate their actual technological competitiveness through other statistics. It is assumed that there is a propensity of both of them to patent their invention in the US patent system, as it is the major market for both.

Studies based on patent statistics of a country(ies) have been applied in two complementary ways; to correlate patents of a country(ies) under various technological sectors/sub-sectors, degree of collaboration, and the like, and secondly to map/compare the technological strength in relation to world profile (see for instance, Narin

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1987 & 1988, Grupp & Schmoch, 1999). Studies have also been done to see whether there is an impact of patents on exports, r&d activity and the like (Basberg, 1983). To an extent these type of studies based on patent statistics are possible for the above two countries (India/China). However, caveats apply when these statistics are used for exploring the relative strength of countries, particularly vis-à-vis world profile when there is low volume of patent activity. Applying relative indicators on the low value results in negligible numbers. This applies in this case for India and China as both have low intensity of patent activity in US. *This calls for reworking the patent data which can reflect the cross-country and relative changes. This paper attempts to address this.* The paper envisages that this approach can be useful in policy analysis of innovation activity/technical change of a country or in cross-country comparison. Examining the patents in the local system which can show another dimension of their technological activity is not explored in this paper. Cross-national comparison in this study is done by analysing their activities under various categories of patents, types of institutions involved in patenting, and the collaboration activity among them. Their patents are matched to technological sectors and similarity/difference in addressing the various technological sectors by their patents are analysed. Another dimension of patenting activity of both the countries are analysed based on patents 'invented' by them but not 'owned' by them (Trajtenberg, 2001). Implications of the results are then discussed.

Methodology

The patent activities of these two countries, India and China, in the US patent system, are examined over a six years time period, from 1996 to 2001. The USPTO (United States Patent and Trademark Office) database was used for retrieving the patent data. All the patents from 1996-2001 in which the first inventor belonged to India (similarly for China) were downloaded. Additionally patents assigned and not invented (this also includes those patents whose first inventor is not from India/China) were also downloaded. All the patents assigned to India (or China) were kept in separate files and were designated as *assigned patents category* (PA). All those patents whose first inventor were from India/China and not assigned to them were kept in files designated as *patents invented and not owned by them* (PNA). These two files PA and PNA were used for analysis. To even out short-term fluctuations in patenting, the data was aggregated over two-year periods: 1996-1997, 1998-1999, 2000-01. We further segregated the PA and PNA patents under the various patent categories: *utility*, *design* and *plant* patents (please see note 1). *The matching of patents to technological categories have been analysed in this study only for utility patents as they address functional aspects in contrast to design patents which are granted only for ornamental features of an invention.*

Inventors are those individuals directly responsible for carrying out the innovation embedded in the patent. Assignee is the legal entity that owns the patent rights, assigned to it by the inventor(s). According to the conventions of the US patent office, the 'nationality' of a patent is determined by the address (at the time of application) of the first inventor (OECD, 1996b). That is, if a patent has many inventors and they are located in a variety of countries, the address of the first inventor on the patent determines to which country it is deemed to belong. Likewise, if the assignee is located in a country different from that of the first inventor, it is once again the location of the latter that determines the nationality of the patent. This rationale was applied in classifying the patents as PNA patents.

Two types of classification of patents were done. One was based on type of institution which has taken patents (Bhattacharya and Nath, 2002). For this we created five categories: industry (I), university/academy (U), research institute (R), special institutes, including hospitals (S), and individuals (P). This was done for uncovering the type of institutions involved in patenting and determining the nature and type of their collaborations.

Another classification was done by appropriating patents into technological categories based on the classification scheme designed by Hall, et. al. (2001), which appropriates the 400 patent classes applied in classifying the US patents, into 36 'technological sub-categories', and further aggregated into six categories:

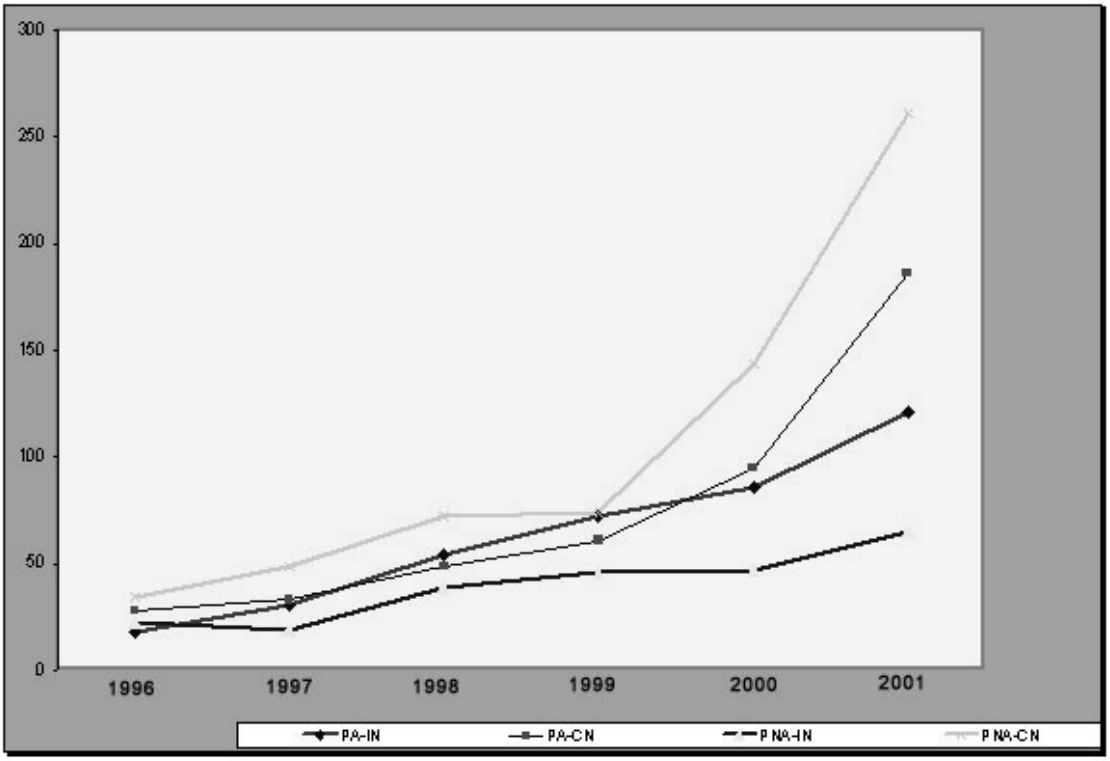
computers & communications, electrical and electronics, drugs and medicine, chemical, mechanical, and others. *Note 2 details the various sub-sectors under each sector as classified by Hall, et. al.* (2001). This classification allows analysis of patent activity in major technological sectors, and sub-sectors. This also helps to focus on areas considered as growth engines of new economy: computers and communications (CC), and drugs and medical (which include biotechnology as a subsector). Activities in traditional fields are also possible to be analysed with the help of this appropriation. It is to be noted that a single patent can be classified under more then one sub-sector (sub-sectors belonging to the same sector or different sectors) as the classification of patents into sectors/sub-sectors depends on the patent being classified by US patent office in one/more then one class. The cross-classification of patents was also investigated providing an indication of the linkages among sectors/sub-sectors. For proper comparison of patents of a country (this includes PA and PNA patents), patents in each sector are normalized by utility patents, and sub-sectors by total patents in a sector. For cross-national comparison, patents in each sector as well as in sub-sector are normalized by its utility patent. These normalizations pertain to total utility patents, and total patents in each sector and sub-sector for each of the three time period (96-97, 98-99, and 2000-01).

RESULTS

Patenting trends of India and China

Both the countries show significant growth in PA patents over the time period of this study (96-2001). There has been an increase of approx. four times the number of patents granted to China and India in 2000-01 in comparison to 96-97. PNA patents also exhibit growth which is steeper for China. The increase for China is approx. five times from 96-97 to 2000-01 (83 to 405 patents), whereas for India the increase is approx. three times (from 42 to 112 patents). *Figure 1 highlights this further*.

Figure1: Patenting Activities of India and China - PA and PNA



China's patent growth in PA has been mainly because of steep increase in design patents (from mere 8 in 96-97 to 148 design patents in 2000-01). India's growth has been in the utility patents itself. Similar phenomena are seen in case of PNA patents also. Design patents in PNA category of China was mere 6 in 96-97 which increased to 133 in 2000-01. Similar to PA patents, increase in PNA patents of India has mainly been due to the growth in utility patents.

Overall, the assigned patents (PA) for India and China within the time-period (96-2001) were 382 and 452 patents respectively. Of the 382 patents, 370 patents were invented from India (this is defined in terms of the address of the first inventor belonging to India), and the rest 12 patents were not invented (this may include also those patents having inventors from India, but none of them being the first inventor). This implies that the assigned patents reflect in majority of cases the innovative activity within the country for India. For China, among the 452 assigned patents, 305 patents were invented from China and the rest 147 patents not invented. This probably indicates that China has potential for attracting innovations not undertaken in their country. Large number of Chinese patents are observed to be invented in Taiwan and assigned to China. Of the 452 PA of China, 256 were utility patents and the rest 167 were design patents. Of the 382 PA of India, 372 are utility patents, 8 being design patents and 2 plant patents. This shows a marked difference between Chinese and Indian patent activity.

PNA patents within the time-period (96-2001) total 634 and 239 patents from China and India respectively. This indicates a large number of patents in which by USPTO convention are attributed to China, in real terms they belong to other countries were they are assigned. This number as we observe is much lower for India. We do not attempt to analyse the countries where these patents are assigned as it is not the intended focus of this paper. Of the 634 PNA Chinese patents, 467 belong to the utility patents and the rest 167 patents belong to design patents. In case of India's PNA patents, out of the 239 patents, 231 are utility patents, seven patents are design patents and one patent belongs to plant patent. This again restates the major difference between Chinese and Indian patenting activity. Table 1 highlights some other aspects of this difference.

Table 1 Relative activity of various categories of patents

PA/PNA	**96-97**	**98-99**	**2000-01**
India	1.17	1.48	1.85
China	0.73	0.75	0.69
PA/IP			
India	0.36	0.44	0.50
China	0.34	0.36	0.38

Note: IP patents include all the patents in which at-least one of the inventor is from India/China, as the case maybe.

Table 1 indicates further the fact that patents classified as Indian patents are better appropriated then China's patents. This also holds true when one includes the patents in which one of the inventor is from India, irrespective of whether the first inventor belongs to it.

Table 2 complements Figure 1, as it highlights the patenting activity of institutions in India and China (PA patents), as well as shows the types of institutions in which PNA patents from both these countries are assigned. Table 2 indicates significant contrasts in types of institutions involved in a patenting. Figure 1 indicates that the gap between the two countries in terms of number of patents has decreased, in-fact in 97-98 India has been granted

more PA patents then China. But still there is a large gap between distinct entities, organizations/individuals involved in patenting. Marked rise in number of patents by India has been primarily because of few organizations. Patents by universities are almost negligible from India. This is an important indication as growth in science based areas require universities to be more important player in r&d developmental process. Patent appropriates this r&d activity to some extent. China's patenting effort is distributed among the different categories of institutions. Unlike India, individuals as well as universities are also active in patenting.

PNA patents of both the countries exhibit a very similar pattern. Most of these patents are from industries. This probably indicates the role of multinationals. However, in this study we have not investigated this fact.

TABLE 2: PATENTING BY TYPE OF ORGANISATION — INDIA AND CHINA

	INDIA – PA & PNA							**CHINA: PA & PNA**					
Period → *Type ↓	**96-97 PA**	**96-97 PNA**	**98-99 PA**	**98-99 PNA**	**2000-01 PA**	**2000-01 PNA**		**96-97 PA**	**96-97 PNA**	**98-99 PA**	**98-99 PNA**	**2000-01 PA**	**2000-01 PNA**
Industry	13	14	28	35	38	43		28	28	51	53	165	110
Research Institute	6		4		14			4		16		19	
University			1	1	3			10	5	16	2	16	5
Specialised institute	2		6	1	14			5		6		8	2
Individuals				2	2			2	1	10	4	12	7

* only unique organisations for each year are counted

Joint patent assignment indicates collaborative linkage in R&D. Table 3 highlights the collaborative linkages. PA patents exhibit marked differences in intensity and types of collaboration. Number of distinct organizations involved in patenting, and number and type of collaborations in China is much more then that of India. In China, universities are active in forging collaboration with research institutions as well as with industries. India's collaboration activity is mainly among research institutions and industry/specialized institutes. International linkages of both these countries are few (these are those patents, having joint assignee in which assignee's are from India/China and organization(s) from another country). However, here again the pattern is different. India's PA patents show USA as the dominant partner, whereas Japan is the dominant partner in China's case.

PNA patents of both the countries show much less activity in terms of entities involved, and collaborations in comparison to their PA patents. However, number of distinct organizations involved in patenting show a marked increase for China in 2000-01. Except for 98-99, the PNA patents from India exhibit no collaborative activity. In China, although it is much less then that of its PA patents, but unlike India at-least there are some collaborative activities.

TABLE 3: COLLABORATION ACTIVITY — INDIA AND CHINA

	INDIA – PA & PNA							CHINA: PA & PNA					
Period → *Type ↓	**96-97 PA**	**96-97 PNA**	**98-99 PA**	**98-99 PNA**	**2000-01 PA**	**2000-01 PNA**		**96-97 PA**	**96-97 PNA**	**98-99 PA**	**98-99 PNA**	**2000-01 PA**	**2000-01 PNA**
***Entities**	21	15	40	38	72	42		53	35	92	49	220	127
Collaborations	1	0	6	2	15	0		7	3	17	2	28	4
Type of Collaborations	1		5	2	6			3	2	10	1	12	1
Intl link	0	N.A.	3	N.A.	8	N.A.		0	N.A.	3	N.A.	6	N.A.

* Only unique entities for each year are counted. This includes Industry (I), University/Academy (U), Research Institute (R), Special institutes includes Hospitals (S), and individuals (P)

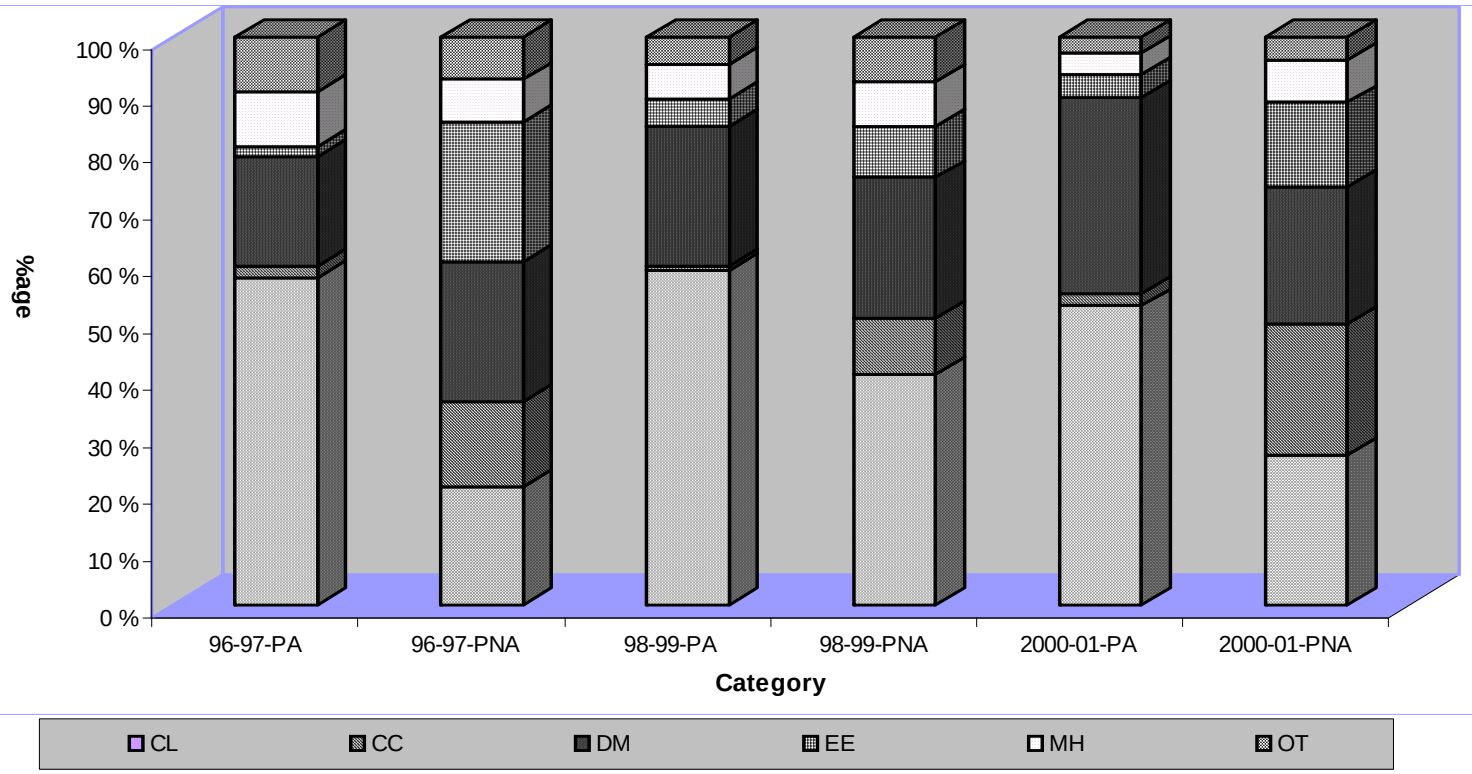
** in these intl. collaborations, the patent(s) is assigned to India/China

Technology profile

Technological profile of Indian patents

Assignee patents are mainly concentrated in two categories: chemical (CL), and drugs and medicine (DM). Activity under the other four sectors: computers & communications (CC), electrical and electronic (EE), mechanical (MH), and others (OT) are very low. PNA patents are better appropriated, particularly in the latter period 2000-01, with four sectors CL, DM, CC and EE being mainly addressed. PNA patents are much better appropriated under various sectors unlike the PA patents. *Figure 2 highlights these attributes.*

Figure 2: Patenting Activity of India in Various Sectors - PA/PNA



In terms of activity in sub-sectors, very few sub-sectors are addressed by PA patents in 96-97. This is not the case in later periods. OC is the dominant sub-sector of activity for all the three time-periods. DR has become important sub-sector of activity for India in the last two time-periods (98-99), and (2000-20001). MC and to an extent RE and BT also show higher level of activity in the last two time periods. We analyse cross-linkages to reveal the strength of linkages among various sectors/sub-sectors. Cross-linkages imply (as per our definition for this study) those patents which are assigned simultaneously in more then one sub-sectors (these can be within a sector or in different sectors). PA patents exhibit only low levels of linkage across the time periods. Most of the linkages are in the range of one to three across the time-periods. Only CL and DM show some activity, with linkage ranging from twelve to fourteen across the time periods. Further only two sub-sectors OC and DR account for most of these linkages.

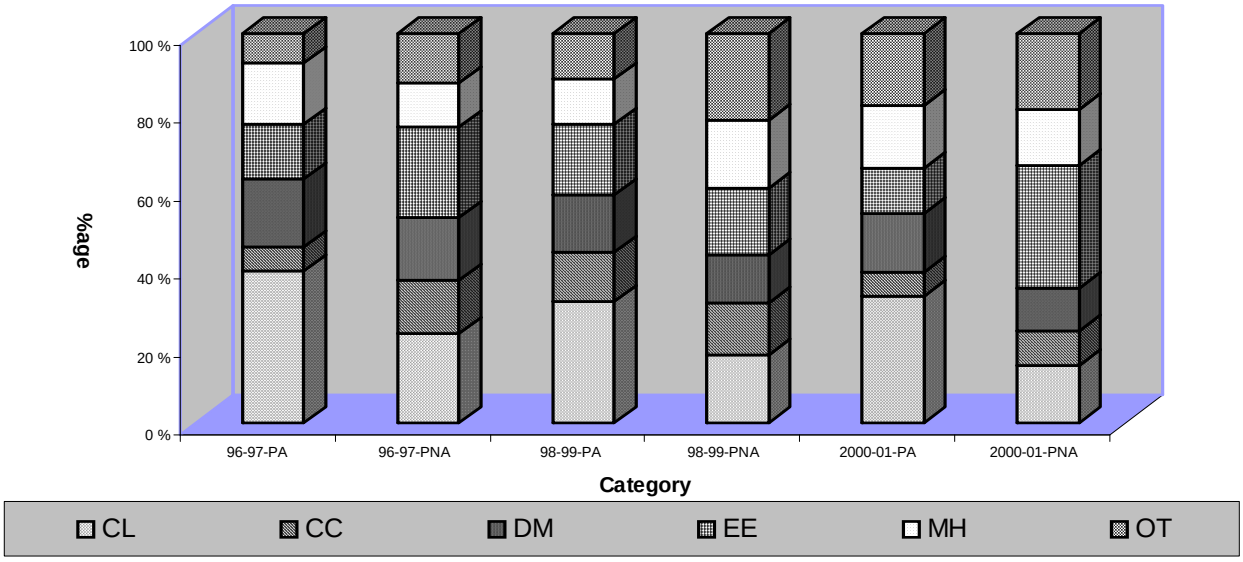
For PNA patents also, CL, and DM still are the most prominent sectors. However, unlike PA patents, the concentration levels in these two sectors are not highly skewed, with levels ranging from 25% to 30%. Only in 97-98, CL shows higher level of concentration with approx. 50% patents addressing this sector. It is interesting to see the activity in CC. For PA patents, this sector had almost negligible patenting activity, whereas significantly large numbers of PNA patents address this sector. In 96-97, and in 2000-01, approx. 25% of patents address this sector. In 97-98, however, the activity is relatively less with approx. 14% of the patents addressing this sector. Another significant change of India's PNA patent is with respect to EE sector. PA patents have low levels of activity in this area ranging from 2% to 5% in the three-time periods. In contrast for PNA patents the activity is significant. Particularly in 96-97, the activity is very high with approx. 33% of their patents accounting for this sector.

However, activity is not so high in the later periods, and exhibits moderate activity of 11% in 97-98, and 16% in 2000-01.

Technological profile of Chinese patents

The PA patents of China primarily address CL sector in 96-97. However, in the later periods, particularly in 2000-01, five sectors CL, DM, EE, MH and OT show patent activity. Even CC has some level of activity with ten patents appropriated to it during this period (2000-01). PNA patents show activity in all the six sectors and increase is uniform over the time period. *Figure 3 highlights these characteristics.*

Figure 3: Patenting Activity of China in Various Sectors - PA/PNA



PA patents show almost all sub-sectors being addressed in 96-97. Among them, MC, OC and DR are relatively better addressed. In 98-99, along with the above sub-sectors, the sub-sector SD is also being prominently addressed. In 2000-01, three sub-sectors under CL: MC, OC, and RE are being prominently addressed. DR and to some extent MO are also addressed.

China's PNA activity shows significant change in EE sector. Whereas its PA patents exhibit approx. 15% - 18% activity in this sector, the activity in PNA patents range from 30% - 36%. However, activity in other sectors matches that of its PA patents.

PNA patents indicate patent activity in the sub-sector MC in all the three periods. Relatively higher technological activity (in terms of patents) in sub-sector MO and to some extent in HS, BT and MM are seen in 98-99. ED is very prominently addressed by PNA patents in 2000-01. The other sub-sectors which are relatively better addressed are DR, EL, HS, PS, MM and PH. Among the sectors, EE shows linkages with CC, and OT. The linkages with these two sectors range from four to six in 96-97, and 98-99 respectively. Further increase in linkage is observed in 2000-01, with 12 linkages between (EE & CC), and 14 (between EE & OT) respectively. Similar to PA patents, CL and DM exhibit linkages, ranging from twelve to fourteen in each period. Among the sub-sectors, OC and DR show maximum intensity, varying from seven to nine across the time period. This is similar to PA patents. In addition for PNA patents, HS and MO subsector is prominent in linkage with various sub-sectors of EE.

Cross-national comparisons of technological profiles: India and China

Assignee patents for both India and China show high level of activity in OC and DM. However, Indian patent activity is highly concentrated and has insignificant levels of activity in other sectors. The level of concentration of Indian patents can be seen from the way their patents address the two sectors CL and DM. CL and DM address approx 60% and 25% patents in each of the three time-periods. On the other-hand, China has moderate levels of patenting activity in all the sectors. In case of China also, CL and DM are most prominent accounting for approx. 20% of patents across the time periods. In the other sectors, across the time-periods, approx 10% of patents are in CC, and approx. 15% of patents are in the other three sectors EE, MH, and OT.

PNA patents of India are much better appropriated and are similar like that of China. DM and CL are still the prominent sector of activity for PNA patents of India, but there are other sectors which also exhibit significant activity. This reflects in general the patent activity of China's PNA patents. Most interesting case is that of CC sector. Comparing this sector with PNA patents from China, shows that India's PNA activity in this sector is higher. In-fact China PNA activity in this sector shows decrease from 17% in both 96-97, and 98-99, to approx. 10% in 2000-01. It has to be kept in consideration that this sector is of negligible activity in India's PA patent.

The low linkage pattern (in terms of a patent addressing more than one sector or sub-sectors) in the patent profiles of these two countries overall does not allow the relative indicator (like intensity of linkage with respect to the total activity in the corresponding sectors) to bring forth any important indication. However, one can observe from the cross-classification data that CL and DM show some degree of linkage for PA/PNA patents of both India and China. Further PNA patents from China exhibits linkage in EE particularly in 2000-01. Its linkage activity is mainly with CC and OT. In terms of sub-sectors, OC and DR are the dominant sub-sector of linkage across the time periods for PA/PNA patents of both India and China.

Conclusions and discussion

In this paper we have tried to show the various important indications which can be available from the patent statistics. We have tried to explore those dimensions which can be important markers/pointers, but which may be masked when we apply aggregates without accounting for them properly. The cases in point are the various categories of patents: utility/design/plant patents which should be analysed and identified separately. Also while analysing the innovative and inventive capability of a country; we feel that it is possible to reveal many 'hidden' aspects by focusing on various types of patents like patents invented, patents assigned and the like (PA/PNA). Another aspect which we tried to address was that it is possible to bring forth many salient aspects even when there is a limitation of applying relative indicators.

Analysis indicates the major differences in patenting activity of assigned patents (PA) of India and China. China and India both show an increase in PA patents over the time periods. However, the growth is dependent on design patents for China and utility patents for India. Analysis has also revealed the differences in the intensity and type of institutions as well as type of collaboration linkages of these two countries in the assigned patents. India's patent activity is concentrated on industry and research institutes. Whereas China's activity is varied and universities also play an important role in patenting activity. Various types of collaborations between university and industry/research institutes as well as between industry and research institutes is observed in the Chinese case. India's collaboration is much less and is concentrated among industries, or among research institutes. Some industry and research institute collaboration is also seen. PNA patents of both these countries however exhibit similar characteristics. The difference is only in terms of patenting types, which imitates similar characteristics as their PA patents.

The analysis of the patent profile based on patent assigned PA, and PNA show different technological composition, particularly for Indian patents. Their PNA patents mainly address advanced/emerging technological areas. This has major policy implication. PNA patents can lead to value-added advanced technology product development. This indicates that R&D capabilities exists in advanced technology areas but are not exploited internally as otherwise it should have led to assigned patents addressing them. However, one has to keep in consideration the implicit assumption that it was the first inventor who had a major role in the "innovative act" that led to these patents.

The varied nature and intensity of collaboration in Chinese patents indicate that there is increasing awareness and thrust to link university-industry-research organisations in R&D activity, which is not reflected through the Indian patent activity. Many of the emerging areas which are science intensive like biotechnology requires active participation of universities in r&d process. The activity of university sector in patenting for China is a good indication for its future prominence in these emerging areas.

The implications of this study are twofold. We have attempted to show the potentiality for determining the innovative/inventive capacity/capability of countries irrespective of their patent size. These can complement relative indicators. Secondly, the various distinctions in terms of patent categorization, PA/PNA can be used for policy analysis as indicated above.

This study shows some aspects of the innovation activity/technical change of the two countries, India and China. Further research is required to bring forth the other dimensions of their technological activity, and causality issues. An important extension of this study would be to carry out the same comparison within the European system. The PA/PNA analysis as done in this study indicates some aspects of innovation activity of these two countries. It would be interesting to see how these distinctions are influenced by IPR policies in India and China. Another novel approach can be by analysing patents in terms of country of invention Vs country of control (see e.g. 2nd EU report on S&T indicators, 1997), the country of invention being the country of address of the inventor(s), whereas country of 'control' of the patent imply the country of the headquarter country of the industrial group that controls or may control the firm that is the assignee of the patent.

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Note

1. The patent laws of the United States provides for the granting of Utility patents, Design patents, and Plant patents.

A *utility patent* can cover a useful process, machine, article of manufacturer or composition of matter. A utility patent is granted for a period of 20 years from the date of issuance.

Design patent is granted to any person who has invented any new, original, and ornamental design for an article of manufacture. A design patent protects only the ornamental appearance of an article, and not its structure or utilitarian features. If a design is utilitarian in nature as well as ornamental (such as computer mouse design which is more comfortable to use), a design patent will not protect the design. Such combination inventions (both ornamental and utilitarian) can only be protected by a utility patent. An application for a design patent is much simpler than that of a utility patent. Only one claim is permitted, and a design patent has a term of 14 years from the date of issuance.

Plant patent is granted to anyone who has invented or discovered or asexually reproduced any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber-propagated plant or a plant found in an uncultivated state. The term of a plant patent is 20 years from the date of issuance.

2. Sectors and sub-sectors as delineated by Hall, et. al. (2001)
Chemical (CL): AF: Agriculture, food, textiles, CO: Coating, GS: Gas, OC: Organic compounds, RE: Resins, MC: Miscellaneous-chemical
Computers and Communications (CC): CM: Communications, HS: Computer Hardware & software, CP: Computer peripherals, IS: Information storage,
Drugs and Medical (DM): DR: Drugs, SM: Surgery & medical instruments, BT: Biotechnology, MD: Miscellaneous-drug &medical
Electrical and Electronic (EE): ED: Electrical devices, EL: Electrical lighting, MT: Measuring & testing, NX: Nuclear & X-rays, PS: Power systems, SD: Semiconductor devices, ME: Miscellaneous-electrical.
Mechanical (MH): PH: Materials processing and handling, MW: Metal working, EP: Motors, engines and parts, OP: Optics, TP: Transportation, MM: Miscellaneous- mechanical
Others (OT): AH: Agriculture, husbandry, food, AD: Amusement devices, AT: Apparel & textile, EW: Earth working & wells, FH: Furniture, house fixtures, HE: Heating, PJ: Pipes & joints, RC: Receptacles, MO: Miscellaneous-others

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