Using patent statistics as a measure of 'technological assertiveness': A China–India comparison

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The article compares relative technological assertiveness of India and China by using patenting as a strategic act for protection of respective trading interest. Patenting activities (in the US) of both these countries in the pre- and post-WTO period have been analysed for this purpose. The analysis suggests that India, although has covered much ground vis-à-vis China in patent-related activities, is yet to activate the process of utilization of the patented technology for economic benefit. The article concludes that India needs a long-run trade-related technology strategy for creation of economic wealth from patent.

TECHNOLOGY-based economic growth has been one of the prime factors in creating 'wealth of nations'. The most developed countries, the OECD block, at least a majority of them, are characterized by wealth creation based on pursuing high R&D investments and translating their innovations into commercial products. For example, it was estimated that R&D accounted for 20% of US economic growth between 1939 and 1957. Many developing countries have also taken this approach for development, as resource-based/low technology exports (note 1) are dependent on natural and other limiting factors.

One of the pre-requisites for technology-based economic growth of a country is transition to medium/high technology export (see, for instance, Wakelin[1] and Rodrigo[2]). It has been observed that to sustain this type of growth, a country has to assert itself as a visible competitor in the technology product market. Technology gap between the countries, innovation in product design and manufacture, and quality levels, were determined as some of the distinguishing criteria for creating a niche for any country. This has resulted in major production sites around the international economy shifting from economy of scale towards the economy of scope (note 2). This calls for innovation and product differentiation[3]. Asserting the technological presence of a country becomes more important in this new paradigm of international trade. It becomes particularly interesting to gauge the efforts of developing countries in this changing international economy.

Among the developing countries, India and China evoke special interest because they have the potential to emerge as significant players in the global technology market as well as technology-differentiated product market. Several scientific and technological institutions of excellence, huge pool of science and technology (S&T) manpower and a long tradition of S&T are promising signs of their capability. There is an undeclared race between them to assert their presence in the world market as technology-savvy countries (see, for instance, Rausch[4]). The race is discernible from various trade-related indicators and also from a determined policy to get strong footholds in thrust areas like information technology, biotechnology, etc.

It would be interesting to examine the nature of this race and also to assess who is likely to emerge as a prominent player in the predictable future. The present study makes an effort to assess the extent and nature of this race using the patent activity of India and China in the US patent system.

Methodology

Utilizing patents to gauge technological assertiveness

Patents have long surpassed their use as a legal incentive to innovation[5]. Technological competitiveness among countries has brought in strategic use of various provisions in patent-related laws to prevent competitors from possible early lead. Many such strategic moves together constitute abuses of patent right. Countries design patent laws according to their respective economic interest. What, therefore, is use of patent to a country could obviously be abuse for others. Pending the use and abuse debate, it is fairly appropriate to distinguish between the two sides of the patent right. One is incentive to invention and innovation, and other is right to appropriate 'temporary mono-

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poly' lead through patent right. It is the latter that enables strategic actions to create early leads and checkmate the parallel claimants. Negotiations under WTO (World Trade Organization) are mainly around the preventive clauses of patent rights as defined under the TRIP's (Trade Related Aspects of Intellectual Property Rights) Act. Under WTO, countries are supposed to enhance patent activities in other countries to strengthen trading interest.

This extended use of patent right, from incentive to protection of trading interest, can be stated as an act of asserting technological presence of a company or country in the international arena. So even if patenting does not approximate the actual invention, innovation and technological capability of the patentee, as the debate indicates, it is definitely an indication or the patentee's (a country, company, or individual) intention of asserting technological presence. In other words, patenting is a strategic act by the patentee and intended to assert new technological ventures by the patentee. This understanding of the patent helps in using patent-related information to assess the technological assertiveness of countries/firms.

Type and source of data

We analysed the patenting profile of India and China in this context of technological assertiveness, as argued above. The patenting by these two countries in the US patenting system was used for this study as it helped to maintain consistency, reliability and comparability, as patenting systems across both the countries differ in the application of standards, system of granting patents, and value of protection granted[6]. USA, being the largest single market place for technological products, results in countries/major companies patenting their significant inventions there[7]. The US would also be a preferred choice of both India and China to patent their cutting-edge technologies, as it is their biggest trade partner.

We expect significant patenting activity of both India and China in the post-WTO period, as world trade is increasingly governed by TRIP's Act and other related regulations in this period[8]. It would be interesting and important to see this, not only in terms of increase in number of patents being filed in the US, but whether it has resulted in the increase in activity in organizations involved in patent filing, enhanced collaborative linkages, and a corresponding increase in patent families. The change in patenting activities in various technology sectors (in both these countries) is the other issue we intend to study in this article. We attempt to interpret our results on the basis of export performance of these two countries in the US, as the propensity to patent in the US may be influenced by the level of trade with it, as the expected market share influences the firms' willingness to take out patents[9].

Three time periods, viz. 1992–94 (pre-WTO period), 1995–97 (post-WTO – initial period), and 1998–2000 (to gauge recent activity and assess future trend) were selected for this study. US patents that were assigned to India and China were downloaded from USPTO (United States Patent and Trademark Office)[10] database for these three time periods. Two types of classification of patents were done. One was based on patents reassigned to technological sectors using concordance index relating IPC (international patent classification) codes to technological sectors[11]. This was further modified based on the 7th IPC code. This index allowed us to segregate patents in different technological sectors for each of the years chosen for this study. As our focus was on uncovering the comparative strength of both the countries, we translated the activity in their technological sectors into relative lead. Thus by this translation, it was possible to observe the relative technological strength of these two countries. The second type of classification of patents was based on the type of institution, which has taken patents. For this we created five categories: industry (I), university/academy (U), research institute (R), special institutes, including hospitals (S), and individuals (P). This delineation showed the type of institutions that are patenting and the collaboration among different types of institutions (in both the countries).

To assess the impact of patents of these two countries, we analysed the citations received by their patents. Patent citations, unlike citations in scientific publications, serve as an important legal function since they delimit the scope of the property rights awarded by the patent[12]. The applicant has a legal duty to disclose any knowledge of the 'prior art', i.e. background knowledge (in the US patents), but the decisions regarding which patent to cite (for satisfying the legal functions) ultimately rest with the examiner[13]. In the patent document, the examiner citations are present in the title page, the applicant's citations are found in the main text. Patent citations include those to scientific references as well as to patents. In this study only 'examiner citation' was analysed. This was done for the two time periods; 1992–94 and 1995–97. For proper comparison, we calculated the impact for 1992–94 patents till the period 1997, and the 1995–97 patents till the period 2000. Patent families indicate the number of countries a patent has sought protection and also the global reach of R&D efforts. We analysed the patent families for this purpose.

Results

Overall patenting trends of India and China

Figure 1 shows the patenting rights in USA by India and China from 1990 to 2000. An increasing trend in patenting is shown by both these countries, the growth being more rapid in India. Till 1994, the number of patents by China is almost triple in comparison to India. From 1997 onwards the patenting by these two countries is almost at similar levels.

Table 1 compliments Figure 1, as it highlights the patenting activity of institutions in India and China. Table 1 indicates significant contrasts in patenting pattern in terms of the type of organization involved in patenting activity in both the countries. An appreciable growth in the number of organizations/agencies involved in patenting in both the countries is observed. The relative growth (taking the period 1992–94 as base year) shows that the number of organizations involved in patenting in India has grown significantly. But there is still a large gap between India and China in terms of distinct entities, organizations/individuals involved in patenting. As shown in Figure 1, the gap between the two countries in terms of number of patents has become narrower. This implies that the marked rise in number of patents in India has been primarily because of significant activity by a few organizations and not due to the involvement of a large number of organizations. Detailed analysis bears this fact. In India, the patenting according to institutions/companies shows CSIR (Council of Scientific and Industrial Research) as a very dominant player. Almost half of the patenting is done by CSIR during each year. The patenting activity is distributed among most of its forty major laboratories (although patent assignee is generally by CSIR and not by individual laboratories; it is possible to uncover this fact from the assignee address). The National Chemical Laboratory, Institute of Chemical Technology, and the Indian Institute of Petroleum are the most active among them. Apart from CSIR, Indian Oil Corporation Ltd, Reddy Research Foundation along with its subsidiary Reddy-Cheminor Inc, Ranbaxy Laboratories, and the Indian Petrochemical Corporation also show some degree of patenting. Other institutions which show patenting mainly belong to the pharmaceutical sector.

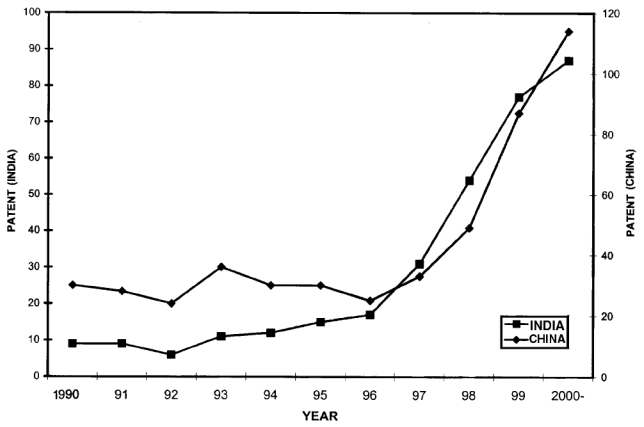

Figure 1. US patents assigned to India and China (1990–2000).

In China, in general, patenting is not concentrated among a few institutions/companies as it is in India. China's patenting activity is distributed among varied types of organizations. Individuals as well as universities are active in patenting. In case of India, patenting by this segment is negligible. China Petrochemical Corporation and various institutes under Chinese Academy of Medical Sciences are prominent in the patenting activity.

Joint patent assignment indicates collaborative linkage in R&D. Table 2 highlights the collaborative linkages. There is a much higher level of collaboration among institutions in China compared to India. Only in the later period of 1998–2000, some degree of collaboration is observed in India. Still the degree of collaboration in China is almost three times that in India. Collaborations involving varied types of organizations in China are also very active. Universities play a key role in patent filing (see Table 1) as well as collaborating with the different types of organizations. Between industry and university, and industry and research institutions, there is a healthy linkage. Interesting details emerge from their university–industry interactions. One patent is assigned to a firm, which is part of a university (Sunlee Hi-Tech Industry Co Ltd of Nankai University). China Petrochemical Corporation has the maximum number of joint patent assignees, mainly with research institutions and universities. These are mainly in the later half of 1998–2000, accounting for 15 joint patents. Three joint patents were filed in 1997.

Table 1. Patenting by type of organization in India and China

Patenting	India			China		
Period → Type of orgnization* ↓	1992–94	1995–97	1998–2000	1992–1994	1995–97	1998–2000
Organization/agency/ individual	16	27	68	75	78	186
Industry	12	16	47	30	40	119
Research institute/ foundation/academy	3	7	11	19	15	33
University			1	16	8	16
Specialized institute (including hospital)	1	3	11	11	9	13
Individual				13	8	15

Source: Constructed from USPTO database[10];
*Only unique organizations for each year are counted.

Another feature of the Chinese collaboration activity is multiple assignee of a patent involving industry, research institute and university or specialized institute.

In India, collaboration is mainly observed among firms, or between firms and research institutions. Some collaboration between research institutions and specialized institutes is also observed. In spite of CSIR being a dominant player of Indian patenting efforts, there is conspicuous absence of different laboratories under it involved in joint patent activity (it is possible to uncover this fact through the inventor's address in spite of patents being filed under CSIR as a corporate entity). Joint assignment can be observed only in few patents.

The degree of international linkage (one of the assignees is in India/China) shows similar levels in the later period (1998–2000). However, there is marked contrast in their linkage pattern. For India and China, the US and Japan are the prominent collaborators respectively.

Impact of patents and patent families

Citation weight, calculated in terms of total citations received by the patents (a citation window of three years is chosen in this study) divided by the number of patents, indicates the impact of patents in later innovations. The citation weights of Indian patents are greater than one in both the periods (1992–94, 1995–97), 2.52 and 1.37 respectively. Similarly, the citation weights of Chinese patents are greater than one in both the periods (1992–94, 1995–97), 1.91 and 1.45 respectively. It can be observed that the impact of patents from both the countries has decreased in the post-WTO period. The decrease is more prominent for India. The reason behind this observation requires further investigation.

Patents filed by residents of the US are providing maximum citations to the patents of both the countries. Self-citation and patents filed by residents of Japan are other major contributors to patent citation. For India, citing pattern of the patents shows in addition to self-citation, patents filed by residents of the US are prominently cited. However, along with self-citation and citing patents filed by residents of the US, Chinese patents also prominently cite those filed by Japan, Taiwan and Korea.

Patent families imply countries where a particular innovation has been patented for protection. The validity of commercial exploitation or IPR protection of a patent is possible only in those countries where the innovation has been patented. Logically, an innovation is patented in a particular country if there is a possibility of strategically exploiting the patent for commercial gain. When we consider the patent families of all the patents of a country, a high number would imply a more global reach of a country to compete in the world market. We observe increase in the patent families of both the countries (India and China). The increase is very significant for India. Twenty-nine patents had 122 families in the period 1992–94, whereas 63 patents in the period 1995–97 had 408 families. For China, 90 patents covering the period 1992–94 had 438 families, and 88 patents in the period 1995–97 had 465 families (Table 3).

Technology profile

Table 4 shows the relative technological strengths in different sectors for these two countries. It also indicates the general activity of these two countries in a particular sector by assigning different levels; low patenting ≤ 10, moderate patenting ≤ 20, high patenting > 20, and active patenting = significant positive change (from low to moderate). Indian or Chinese is mentioned, if it is specific to any particular country.

Table 4 indicates the areas of relative technological lead of India and China in terms of patent activity. The technological profile that emerges for India during the period 1992–94 depicts a very poor assessment of its technological strength. On comparison, China presents a very active profile during this period. It shows presence in most of the sectors, with intense activity in PE and BA. Wherever there is an Indian patenting activity, China has an appreciable lead in it.

Focusing on the period 1995–97 indicates a healthy improvement in the Indian profile. India shows strength in two sectors, OC and GP during this period.

China shows that it has maintained its activity with relative improvement to its position in 1992–94, in terms of addressing new fields and intensity in some sectors.

Table 2. Comparative collaboration activity of India and China

Patenting	India			China		
Period →	1992–94	1995–97	1998–2000	1992–94	1995–97	1998–2000
Collaboration	1	1	11	12	11	32
Type of collaboration*	1	1	6	6	6	10
International collaboration**	–	–	5	3	–	5

Source: Constructed from USPTO database[10].
*Industry, university/academy, research institute, special institute, including hospital, and individual.
**We only include patents, which as a result of international collaboration, are assigned to India or China.

Three sectors PE, OC and GP mainly address their patents. However in OC, India has a much higher patenting strength. In GP, the gap between India and China is very narrow, with China having only one patent more than India.

The last period, 1998–2000, shows some marked changes in relative strength of both countries. China has maintained its activity with intensification in some sectors. However, India has done tremendous catching up. In two sectors, GP and OC, India's lead is four times and three times respectively, in comparison to China. It is to be taken into account that these two sectors are also the areas of strength of China. Looking at some other sectors, for example, PE an area of high patenting activity of China depicts India's catching up throughout. India had no presence in this sector during 1992–94, only few patents in 1995–98, but shows strong activity in 1998–2000. However, in four sectors, ET, MM, TE and PP, China shows vigorous activity in this period (1998–2000). In contrast, India has no presence in PP, and shows low activity in ET.

Overall, the technological profile in terms of patent output shows similarity as well as contrast for both the countries, at least in the later periods. GP and OC are areas of maximum activity for both India and China. There is an increasing similarity of profile in the current period with PE (an area of strong activity of China) also showing enhanced activity by India. Similarly, many areas of low activity previously for India have more comparable profiles in the current period.

Table 5, derived from Table 4, brings out some of the other salient aspects of their technological profile. From Table 5, the trend can be easily observed. India's efforts in catching up with China can be clearly seen. In the period 1998–2000, India and China are more in comparable terms, India having doubled its spread (addressing new fields) in 1998–2000 from the earlier period of 1992–94. Another important observation is that India has addressed a patent in a sector once it has entered it. On the other hand, China has entered some new fields in 1995–97 at the cost of leaving out some fields where it had patents. However, China's position is still dominant, as can be observed from the large number of independent fields it has in comparison to India. If we look at the lead positions, which indicate numerical strength in each of the sectors between the two countries in that particular period, both countries have leads in equal number of sectors in 1998–2000. The patent intensity shows that India has actively

Table 3. Comparative patent citation and patent family of India and China

	India		China	
Year	Cited	Family	Cited	Family
1992	7	22	42	117
1993	31	63	57	153
1994	35	37	72	168
1995	28	51	45	209
1996	32	67	52	93
1997	26	290	31	163

Source: Constructed from USPTO database[10].

Table 4. Competitive position of India and China in terms of patent activity in technological sectors

Technology sector*	Initial status 1992–94	1992–94 to 1995–97	1995–97 to 1998–2000	Trend
BA	↓	↑↑↑	↑↑↑	Low patenting
CO	↑↑	↓↓	↓↓↓	Low patenting
DA	No patent	↓↓	↓↓	Low patenting
EL	No Indian	No Indian	↓	Low patenting
EN	No Indian	No Indian	No Indian	Low patenting
ET	No Indian	↓↓	↓↓	Moderate Chinese
GP	↓↓	↓	↑↑↑	High patenting
HA	No Indian	No patent	No Indian	Low patenting
IC	↓	No Chinese	↓	Low patenting
IM	No Indian	No patent	No patent	Low patenting
IN	No Indian	No Indian	↓	Low patenting
IS	No patent	No Indian	No patent	Low patenting
LA	No Indian	No Indian	No patent	Low patenting
MA	—	↓	↓	Low patenting
ME	No Indian	No Indian	↑↑	Low patenting
MM	↓↓	↑↑↑	↓↓	Active patenting
MS	No Indian	No Indian	↑↑	Low patenting
MT	No Indian	No patent	—	Low patenting
NA	No Chinese	↑↑	↑↑	Moderate Indian
OC	↓	↑↑	↑↑↑	High patenting
OP	No Indian	No Indian	No Indian	Low patenting
PC	–	↓	↓	Active patenting
PE	No Indian	↓↓	↓	High patenting
PO	No Indian	↓↓	↑↑↑	Low patenting
PP	No Indian	No patent	No Indian	Active Chinese patenting
TC	No Indian	↓	↓↓	Low patenting
TE	↓↓	↓↓	↓↓	Moderate patenting
TR	No Indian	No Indian	No Indian	Low patenting

Source: Constructed from USPTO database[10]. Patents assigned to sectors based on Grupp and Schmoch[11] classification scheme. 7th IPC codes have been used for classifying new patent codes.

A patent is assigned to more than one sector on the basis of IPC codes assigned to it.

↑, Lead in favour of India; ↓, Lead in favour of China; —, No lead. Single arrow implies lead is within the limits ≤ 50; Double arrow, ≤ 100; Triple arrow, > 100.

*BA: Mining, civil engineering, building materials, air-conditioning, waste disposal, and related topics not included elsewhere; CO: Coating, crystal growing; DA: Data processing; EL: Electronics, electronic components not included elsewhere; EN: Nuclear technology, electricity; ET: Electrical engineering, electrical machinery; GP: Bio- and genetic engineering, genetics pharmacy; HA: Handling, conveyor equipment, robots; IC: Inorganic chemistry, glass, explosives; IM: Image transmission; IN: Instruments not included elsewhere, controls; IS: Information storage; LA: Mechanical engineering, machinery not included elsewhere, armament; MA: Mechanical engineering, Machinery not included elsewhere, armament; ME: Biomedical engineering, medicine; MM: Material processing, machine tools; MS: Metrology, sensors; MT: Engines, motors, turbines, pumps; NA: Agriculture, nutrition, beverages, tobacco; OC: Organic chemistry, petrochemistry; OP: Optics; PC: Polymer materials, polymer chemistry; PE: Process engineering, separation, mixing; PO: Polymer processing, synthetic resins, paints, and other synthetic substances not included elsewhere; PP: Paper and printing; TC: Telecommunication; TE: Textiles, apparel, leisure, textile machinery; TR: Transport and traffic.

Table 5. Comparative patenting activity in India and China

Patenting	India			China		
Period →	1992–94	1995–97	1998–2000	1992–94	1995–97	1998–2000
Spread	10	15	20	25	22	25
New field	–	5	5	–	3	0
Missing field	N.A.	0	0	0	6	3
Independent	1	1	–	17	8	5
Lead positions	1	4	8	6	10	8
Intensity (%)	82.14	225	910.7	150	285.7	786.7

Source: Constructed from USPTO database[10].
Spread means the technological fields over which patents can be distributed. New field means technological field where patents have been taken in the current period, and there were no patents in the field in earlier periods. Independent means fields where the other country does not have any patent. Intensity is the number of fields covered by the patents over the total number of fields. New field and missing field are with respect to previous periods.

increased patenting in all possible technological sectors to derive maximum benefit from a patent. In this respect India has clearly left China way behind.

It is worth noting that within the sectors, the activities are in various sub-sectors. These have not been detailed, as it would have made the comparative assessment difficult. However, the classification of patents under sectors leads to difficulty in appropriating some patents and masking the activity in a prominent sub-sector. In this context it is worth mentioning that lighting was a prominent patenting activity for China in 2000, with nine patents (this has been classified under ET). Similarly for India, there were four patents in jewellery in the period 1995–97, and three in the period 1998–2000 (these patents have been appropriated under CO).

Assessment of trade based on technological profile

Patents in a foreign country are considered to be the protection of export products. However, resource-based/low technology exports to a country are not determined to have significant relationship with patent activity there[14]. International trade, particularly in high and medium technology, depends on product innovation as well as product differentiation, where intellectual property protection through patents comes into play. To what extent the changing patent profile of both the countries has affected the composition and volume of trade of India and China remains to be analysed. We look at the trade characteristics of both these countries in USA, keeping in context the technological intensity of the sectors addressed by their patents there.

Among the top ten export items of India to the US in 1999 (USITC trade database)[15], resource-based ones form 36% of the total exports. There is a fraction of low technology items like jewellery. Textile-related items (low technology) form 28%, 2.3% in organic chemicals (medium technology), and 2% in nuclear reactors and related items (high technology). From the technology profile it can be observed that OC and GP are major patent activities of India. Modest patent activity is observed in TR. Thus it can be interpreted that technological activity is not much appropriated by the nature of India's export. On the other hand, for China, textiles and to some extent consumer items are among the top ten export items accounting for 51% of their total exports. Electrical machinery/electronic items (medium technology) form 18% of their top ten exports. Nearly 15% is in high technology, 12% of it in nuclear-related items, and 3% in precision instruments. China's major patenting activity is in PE, GP, ET, OC, MM, TE and PP. Only ET and to some extent TR may have some of the exports bearing on technological lead governed by their patents. Thus our preliminary investigation indicates patents not playing a major role for both the countries in their export performance.

Conclusion and discussion

Our study shows significant increase in patenting activity for both the countries from 1995 onwards, the post-WTO period. This increase is not only in the number of patents, but also in terms of addressing new technological sectors. The changes are more significant for India. India has done a lot of catching up in comparison to China; their patent profiles being at more comparable levels now. The global reach of Indian patents, as determined by patent families, is more intense in comparison to China, implying greater desire of Indian companies to make their presence felt. Patents of both these countries are also getting noticed, as citation weights of their patents are more than one. However, a slight decrease in impact is observed in the later period. Similar trends in future would be a matter of concern and would require introspection.

However, the technological catching up by India is not reflected in its trade activity. The nature and volume of Chinese trade is also in contrast to its technological profile, as reflected by the patent data. However, China has over the years established its presence in the medium

technology and to some extent in the high technology exports (as evident from the US trade data). Observations on the changing nature of world exports may provide some general trends/indications in this context. Most of the world's exports are covered by WTO disciplines, especially exports from developing countries[8]. The composition of many developing countries' exports has also transformed over the last decade; changing from resource-based/low technology to medium/high technology exports. A similar observation is also true for the historical growth pattern of the newly industrialized countries of Asia. These countries made strategic moves for developing manufacturing capabilities in the medium technology areas to graduate to high technology export (case of Taiwan, refs. 16, 17). In the case of India, however, the changes are not that promising, whereas China has shown some significant jump in medium technology-based exports. For example, in 1985 the components of resource-based/low technology export for India and China were 86% and 93%, which in 1996 changed to 83% and 66% respectively. On the other hand, in 1985, the medium technology exports from India and China were 14% and 7%, which in 1996 changed to 17% and 34% respectively[8]. This changing nature of Chinese exports towards medium technology indicates the emergence of a technology-governed trade pattern which calls for increasing role of patent in protection of export products through infringement violations, IPR protection, etc.[14]. This augurs well for creating a manufacturing/production base where patents may play a key role in bringing out exclusive products protected by proprietary clause. On the other hand, India's trade pattern is still not technologically governed. This indicates that research and development activities are not connected to industrial applications, i.e. application of research and development in the production sector is minimal. India is clearly lacking in strategy to put into use its patents for wealth-creation. In the present scenario, at best it can get some returns from important patents by licensing them to foreign companies and earning royalties from them. This is appearing as a major trend for most of the important patents granted to India. On the other hand, if these patents are exploited within the country, niche products can be created which can capture the world market. However, this can only happen if production units are created in the country, which are governed by intensive technological applications. Moreover, the focus should be on concentrating on a more technology-specific domain for patenting activity rather then trying to address different technological sectors. This calls for a long run strategy for developing manufacturing capabilities synchronized with technological advantage created through patenting. These steps would help create a national innovation system that can generate technological leads and translate them into economic goals[18]. Schumpeterian[19] wisdom that 'Economic leadership in particular must hence be distinguished from invention. As long as they are not carried into practice, inventions are economically irrelevant', stands valid even today.

Note 1: World Bank definition (World Bank Report 1999/2000) is used for defining the different technological categories. Under their assignment of technological categories, export groups are based on the use of scientists and engineers in production and the amount of research and development activity required. Resource-based exports are unfinished raw products. Low-technology exports are typically labour-intensive manufacturers with low worker-skill requirements. Medium-technology exports are products that entail fast-moving production technologies and some design efforts. High-technology exports are products that combine intensive use of highly skilled employees with substantial research and development.

We have additionally included a factor of competitiveness and exclusiveness defined by a high-technology product. Patent provides 'temporary monopoly' which is one of the characteristic attributes of a high-technology product.

Note 2: A distinction between economies of *scale* and economies of *scope* is essential to understand the dynamics of contemporary knowledge production. Economies of scale are the gains made possible by the combination of technology and organization in which the number of units of production or distribution increases while unit costs fall. Economies of scope, in contrast, are gains arising from repeatedly configuring the same technologies and skills in different ways to satisfy market demand[3].

1. Wakelin, E., *Trade and Innovation: Theory and Evidence*, Edward Elger, Massachusetts, 1997.
2. Rodrigo, G. C., in *National Economies for Countries in Transition: Evidence from Eastern Europe and Asia Pacific* (ed. Scholtes, P. R.), University Press, Cambridge, 1996, pp. 3–33.
3. Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M., *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, Sage Publications, London, 1994.
4. Rausch, M. L., An SRS Special Report, National Science Foundation, Washington, DC, 1995, pp. 95–309.
5. Griliches, Z., *J. Econ. Lit.*, 1990, **27**, 1661–1707.
6. Ahuja, G., *Adm. Sci. Q.*, 2000, **45**, 425–455.
7. Bhattacharya, S. and Khan, M. T. R, *Res. Eval.*, 2001, **10**, 33–46.
8. World Development Report 1999/2000, Oxford University Press, New York, 2000.
9. Fagerberg, J., *Res. Policy*, 1987, **16**, 87–99.
10. United States Patent and Trademark Office database (http://www.uspto.gov/main/patents.htm).
11. Grupp, H. and Schmoch, U., in *Dynamics of Science-Based Innovation* (ed. Grupp, H.), Springer-Verlag, Berlin, 1992, pp. 73–122.
12. Hall, B. H., Jaffe, A. B. and Trajtenberg, M., Working paper 8498, National Bureau of Economic Research, October, 2001.
13. Meyer, M., *Scientometrics*, 2000, **49**, 93–123.
14. Basberg, B. L., *Res. Policy*, 1983, **12**, 227–237.
15. USITC trade database (http://dataweb.usitc.gov).
16. Chang, P-L., Shih, C. and Hsu, C-W., *Technol. Anal. Strategic Manage.*, 1993, **5**, 173–178.
17. Chang, P-L., Shih, C. and Hsu, C-W., *Int. J. Technol. Manage.*, 1993, **8**, 697–712.
18. Nelson, R. R., *National Innovation Systems: A Comparative Analysis*, Oxford University Press, Oxford, 1993.
19. Schumpeter, J. A., *The Theory of Economic Development*, Oxford University Press, New York, 1961 (translation).

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