Technology development in China and India: a comparative evaluation

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Abstract

Purpose – During past ten years China and India have emerged as the favorite destination for R&D investment. In this paper a comparative evaluation of the process of technology development in China and India is carried out. The objective is to identify the rate of growth of technology and the patterns of development in different technology sectors.

Design/methodology/approach – The analysis is based on the tangible, measurable and recorded output of the technology development process – namely grant of patents. The authors have used US patents as the surrogate measure for the technological output between 1992 to 2007. The authors obtained data on inventor's background, ownership pattern of the patents, as well as technology sectors and descriptive statistics are used to compare the trends between the two countries.

Findings – The paper finds that both China and India have achieved very high growth rates in patents granted with some resident research between 1992 and 2007. Both have a high percentage of foreign-owned and low percentage of joint ownership of patents. Also, a clear polarization in the composition of research teams is detected in both China and India in that international researcher teams have largely been used only for foreign and jointly owned patents. The authors find that corporations have become much more active in recent years in patenting and multi national companies have led the local companies in patent development across many sectors. The authors also detect some significant differences in the Chinese and Indian pursuit of patent development. About 30 to 35 percent of all patents developed in China are design patents – the rest being utility patents. For India almost all such patents – more than 95 percent – are utility patents. The authors find a clear dominance along the mechanical trajectory among the patents developed in China, while for India a similar dominance is along the chemical trajectory that includes pharmaceuticals and biotechnology. Another interesting finding is the growing share of ICT patents in both China and India, particularly in the last few years China has emerged ahead of India in terms of its patent development as well as in the internationalization of its patent development as reflected in the

ownership of patents developed. However, even for foreign patents developed in these countries, researcher collaboration is showing a downward trend.

Originality/value – This paper carries out a comparative evaluation of the process of technology development in China and India. The analysis is based on the tangible, measurable and recorded output of the technology development process – namely grant of patents. The paper uses US patents as the surrogate measure for the technological output from China and India.

Keywords India, China, Research and development, Patents

Introduction

Recent changes in the global economy, brought about by increased globalization of the world's economies, accelerated technological changes and the special role of transnational companies are transforming research and development (R&D) activities around the world. Fundamental changes are taking place both in terms of the rate and nature of technology development and also who does the R&D and more importantly how and where it is done.

According to a trend that started in the 1980s and gathered momentum in the 1990s, important elements of the innovation process tended to become transnational and global rather than national. Some of the big multinational corporations increasingly focused on building a global innovation network, comprising of R&D units located in clusters of excellence around the world (Florida, 1997; Kuemmerle, 1997; Frost et al., 2002; Feinberg and Gupta, 2004) thereby weakening their ties to their home-base country and spreading their innovative activities and "sourcing" different national systems of innovation (Lundvall, 1992). These changes challenged the traditional roles of national systems of innovation. It seems that in the first phase, national innovation systems of other industrialized countries were "sourced". However, in the second phase that is currently on in the 2000s, national innovation systems of some emerging countries are increasingly being used. Significantly, this is not happening in a few limited industrial sectors, but is quite widespread across many sectors, particularly those that are science-based where communication is easier to formalize and codify. While several empirical studies have established that individual subsidiaries of

multi-unit firms do successfully tap into external knowledge sources in their respective locations (Almeida, 1996; Frost, 2001; Singh, 2007), there has been less clarity on whether this actually improves the firm's overall innovative ability and the quality of innovation.

While in the first phase, the globalization of R&D has been largely associated with either supply-side approach relating to "capability augmentation" or the demand-driven "capability exploitation" approach (Kuemmerle, 1999), in the second phase it is also actively pursuing low cost solutions through R&D offshoring and the desire to reach closer to the consumers in fast growing economies. With large technical and scientific manpower and with huge and growing market, India and China are emerging as preferred destinations for offshoring of R&D. Huggins et al. (2007) estimated that 25.6 percent of all foreign direct investment in R&D projects was directed to India in 2006. China was the second most popular destination for R&D projects.

In this paper we carry out a comparative evaluation of the process of technology development in China and India. Our analysis is based on the tangible, measurable and recorded output of the technology development process – namely grant of patents. We have used US patents as the surrogate measure for the technological output from China and India. Inclusion of other patents like European and Japanese patents would have made the study more comprehensive.

A patent may be a controversial indicator as not all technology is or can be patented and not all patents are translated into commercial products or processes. However, patent statistics have probably been the most extensively used among the various indicators of science and technology activities available to researchers (Bound et al., 1984; Basberg, 1987; Glisman and Horn, 1988; Griliches, 1990; Archibugi and Pianta,

1992). Patents have been used as a metric to measure the level of innovative output for comparing the competitiveness of nations (Atun et al., 2006). Bhattacharyya and Nath (2002) used US patents as index of performance in their comparison of China and India as they found this to be a consistent and valid measure. They also noted that firms often take US patents as the US represents the largest market. Patents also have an

important and effective role in stimulating innovation and growth, which is not unanimously recognized (Peeters and de la Potterie, 2006).

For a comparative evaluation of technology development in China and India, a common framework has been used for analyzing the patents developed in China and in India. For this purpose, an analysis of all the patents granted by USPTO with at least one inventor being a resident of China (for China) or of India (for India) has been used. We have focused on patents with resident research content rather than on patents granted to assignees from the respective countries because many of the patents developed with Chinese or Indian researchers are assigned to and so become the intellectual property of other countries, although the technology was developed either fully or partly in China or India.

All such patents issued between 1992 and 2007 have been individually analyzed – a total of 8,068 patents for China and 4,248 for India. For each patent, its patent number, year in which patent was granted, assignee country(ies), inventor country(ies) and the name of the assignee(s) were recorded. Finally, from the details about the patent, two categorizations were made for each patent – the sector it related to and the entity that was assigned the patent. Each patent was first categorized into one of 16 technology sectors, which was then compressed to four broad technology trajectories namely mechanical, chemical, electrical, and information and communication technologies (ICT). Similarly, the assignee was categorized into one of four research entities – corporate, individual, institute or university.

The rest of the paper is organized as follows. After this brief introduction we analyze the patent development in China and India in the global perspective in section 2. This is followed by sketching brief profiles of patent development in China and India in section 3. Section 4 highlights some of the major similarities and section 5 some of the major differences in the patent development processes of China and India. Finally, conclusions are drawn in section 6.

A global perspective

Before analyzing the patent development processes in China and India, we take a look at these two countries in the global context. We notice that there is a general upward

trend in the number of patents granted by USPTO as shown in Figure 1. Patents of US origin still dominate the total patents granted by USPTO, with slightly more than half the total patents granted in 2007 being of US origin (93,691 out of a total 182,930 patents). The dominance of US, however, is vigorously challenged by other countries. This can be seen from the fact that while pre-1994, US origin patents constituted 56.9 percent of all patents granted (787,044 out of 1,382,827), by the end of 2007, this percentage fell to 55.1 percent (2,004,080 out of 3,638,816). The serious challengers have emerged from Asia and can be seen when country specific growth rates are analyzed. China and India had relatively small number of patents in 1994 but seem to be catching up fast. In Figure 1 the top ten countries are as ranked according to the total patents granted to them till 2007.

This analysis is based on origin of the patents granted. Our detailed analysis of patents from China and India, on the other hand, is of patents granted where at least one inventor is from the respective country. Therefore, although the trends mentioned here are valid, the exact figures mentioned here and in detailed analysis later, would not tally.

Figure 2 analyzes the CAGR of patents granted to the world top ten countries, China and India. Total patents granted by USPTO (US Patent and Trademark Office, 2008)

Figure 2.

CAGR of top ten counties, China and India over the period 1994-2007

Figure 1.

Patents granted to top ten countries, China and India by USPTO (1994-2007)

over the period 1994-2007 grew at 3.5 percent per annum, while patents of US origin grew only at 2.7 percent per annum over the same period. Even patents of Japanese origin – the country with the second highest number of patents granted – grew at a rate (3.1 percent) that was lower than the world growth rate. Many of the top ten countries – like Switzerland (0.2 percent), France (1.6 percent) and Italy (2.2 percent) –

had growth rates much smaller than the world growth rates. On the other hand some of the countries from East Asia like South Korea (15.2 percent) and Taiwan (10.7 percent) had very high growth rates of patent development suggesting that the locus of innovation is undergoing a pronounced Eastward shift. We also notice that patents of Chinese and Indian origin have registered significantly high CAGRs of 15.4 and 24.1 percent per annum over the 13-year period 1994-2007. For our analysis, patents of Chinese origin include patents originating from both China-Hong Kong SAR and from China-PRC.

It is true that these growth rates of 15.4 and 24.1 percent per annum are over a comparatively small base (only 268 patents for China and just 28 patents for India in 1994), but since this is the CAGR over a long period of 13 years, this is still highly significant and may reveal secular shifts. The absolute number of patents of Indian origin are much lower than for those of Chinese origin (578 and 1,991 respectively for 2007); the CAGR is higher because of the smaller base of 28 in 1994.

It is notable that during 2007, such high long-term CAGR has already enabled patents of Chinese origin (1,991) to overtake those of Switzerland (1,280) and Italy (1,836) and reached levels close to those of France (3,720) and Canada (3,970). In fact, if countries are ranked based only on patents granted during 2007, China (including Hong Kong) would rank at a respectable number 9 as shown in Figure 3.

These differences in CAGR have resulted in shifts in global rankings as shown in Figure 3. China and India had ranks of 20 and 34 respectively in global rankings according to patents granted till 1994. They improved their positions to 24 and 16 respectively based on patents granted till 2007 because of their high growth rates of patent development. In fact if patents granted in 2007 alone are considered, China is already in the top ten with ninth rank, while India is the 17th largest patent developer.

Figure 3.

Changing rank of Asian countries

Brief profiles

Moving away from the global scene, we now present brief profiles of the patent

development processes in China and India in this section. Our study uses patent data for 16 calendar years – from 1992 through 2007. We have broken up this span into four distinct four-year periods – namely 1992-1995, 1996-1999, 2000-2003 and 2004-2007. This allows us a simple mechanism to study the changing patterns, trends and priorities in the patent development process over different periods of time. Also, we shall treat all patents with some Chinese research input to have been developed in China and similarly, all patents with some Indian research input to have been developed in India. Although there could be exceptions, the large amount of offshoring of R&D centers that have taken place from other countries to both China and India would make this assumption appear reasonable.

We analyze the ownership pattern of the patents developed in Figure 4 by categorizing the patents developed into three categories – for example a patent developed using some Chinese research content could have China as the only assignee country (domestic patent), only some country(ies) other than China as the assignee country(ies) (foreign-owned patent) or China and some other country(ies) as assignee countries (jointly-owned patent). The figure above shows the distribution of all patents in each of the four periods between domestic and foreign and jointly-owned patents. We find that for China, the share of foreign and jointly-owned patents have been continuously rising from 38.0 percent in 1992-1995 through 58.5 percent in 2004-2007. On the other hand, as many as 63.0 percent of all patents developed in 1992-1995 with some Indian research content had been foreign and jointly-owned. Subsequently, this share fell to 48.6 percent in 1996-1999 and to 43.5 percent in 2000-2003 but recovered to 58.2 percent in 2004-2007. In fact in 2004-2007, both China and India had similar shares of domestic patents (41.5 and 41.8 percent respectively).

This suggests that foreign entities had continuously been providing greater and still greater impetus to patent development in China, while in case of India it appears that Indian entities took the lead during 1996-2003 but finally yielded to the foreign entities in 2004-2007. Looked at differently, while domestic patents grew at a CAGR of 22.8

Figure 4.

Ownership profile

percent per annum in China and 23.3 percent per annum in India, foreign and jointly-owned patents grew at a higher CAGR of 28.5 percent per annum in China and a lower 20.9 percent per annum in India.

In China, growth in domestic patents slackened from 19.8 percent in 1992-1995 to 9.5 percent in 1995-1999, then peaked to 42.6 percent in 1999-2003 and then stabilized close to the long-run average CAGR at 21.0 percent in 2003-2007. Domestic patents are more sensitive to government policies and it appears that concerted efforts were put in place during 2000-2003 to get more patents; this effort seems to have lost some steam in 2003-2007. Also, it is reasonable to expect a fall in rate as the base expands, even with similar levels of effort. Incidentally, CAGR of foreign and jointly-owned patents also peaked to 45.1 percent per annum in 1999-2003 in China.

In the case of India, growth in domestic patents was more uniform during 1992-2003 registering a CAGR of 27.7, 34.6 and 33.2 percent per annum in 1992-1995, 1995-1999 and 1999-2003 respectively. However, growth in Indian domestic patents almost disappeared in 2003-2007 when the CAGR reached an abysmally low value of only 1.8 percent per annum. Foreign and jointly-owned patents, on the other hand gathered momentum with passage of time and the CAGR increased continuously from 9.4 in 1992-1995, to 17.7 in 1995-1999, 25.8 in 1999-2003 and 28.7 in 2003-2007 percent per annum. In the current phase, i.e. in 2004-2007, more than half the patents developed in China and India are either owned by foreigners or jointly-owned.

The development of patents in China and India along different technology trajectories is studied in Figure 5. China has traditionally been strong in patent development in mechanical technologies. About 54.8 percent of all patents developed in China are along the mechanical trajectory, followed by chemical (17.5 percent). In the recent years, ICT patents exhibited a major surge in 2004-2007 and ended up constituting 19.9 percent of all patents developed in these years. Although patents along all technology trajectories continued to grow, the share of ICT patents in 2004-2007 gained at the cost of patents along the older technologies namely mechanical and chemical.

India has traditionally been strong along the chemical trajectory with more than 50 percent share; another 15 to 20 percent of the patents were along the mechanical

Figure 5.

Trajectories profile

trajectory. However, there has been a perceptible shift towards electrical technologies from 2000 onwards and more than a fifth of all patents developed in 2004-2007 have been along the electrical trajectory. Just as in China, ICT patents had a very high growth rate in 2004-2007 and in this period comprised 22.5 percent of all patents developed in India. Surprisingly, chemical patents had a lackluster growth in 2004-2007 and the share of chemical patents fell drastically (from 60.0 percent in 2000-2003 to 39.5 percent in 2004-2007) while those along other trajectories rose.

If the assignees are categorized into four categories – namely companies, individuals, institutes and universities, we notice a clear and significant increase in the share of companies in the case of China as shown in Figure 6. Individuals have always constituted the second major category of research entities in China. Thus, while both companies and individuals had an almost equal share of about 37 percent of all patents developed in China in 1992-1995, by 2004-2007, companies had increased their share to 80.9 percent while the share of individuals had fallen to a mere 13.7 percent. In fact in China, the rise in the share of companies is accompanied by a fall in the share of all the remaining three categories.

Unlike China, individuals have not been a major category of assignees in India. Also, companies have always had the major share (more than half) among all patents developed in India. Another major difference between China and India is the role of institutes. Even in 1992-1995, about a fifth of all the patents developed in India were by institutes. Institutes raised their share in 1996-1999 to 29.7 percent and again in 2000-2003 to 35.2 percent. Institutes seem to have lost their steam in 2004-2007 as companies emerged as the dominant patent getter with a share of 71.9 percent of all patents. Both individuals and universities have been rather small players in India. One common thread between both China and India is the rather insignificant role of universities directly in getting patents as a result of their own research.

The composition of the researcher teams is studied in Figure 7. A very large

percentage (78.8 percent) of all patents developed in China have used all-Chinese researcher teams, international research teams involving both Chinese and

Figure 6.
Research entities

non-Chinese were used in the remaining 21.2 percent. The share of resident inventors increased between 1992-1995 and 1996-1999, but has been falling since then and in 2004-2007 as many as 80.4 percent of all patents developed in China used only resident researcher teams.

The dominance of resident researcher teams has not been as strong for patents developed in India, even though the share of patents developed by all-Indian researchers has generally been increasing from a low of 44.0 percent in 1992-1995 to 64.9 percent in 2004-2007.

We, therefore, observe a very interesting trend in both China and India. Although a majority of the patents developed in both these countries are foreign and jointly-owned (about 58 percent in 2004-2007), international researcher teams have been used in only 19.6 and 35.1 percent of all locally developed patents, respectively. It seems that the offshore R&D centers are using more and more all-local researcher teams in their technology development initiatives.

Some similarities

After the brief profiles of the patent development process in China and India, we now present the major similarities in the two processes.

Analyzing the patents developed in China and India, i.e. patents developed where at least one researcher is from China or from India respectively, we observe from Figure 8 that both the countries have achieved high growth rates in patent development. Rather than calculating the CAGR using the first and the last year of the study, we fitted the exponential trend line and as shown above, the annual growth rates are 24.93 percent per annum for China and 22.18 percent per annum for India. It can be seen from the chart above that although the difference in the annual growth rates is small, the

difference between the absolute number of patents granted has continuously increased. Thus, while 58 and 41 patents were granted in 1992, by 2007 these increased to 1,824 and 779 respectively.

Figure 9 shows that in both China and India, foreign-owned patents constitute the majority with about 51.1 percent of all patents granted over the period of study, i.e.

Figure 7.

Researchers profile

from 1992 till 2007. In both the countries jointly-owned patents form a very small share of all patents granted. While foreign-owned patents had a continuously rising share in China, in the case of India their share fell till 2003 but increased in the last four years of the study. The share of domestic patents exhibited a trend that was just the opposite of that of foreign-owned patents.

Another common feature of the patent development process in China and India is the extent of researcher collaboration. As shown in Figure 10, domestic patents are almost exclusively developed by local researchers in both China and India. International teams of researchers are used almost completely for developing foreign and jointly owned patents. Surprisingly, the use of all-resident researcher teams has continuously increased from 32.4 in 1992-1995 to 67.1 percent in 2004-2007 for foreign

Figure 9.

Large share of foreign owned patents

Figure 8.

High growth rates

and jointly owned patents in China. The corresponding figures for all-Indian researcher teams are 14.7 in 1992-1995 and 41.0 percent in 2004-2007 in India.

Significant differences

Just as there are similarities, there are major differences as well in some characteristics of the patent development processes in China and India. The present section highlights some of these.

In the initial years of the study, almost all the patents developed in China and India were utility patents; very few were non-utility patents. However, from 1997 onwards a gradually increasing share of all patents developed in China were of non-utility type as shown in Figure 11 here. In the case of India, most patents developed continue to be of utility type and less than 5 percent of all patents are of non-utility type. For China, non-utility patents have grown and have stabilized at around one-third of all patents.

Figure 10.
International teams used only for foreign and jointly owned patents

Figure 11.
Utility and non-utility patents

Among different categories of patents, utility patents may be considered to be the most valuable. They represent new knowledge, new ideas, new products and new processes and may even have a multiplier effect on the development of other utility patents. If this assumption is true, the larger share of utility patents in India would mean a higher intensity of knowledge development and that the difference in levels of technology development between China and India is perhaps less than implied by the difference in the total number of patents developed in these countries.

The growth of design patents and other non-utility patents is shown in Figure 12. In the case of China, almost all non-utility patents are design patents and they constitute about a third of all patents developed in China between 2000 and 2007. For India, design patents have generally been between 2 and 3 percent of all patents. Also, India has also been getting about 1 percent of all its patents as plant patents after 1996. Design patents constitute works of art, ornamental design, part design, module design and product design having possible commercial value. A high percentage of

design patents might mean more patents developed by designers and product development teams in manufacturing companies than real valuable knowledge breakthroughs and knowledge enhancements achieved by R&D centers.

In Figure 13 we study the distribution of non-utility patents among different technology trajectories in China and India. Among patents developed in China, non-utility patents (almost all design patents) are weighted more heavily along the mechanical trajectory vis-a`-vis utility patents. Only in 2004-2007 have the share of ICT design patents reached almost the same level as that of ICT utility patents. By and large the share of chemical and electrical patents has been lower among design patents as compared to their respective share among utility patents.

Design patents developed in India have largely been along the chemical trajectory (about 70.4 percent) followed by the mechanical trajectory (about 24.5 percent) with relatively few electrical and ICT design patents. The strength along a technology trajectory seems to get magnified among design patents. China has been strong along the mechanical trajectory and the share of mechanical patents is higher among design patents (65.1 percent) in China than among utility patents (50.1 percent). Similarly, India has traditionally been strong along the chemical trajectory and the share of

Figure 12.

Growth of design and other patents

chemical patents is higher among design patents (70.4 percent) than among utility patents (47.3 percent).

We also observe that China has embarked on getting ICT design patents in 2004-2007 (19.7 percent of all design patents), while India does not really have any worthwhile ICT design patents although in 2004-2007 23.4 percent of all its utility patents were ICT patents. It appears that design patents appear in the portfolio of patents after the maturing of a sector and if this is true then we would expect more design patents for India in future.

If we analyze at the level of a technology trajectory, we find that 62.8 percent of all mechanical patents in China are utility patents while as many as 81.8 percent of all

chemical patents are utility patents. In the case of India the share of utility patents varies between a low of 94.5 percent for chemical patents and a high of 99.5 percent for ICT patents as there are few design patents across different technology trajectories. Figure 14 presents a cross-tabulation of domestic and foreign and jointly owned patents developed in China and India along the technology trajectories and the research entities.

In China, the share of mechanical patents is 54.8 percent of all patents; but among domestic patents their share is higher at 60.9 percent. Correspondingly, their share among foreign and jointly owned patents is just 50.0 percent. A similar but milder pattern exists for chemical patents. Among electrical patents, there is not much of a difference between domestic and foreign and jointly owned patents while the share of ICT patents (23.7 percent) is much higher among foreign and jointly owned patents vis-a`-vis domestic patents (5.6 percent). Similarly, in the case of India the share of chemical patents among domestic patents (73.4 percent) is much higher than among foreign and jointly owned patents (26.1 percent). Among mechanical patents, there is not much difference between domestic and foreign and jointly owned patents while the shares of both electrical (30.5 percent) and ICT patents (27.1 percent) are much higher among domestic patents than among foreign and jointly owned patents (5.7 and 2.4 percent, respectively). In both China and India, foreign entities have complemented the domestic entities by strengthening technology development along the new ICT

Figure 13.

Trajectory concentration of utility and non-utility patents

trajectory where the domestic entities had almost no presence. In India's case a similar benefit has accrued along the electrical trajectory as well.

Beyond the ownership, if we analyze at the research entities level, we find that all domestic entities have ignored the ICT trajectory in both China and India. In China, domestic individuals and foreign companies have concentrated less on electrical and chemical patents, respectively. On the other hand domestic individuals have concentrated more on mechanical, foreign companies on ICT and to some extent

foreign universities on chemical patents. In India, domestic companies, individuals and institutes have concentrated less on electrical and foreign companies have concentrated less on chemical patents. On the other hand, domestic companies and institutes have focused more on chemical and domestic individuals on mechanical patents. Simultaneously, foreign companies have focused more on electrical and ICT patents.

In terms of ownership, US-owned and Taiwan-owned patents have the largest share of the foreign-owned patents in China. Similarly, US-owned patents constitute the largest segment of the foreign-owned patents in India. In Figure 15, we investigate if there is any difference in the technology focus of domestic and these foreign-owned patents.

We notice that in China, US entities followed the lead of Chinese entities in developing non-utility (largely design) patents from the year 2000 onwards. In utility patents Taiwanese entities opened up the electrical technology trajectory in 1996-1999 and the ICT trajectory in 2000-2003 for Chinese and US entities to follow. Taiwanese entities are not at all active along the chemical trajectory but have exploited the demonstrated strength of Chinese researchers along the mechanical trajectory. On the other hand, US-owned entities got the highest number of patents along the chemical trajectory till 1999, but changed their focus to ICT in 2004-2007. Thus China has benefited from Taiwanese focus on electrical and ICT utility and ICT non-utility patents. Similarly, the recent focus of US focus on ICT patents has enabled China to register a high growth along this new technology trajectory.

Figure 14.

Concentration of domestic and foreign patents

In India's case, the growth of India-owned patents is slower and largely along the chemical, and to a much smaller extent along the mechanical technology trajectory. US owned patents have helped in increasing the growth rate of patents developed in India and in opening up the electrical and the ICT trajectory for patent development.

The role of domestic and foreign entities in patent development in China and India

is studied in Figures 16 and 17. We find that though the number of foreign and jointly owned patents in 1992-1995 in India (116) exceeded those in China in the same period (111), this initial relatively high involvement of foreign entities tapered off very soon as foreign entities increased their involvement in China in a big way. Domestic patents also grew at a high rate in China and China soon had much higher number of patents for each research entity category and by 2004-2007 outnumbered the patents developed in India in each category except that of domestic institutes. Within the National

Figure 15.
Characteristics of US and Taiwan owned patents

Figure 16.
Role of domestic and foreign entities

Innovation System of India, CSIR research institutes set up by the government of India performed a stellar role in patent development and generated more patents than all Indian companies put together.

Both in China and India, we notice an increasing corporatization of technology development. Among all patents developed in 1992-1995 in China, 16.1 percent were developed by domestic companies and this figure reached about 25.4 percent in 2004-2007. The share of foreign companies grew more relentlessly from 21.6 to 55.5 percent in the same period. Thus while 37.7 percent of all patents developed in 1992-1995 in China were developed by companies – both domestic and foreign, this figure grew to 80.9 percent in 2004-2007. The share of all other entities fell to accommodate this increase. In China, the only other category which had a significant share of patents developed was domestic individuals, but their share also continuously declined from 33.9 percent in 1992-1995 to 12.3 percent in 2004-2007.

The trends in India are similar to those in China except that institutes have had a major role here rather than individuals and the rate of corporatization has been much slower for both domestic and foreign companies. Thus we see that among all patents developed in India in 1992-1995, 6.0 percent were developed by domestic companies

which share continuously increased and reached 17.0 percent in 2004-2007. The share of foreign companies grew from 51.6 to 54.9 percent in the same period. The share of domestic institutes increased from 16.3 percent of all patents developed in 1992-1995 through 25.1 percent in 1996-1999 and 34.2 percent in 2000-2003 and fell back to 20.5 percent in 2004-2007. Thus while there is a slow increase in the share of domestic companies, there have been two other major forces defining the process of technology development in India. These are the push from domestic institutes from 1995 onwards which seems to have weakened since 2004 and the stronger impetus from foreign companies 2004 onwards.

From Figure 18 we notice that patents developed by resident inventor teams have grown faster in both China and India vis-a`-vis those developed by international research teams. More widespread use of all-resident teams may signify maturation of

Figure 17.

Share of domestic and foreign entities

local talent requiring little outside inputs or guidance. We have already seen that both in China and India, international researcher teams are used only by foreign entities and not by domestic entities.

In China, about 78.8 percent of all patents have been developed by resident inventors and this percentage has by and large been growing. Although the actual percentages are lower (64.9 percent), a similar trend exists for patents developed in India, although this has fallen in 2004-2007 as the growth of domestic patents has slackened in this period.

For patents developed in China, there are four major composition of researcher teams – only Chinese researchers, Chinese and Taiwanese researchers, Chinese and US researchers (with or without researchers from other countries), and researchers from China and other countries – i.e. other than from Taiwan and US. Similarly, for patents developed in India, there are three major compositions of researcher teams – only Indian researchers, Indian and US researchers (with or without researchers from other countries), and researchers from India and other countries – i.e. other than from US. In

fact, internationalization of researcher teams has largely been with US researchers in both China and India, in China's case researchers from Taiwan have also collaborated in a big way in patent development in China.

As observed earlier, we notice again from Figure 19 that domestic patents are almost completely obtained by resident researchers in both China and India and this has not changed over the years. In China, collaboration with Taiwanese researchers has increased in 2004-2007 and collaboration with US researchers has continuously grown over the years. What is striking is that in China from 2000 onwards, only resident Chinese researchers have developed a majority of even foreign and jointly owned patents. Among patents developed in India, a majority of foreign and jointly owned patents is still developed in collaboration with US researchers in 2004-2007.

When the composition of foreign and jointly owned patents in China is analyzed, we find from Figure 20 that the share of patents developed by only Chinese researchers and those developed by researchers from China and Taiwan have been increasing

Figure 18.

Use of international researcher teams

while the share of the other two categories has been falling over the years. Thus while Chinese researchers used to collaborate with US researchers in 53.2 percent of all foreign and jointly owned patents developed in China in 1992-1995, this percentage fell to only 21.5 percent by 2004-2007. A similar pattern is discernible among foreign and jointly owned patents developed in India as well; consequently the share of all-Indian researcher teams increased from 14.7 percent in 1992-1995 to 41.0 percent of all foreign and jointly owned patents developed in India in 2004-2007.

With increasing corporatization of technology development, companies have emerged as the major assignees of patents granted in both China and India. We analyze the technology orientation of domestic and foreign companies in China and India in Figure 21. In China, domestic companies have got their patents along the mechanical

Figure 20.

Researcher collaboration versus ownership

Figure 19.

Major researcher collaborations

and to a smaller extent the chemical trajectory. Only in 2004-2007 have they included electrical and ICT trajectories on their radar, perhaps after seeing the success of foreign companies. Foreign companies had a significant increase in their patents from 2000 onwards and they have been active along all four technology trajectories although the major emphasis has been along the mechanical trajectory. In 2004-2007, foreign companies registered their highest growth along the ICT trajectory.

In India, domestic companies have continued to remain focused only on the chemical trajectory with only a recent minor interest in electrical patents. Foreign companies have had a different focus and have been active along all four technology trajectories including electrical and ICT. Even in India, in 2004-2007 foreign companies registered their highest growth along the ICT trajectory.

We also find that the share of domestic companies among mechanical patents has been continuously falling in China as foreign company patents have grown faster than their domestic counterparts along this technology trajectory. The share of domestic companies has by and large risen along the other three trajectories vis-a`-vis foreign companies in China. This suggests that patents obtained by domestic companies have grown faster than those obtained by foreign companies along these trajectories and this has happened even when patents to foreign companies have grown very fast in 2004-2007.

In India, the share of domestic companies has registered a continuous increase along chemical and electrical trajectories and not so clear trends along the other two trajectories. Along both mechanical and ICT trajectories, foreign companies have got about 80.4 and 94.9 percent of all company patents in 2004-2007. In fact foreign company patents outnumber the domestic company patents along all trajectories except chemical. Therefore, not only the domestic institutes, domestic companies also have been significant players along the chemical trajectory in India particularly when

compared with foreign companies.

In China, domestic companies have been active mostly along the mechanical and chemical trajectories and recently, i.e. year 2000 onwards along electrical and ICT trajectories as well. In fact the entry of domestic Chinese companies in electrical and

Figure 21.

Company patents –technologywise breakup

ICT patents has been preceded by significant growth along the same, i.e. electrical and ICT trajectories by foreign companies in an earlier period as shown in Figure 22.

In India domestic companies have been active mostly along the chemical trajectory and have obtained some electrical and ICT patents in 2004-2007. Just as in China, foreign companies have opened up the electrical and ICT trajectories to Indian domestic companies and by 2004-2007 some Indian companies have begun to get patents in these technologies, although the absolute numbers are still small as can be seen in Figure 22.

We can see from Figure 23 that along the relatively new electrical and ICT trajectories, both China and India had relatively few patents in the initial years. After the lead of foreign entities, domestic entities also entered these areas and soon started

Figure 23.

Domestic patents follow the lead of foreign patents

Figure 22.

Technology focus of companies getting respectable number of patents.

The chart above shows that while foreign

entities had decent number of patents in 1996-1999, domestic patents were rather low till 1996-1999, but 2000 onwards domestic patents registered a steep increase in electrical and ICT patents.

Foreign and jointly owned patents constitute more than half the total patents developed in either China or India. These have also been the precursors to structural

changes and have opened up newer trajectories for patent development. From Figure 24 we notice that both in China and India an ever-increasing percentage of such patents have been developed by all-resident researcher teams. It appears that with growing competence of local researchers, more and more of patent development work is being entrusted to local teams by foreign entities. In China, while all-Chinese researcher teams developed only 32.4 percent of all foreign and jointly owned patents in 1992-1995, this increased to 33.3, 60.7 and 67.1 percent in 1996-1999, 200-2003, and 2004-2007, respectively. For India, the actual percentages are lower but the pattern is identical and the corresponding percentages are 14.7, 19.7, 30.1 and 41.0 percent, respectively.

We find that greater use of all-resident researcher teams is also made for electrical and ICT patents developed by foreign entities in both China and India as shown in Figure 25. In 2004-2007, 65 to 70 percent of the electrical and ICT foreign and jointly owned patents in China and 45 to 50 percent in India were developed by all-resident researcher teams. Thus even in the newer trajectories (for China and India), the resident researchers are maturing fast.

Conclusions

We found that both China and India have achieved very high growth rates in patents granted with some resident research between 1992 and 2007 (24.93 and 22.18 percent per annum, respectively). Among such patents, both these countries had a high percentage of foreign-owned and low percentage of joint ownership of patents. Also, we detected a clear polarization in the composition of research teams in both China and India – all-Chinese researcher teams used mostly for China-owned and similarly

Figure 24.

Maturing of resident researcher teams

all-Indian researcher teams used mostly for India-owned patents. In both countries international researcher teams have largely been used only for foreign and jointly owned patents. We detect that corporations have become much more active in recent

years in patenting and MNCs have led the local companies in patent development across many sectors.

Although there are some similarities as mentioned above, we also detected some significant differences in the Chinese and Indian pursuit of patent development. About 30 to 35 percent of all patents developed with some Chinese research input are design patents – the rest being utility patents. For India almost all such patents – more than 95 percent – are utility patents. In general, utility patents could be considered more valuable as they represent knowledge enhancements and process enhancements vis-a`-vis works of art, part design, module design and product design having possible commercial value that are registered as design patents. Design patents are generally relevant only for manufacturing organizations and can be developed by designers and others with hands-on experience with the part, module or product. These may not require huge investments in R&D but represent codification of the work of designers for immediate or future use. However, if utility patents are considered and particularly company owned utility patents, then India's performance looks much better than revealed by the trend in total patents.

The composition of the patents granted among the different technology trajectories is also quite different. We divided all the patents granted into four major technology trajectories – namely mechanical, electrical, chemical and ICT. We found a clear dominance along the mechanical trajectory among the patents developed in China, while for India a similar dominance has been along the chemical trajectory that includes pharmaceuticals and biotechnology. Another interesting finding is the growing importance of patents developed along the ICT trajectory in both China and India, particularly in the last few years. This convergence along the ICT trajectory is likely to strengthen further as it rides over the offshoring trend. Overall, China has a wider coverage of all four technology trajectories and particularly has done very well in ICT patents in recent years.

Figure 25.

Resident researcher teams for foreign patents

While companies have been the major drivers of patent development in both China and India, the second largest segment is constituted by individuals in China and by institutes in India. Universities seem to have had rather low involvement in the patent development process in both China and India.

All-Chinese research teams have been very common in China while all-Indian teams have been less common in India. Although international research teams have been relatively less common in China, China has been able to establish links with researchers from a larger range of collaborating countries – both developed and developing. USA has been a major assignee country for all patents developed in China and India. China has developed a wider research network in terms of links with other countries although its strongest links are with US and lately with Taiwan. India has strong links with US. We also found that China has recently become a major beneficiary from Taiwanese offshoring of patent development. An important finding of this study is that in both China and India, a greater percentage of foreign-owned patents are being developed by all-resident researcher teams. Although the trends are similar for India, the percentages are much smaller. Chinese researchers seem to have matured more than their Indian counterparts. This portrays a gradual maturing of resident researcher capability and an important benefit for the host countries.

China has emerged ahead of India in terms of its patent development as well as in the internationalization of its patent development in terms of the range of countries that have used Chinese researchers. Simultaneously, its researchers have matured more and all-Chinese researcher teams develop currently more than two-thirds of its foreign and jointly owned patents.

There are major cultural, political, societal and economic differences between China and India and some of these may have contributed to the observed differences in patent development in these two countries. For example, strong preference for personal and avoidance of impersonal ties to contain transaction costs flows from specific Confucian values and is a common feature of many Chinese firms' behavior. This cultural trait may have been instrumental in some Taiwanese firms establishing their R&D facilities in China. Apparently, the integration of Hong Kong SAR into China has also benefited it immensely in patent development, particularly in the last decade of the previous

century. In India's case the democratic safety valves have quite often weakened as well as slowed down the implementation of many a new policy.

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