GLOBALISATION OF KNOWLEDGE DEVELOPMENT AND DELIVERY : TECHNOLOGY AND POLICY PERSPECTIVES

By

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ABSTRACT

During the past decade globalization is becoming deeper through technology and knowledge sharing between various actors in the global value chain. It is a positive development for countries whose firms and institutions are also oriented and geared up to play an increasingly greater role in knowledge development and delivery. On the surface it appears to be a free flow driven by market forces just as it is for trade and financial flows. Many policy makers and leading industrialists in developing countries like India, as can be seen by their statements and actions, believe that any needed technology or knowledge can be bought at a price and factored into their business plans. This may be partly true for a follower type businesses or low value part of the global chains. However with their growth when they attempt to get into new pioneering areas, they will find that the knowledge rights are with a limited number of big players in well developed countries. Even new development by them may become difficult as most options are well covered by intellectual property rights (IPR's) obtained by them much earlier. Several examples will be discussed.

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This paper is an attempt to point out an important new dimension which may turn out to be a barrier, if not well understood, for global knowledge development and delivery. Some policy directions are also given.

INTRODUCTION

Firms (or loosely stated as Industry) in most developing countries including India fall into two very broad categories : laggards or follower types. They operate with technologies purchased from developed countries or under licence production. Even foreign companies which establish industries in these countries do not use the frontline technologies. The firms which supply the knowledge and technologies to industries in the laggard or follower type countries do not often give their latest ones; they are the ones which these firms had used several years ago and themselves had phased out of their own operations (for variety of reasons such as their local laws, competitive advantages etc).

Even for technologies which are not legally protected through patents, designs, trademarks etc; and thus passed on to the general public use (generic technologies) it is often not easy for the firms in the developing countries to start production. They require a number of tacit knowledge which are usually embedded in the individuals or institutions which made the original products or became followers almost immediately after the pioneer launched the product. Mere documentation will not suffice. That is the reason why many firms of developing countries engage foreign consultants to assist them even when the technologies used by them can be categorized as 'laggard' type (i.e. a decade or more older than the current ones in that area of operation in the developed world).

Only those firms in developing countries which have developed some of their own R&D capabilities though they may even be in terms of marginal changes to the bought out technologies etc., are able to utilize the opportunities of use of technologies when they go out of patent protection. This is an area in which some of the Indian pharmaceutical firms made their presence globally.

Often they did not invent a new molecule or drug. But due to the earlier patent regime in India, they were able to find out a new process of making the basic drug which had been invented abroad. Thus they developed the capability of using the knowledge available in the public domain to do their own development to capture the generic market. Now they are facing new challenges; the case of Ranbaxy may perhaps be the beginning of a new phase.

In the field of manufacture of machines or products out of materials (metals, composites etc), firms of developing countries such as India, copied the foreign designs, and processes to make indigenous machines to supply to the own laggard industries. It was so in India also . Many machines in traditional sectors like textiles, sugar, paper, metallurgical products, etc fall in this category. In the years before liberalization (pre 1991), these industries were protected by high import duties and therefore pressure on them to innovate was low.

Post-liberalisation period ushered in new regimes in which import duties were brought down. With the easing of restrictions on foreign exchange especially for the firms, most Indian firms who wanted to upgrade themselves were able to do so with newer machines and technologies. This was done through import of new machines (imbedded knowledge) and also through foreign consultancies. In some cases joint ventures helped the flow of new knowledge (new for Indian firms but often used globally by developed countries years or decades ago).

EVOLUTION OF KNOWLEDGE IN FIRMS

The process described above still continues for most firms in India. Most automobile companies in India are either foreign companies or joint ventures with foreign companies. Even indigenous ventures for example passengers cars like Indica, Indigo etc have many technology and knowledge packages purchased from abroad.

Let us look at the consumption of metal working machine tools in India. From the publications of Indian Machine Tool Manufacturer's Association (IMTMA) one can see the following trade :

(Rs. in Million)

Year	Imports	Indigenous
2003-2004	9,655 (57%)	7420 (43%)
2004-2005	18,208 (62%)	10,950 (38%)
2005-2006	28.986 (68%)	13,420 (32%)

Note: Figure as % indicate share in Indian market for machine tools (Source: IMTMA)

This trend is true of most manufacturing industries. In the services sector, IT sector and telecommunications also foreign technologies dominate with Indian firms operating mostly in the low value end of operations.

Indian firms missed most of the evolutionary period of growth of manufacturing sector post industrial revolution and also the explosive growth of chemical industries in Europe. This was primarily due to the presence of a colonial power whose priorities were different. But it is also to be admitted that the presence of that colonial power brought in some knowledge bases to India though in a limited way. Post-independent India aimed at self-reliance and self-sufficiency. Rapid industrialisation was attempted through large scale import of technologies and machinery from the developed world and providing commanding heights to the public sector. Indigenous production was protected through severe control of imports. Industrial growth was regulated through licensing regimes. (Ref.1 - see Industrial Policies in India – three part article – www.ysrajan.com).

One key assumption in post independence Indian industrialization model was to ignore the growth of knowledge in the firms of the developed world from which the knowledge was imported. It was as if the world, was in a state of status quo ante for all technologies. Another key assumption was that the new knowledge, if any, which is growing abroad can be captured by a large number of science and technology institutions created for almost all sectors and later transferred from them to Indian firms which were created in the public sector through huge investments and import of foreign technologies. This assumption on indigenous knowledge development and delivery to firms did not take place to any successful degree over the past six decades. The debate and dialogue on Industry – Academia interaction continues in the same way over the past three to four decades. The failure to succeed in this front was largely due to the industrial and S&T policies (see the article cited before) which led to isolated and stagnant pools of knowledge developers and users.

The evolutionary process of knowledge development and delivery was not understood by most of the decision makers and implementers in Industry and Government. This ignorance unfortunately continues.

While considering the status of industries and services, it may also be useful to refer to vast part of agriculture and related sectors in India. While some parts of them have derived the benefits of modern knowledge and delivery (follower type) during the time of green revolution and later through certain cooperative sector and private sector efforts, a bulk of Indian agricultural operations suffer from the lack of evolutionary knowledge growth. Most of the marginal and poor farmers are trapped in technological practices which are many decades old, if not a century old. In fact this stagnation in knowledge and skills causes bulk of the poverty prevalent in India. Mere pulls of market forces cannot help them to modernize themselves as they do not have the funds for investment for purchase of knowledge, nor the skills to deliver them on a large scale to those who need. Nor do they have the financial capacity to face the risks of changes.

Competitive pressures from imports may perhaps help industry to import knowledge and modernize as explained earlier. Even this process itself may not help many Indian Micro, Small & Medium Industries (MSME). But in the primary agriculture sector mere global economic pressures cannot help. They may in fact damage many families of marginal and poor farmers and agricultural labourers. It is a matter of lives of hundreds of millions people.

It is not proposed to discuss these aspects of policies here. They are merely pointed to emphasize that *the question of global knowledge development and delivery has applications only to limited segments of Indian economy, and different policy regimes are required for other segments like agriculture, MSME's etc which have not fully evolved as yet to global standards.*

The author has discussed these aspects in one of his earlier papers (Ref. 2 "Towards a knowledge society in India: Issues for management" appeared in the International Journal of Information Technology and Management, Volume 2, No.3, 2003).

Whether one cannot get out of these evolutionary processes and speed up knowledge bases, is an important question to be answered. The economic histories of Japan, South Korea, some of the ASEAN countries, Israel, Ireland, Taiwan, and China indicate that it is possible to overcome the historically accumulated deficits and gaps in knowledge and skills in a period of two to three decades and become knowledge developers in the domestic and global markets. They had right mix of policies and implementation institutions.

This paper does not address all these aspects for a country like India except for pointing out the complex issues involved and that there is no single uniform solution.

In the rest of the paper, the authors attempted to point out an important segment of modern Indian Industries which are speedily following the global developments and trying to be more advanced followers with a hope to graduate to leadership positions at least in a few segments of the industries. Examples are automobile manufacturers; other ancillary manufacturers of auto components; pharma companies, some parts of the energy sector; etc.

FOLLOWER TO A LEADER : CURRENT CHALLENGES

It was never easy for a follower type firm to become a leader. It acquires follower type of technology and other knowledge and skills to be in production and have a market share. Then through acquisition of relevant new knowledge packages and its own internal R&D, it introduces incremental innovations into its product lines. Over a period of decade or more, through well thought out business-technology plans and implementation, it can get into the leadership league. Then again it is a continuous competitive race with newer technologies and newer business strategies. But the positive fact is that a number of firms who were follower types, are in leadership role today. Many Japanese, Korean, Taiwanese and Israeli companies are shining examples. Some firms from China are in that category now.

Sometimes even when the entire firm may not have a leadership type products, a few of the product lines of the firm can reach a stage oaf global leadership.

Some of these examples as to how companies (firms) gain knowledge through various strategies such as mergers and acquisition, through foreign direct investment and R&D, are discussed in the book by N S Siddharthan and Y S Rajan (Ref.3 - Global Business, Technology and Knowledge Sharing : Lessons for Developing Country Enterprises). The crucial role of knowledge sharing for the global businesses including the enterprises from the developing countries are discussed in the book with several data sets and examples. Some of the references cited in the book give many more examples of different situations.

Most of the examples and case studies were before the year 2000. At this point, it is important to look back the earlier years of the twentieth century when most modern businesses grew around the world and the economic and technological business miracles of Japan, Korea etc took place.

For example during the 1960's and 1970's even in the then developed world such as USA, UK, France, W.Germany, and a few European countries though there was free trade and market driven economies, there were many forms of trade protections between themselves and more importantly protection of technologies. As the Cold War was at peak then, there were severe restrictions of transfer or trade of even advanced commercial technologies to the Soviet Union and the East European countries as well to some others who were considered to be their allies. Still countries like France also attempted some independent policies in their national interest of developing their own national high technology businesses. Even USA has a Made-in-USA Act to support local industries.

It is during this period, Japan and later S.Korea started their massive high tech industrialization programme, as also Taiwan and also a few South East Asian countries. They imported technologies from USA, France, Germany etc and also allowed the firms from these developed countries to establish manufacturing bases in their countries. Through this process, they enabled availability of more advanced technology to their country (now the word knowledge is used). Japanese, S.Korean, Taiwanese etc. managers and workers thus got an opportunity to work with most advanced technologies and their knowledge and skill base got a great boost.

But they did not stop at that. They did the usual manufacture with these advanced machine and knowledge/skill packages. Most importantly they invested on their own inventive capability. MITI of Japan played a special role in making the S&T personnel and the persons in the firms aware of the new and emerging technologies well in advance through forecasting studies and other regular reports. MITI also helped the Japanese firms big, small and medium, to organize their technology acquisition, R&D management and above all for winning export markets. So did S.Korea with a different way by creating a few large holding companies and giving them near monopolistic field for actions. Taiwan built up technology parks to develop their industries. All these countries used their own judicious mix of govt. support to firms, govt. controls on imported products which may compete with local companies (through tariff & non-tariff barriers) and endogenous capability building actions by the firms themselves – big, medium & small. Govt. also enabled policies to provide necessary human resources for their growing industries and businesses.

During this period, India built up industries especially in public sector with imported technologies and through license production arrangements. India also built up high tariff structures to protect these industries from imports but did not bother about exports nor building up their endogenous R&D capabilities for continual improvement of technologies and newer skills.

Over a period of two decades Japan, S.Korea and Taiwan emerged as a part of the leadership league in many sectors. Japan became net exporter of technologies and captured many high-tech markets in USA & Europe. S.Korea & Taiwan followed. While Israel was most innovative, its budding entrepreneurs sold of their ventures at a very high price in the initial phases, instead of building big enterprises as Japan, S.Korea & Taiwan did. Japanese & Korean industries became global giants with global brand names and even threatened the market leadership of many US and European firms.

During the 1980's, USA and a few European countries started pushing for a new global order for free market access for trade and technology. The literature during this period was aimed at making such a globalization possible. Not only the direct trade barriers were attacked but also the various firms of non-tariff barriers (standards, Intellectual property rights (IPR), local laws etc). The firms in USA and Europe were worried about the ascendancy of Japanese and Korean firms.

They were also worried about the emerging tigers from the ASEAN countries during the 1980s. China was yet to make its presence as it liberalized its economy for foreign investment only during 1981.

During the mid 1980's Global Agreement of Trade & Tariff (GATT) negotiations also included Technology in its item for consideration, despite feeble fights by developing countries.

One of the biggest weakness of global trade which existed before, was the lack of global regime for IPR. That is the reason why countries like Japan, S.Korea, Taiwan and others who allowed FDI in their countries and who also purchased technologies, could do marginal inventions and come up with their own new products. In addition, they could use certain national standards which acted as a trade barrier for products from other countries, though in a narrow sense they allowed ‘free trade’. It was not possible to stop such actions legally.

Therefore the developed countries managed to include ‘Technology’ as a part of GATT thus linking Technology & Trade, legally in the global arena. There were a long tortuous negotiations. Many business confidential information (knowledge) also came to be called IPR.

During the 1990’s the impact of the fast growth of China and growth of ASEAN countries were being felt in the developed countries. Many of their industries lost out in this globally free competition for market.

India, a much later player opened up in 1991 and slowly liberalized its economy. However, the fears of Y2K and associated dotcom growth during the mid-nineties, helped the Indian IT industries. Indian IT firms undertook off-shoring and outsourcing tasks from the US companies who were in search of low cost outsourcing centres. So also Indian pharma industries who had built up their endogenous strengths in production of generic drugs, started getting into leadership league through high quality, production of low cost generic drugs, though their own original inventions were practically nil. They built up their capability under the 1970 Patent Act of India, which protected them against product patents and they thus captured some markets in the developed world for generic drugs.

Based on GATT negotiations, there was a Dunkel draft of 1995 and soon WTO (World Trade Organisation) came into force through a consensual agreement.

China which had become powerful through earlier regimes somewhat similar to Japan & Korea also joined WTO accepting its new conditions on Trade on Intellectual Property Rights (TRIP’s) and several other technology related restrictions in almost all chapters of Dunkel Draft.

Full force of the new GATT regulations & WTO came into force for countries like India during 2005 especially for enforcing product patents.

Because of WTO regulations, it is no longer possible for the firms or governments of countries to use the methodologies or policies of 1960's, 1970's, 1980's, 1990's to build up competitive capabilities for their firms.

Restrictions on IPR's are not only on the protection of existing IPR's but also in creating new IPR's (Knowledge Development & delivery). For example, even which R&D support of the govt. will be considered as a subsidy is defined in the GATT agreement which led to WTO. These are termed as actionable and non-actionable subsidies. (Govt. subsidies to firms for global competition is reduced to a minimum in order to ensure "free trade").

During the years ahead from now, any facilitation by govt. to firms have to keep the WTO restrictions in mind. IPR regimes are much more stringent now and globally enforced. Technology (or developed knowledge) can only be delivered through channels acceptable to WTO regime.

The earlier methods of copying or having special national regimes of IPR protection is no longer possible. (These earlier opportunities existing through 70's, 80's and partly 90's have helped Japan, S.Korea, Taiwan, Asian Tigers and China and also India in some sectors like Pharma).

So the rules of the game for the firms and Govt. to catch up from the follower category and to graduate into leadership league are very different now. In addition, there are many other global standards which need to be followed for the products. Having a national standard to give an edge to local companies will be treated as a non-tariff barrier and may attract WTO action.

These are the new “barriers” so to say for firms from developing countries – most firms from India will fall in this category.

These are the new realities to be encountered by those firms who attempt to create businesses made of newer technologies. These firms may already exist and may even have global presence supplying products based on earlier technologies, obtained by them through purchase of technologies or through licence production. Such firms may be desiring to leap ahead through newer technologies preferably created by their own capacities. Even with their own internal R&D work and endogenous capabilities, they may not be able to proceed for commercial operations. Even though the knowledge creation and development are their own, they may not be able to deliver the products even in their own domestic markets and of course, in the global markets.

Why ? This is where the trade related intellectual property rights (TRIPS) provisions of WTO come to play. Till recently the IPR’s were the total sovereign concern of a country. Though the Paris Convention and World Intellectual Property Organisation (WIPO) etc were in place, they were primarily the only in information exchange role and some advisory role. Whereas now under WTO regime, a country cannot violate IPR and leave it at that, leaving other countries protesting. The punishments will be given through WTO mechanisms, which may mean blockage of trade by them with other countries.

Also in the earlier years, while the basic idea behind the definition of ‘invention’ was same, most countries had their own methods of assessing state-of-art, inventive step etc. Also the penetration of IT in IPR governance has made global patents and IPR information, available to all almost instantaneously. There is no excuse against a truly global search whether indeed the application for a new patent (even for use within the country) is a new invention. In addition, though in theory the IPR right according authority is the sovereign national govt. agency, applications accepted elsewhere through Patents Cooperation Treaty (PCT) have a special status. Thus patents are more or less globally accepted. The applicant can come into the country much later through PCT route; it will be very difficult to reject them.

In addition, world over the courts are very conscious of global applicability of IPR and they look for only global level 'inventiveness'. Hence cannot claim that they have produced the knowledge all by themselves and with their own money and other resources (i.e. own knowledge development) and thus claim their genuine right to make products and sell (i.e. knowledge delivery). Their right to enter into the market depends on who possesses IPR. Even in case of filing of fresh IPR, if the firm is late comer, then it loses its rights. Those who have filed for IPR for that particular product or process first, have the right; there is no second right !

Over and above these, there are many other non-IPR type constraints through international standards. Also there are national procedures and laws within countries. For example sale of food and drugs within USA are governed by stringent FDA regulations. There are also stringent environmental standards in a number of European countries like Germany (including for the packages in which the products are exported into the country).

Therefore even to 'catch up' in the 21st Century a laggard or follower firm has to be very conscious of IPR and other standard regulatory aspects, pointed out above (though not exhaustively).

Often time one finds in developing countries like India there are announcements of major well funded Govt. supported programmes like Biotechnology, Nanotechnology or clean technology like Biofuel etc. Often these governments get alerted only after foreign countries announce their products. (This is a follower/laggard mindset derived from their recent past of several decades.)

Scientists and technologists jump into the bandwagon and get more funds. In India it has happened several times over the part two or three decades be it for supercomputers, or superconductivity or biotechnology. Currently the fashion is around nanotechnology, biofuel, stem cells, and some select areas of biotechnology. Even assuming that they are focused on end processes or products and also that the projects are well implemented (often rare !), the big question, after such a knowledge development is over and when it is ready for knowledge delivery to firm to get into market, will be whether these “knowledge packages” are adequately protected to fulfill the requirements of IPR regimes in force. Can a firm acquire all other related “Knowledge packages” as (often invariably) a new product comprises several technologies ? It will require many other IPR’s to make a product, in addition to the IPR’s which the knowledge-developer in the laboratory may give to the firm.

In the following sections the authors will give a few examples, centered around the patents, as they currently exist in the global scene, for a few new emerging areas having a potential for huge global market. The following sections describe the patent strategies of big global companies and other firms and institutions in the developed world.

APPROACH OF BIG GLOBAL COMPANIES FOR PATENT STRATEGY

There are four broad categories in which the approach can be divided.

Category 1 : Multiple patents for one single product by a single firm or organization

For example a mobile phone has a large number of patents around it, which prevents the competitors from manufacturing some component, subassembly or a similar product, even with their own endogenous effort. Other examples are as under.

Xerox is a good example. Xerox's entire business is about document management systems. The famous product line is its photocopier machine. In its determination to keep on its competitive edge and its global market share, Xerox has now about 8000 live patents. In 2005 xerox and its joint venture Fuji Xerox together were granted 643 US patents.

Apple's iPod nano is another example. This device is an mp3 player and storage media. In physical size it is thinner than a standard # 2 pencil and can hold about 1000 songs. Apple has most crucial patents for this. Further, Apple has filed patents for additional features such as "click wheel" and in addition an auto sync technology. In addition to patents for technical elements, APPLE also holds Design Patents. In 2008 APPLE was granted six such patents by US Patent & Trademark Office for items such as design wins for the iPod nano, a Dock insert, "Medida Device" design and iPod earphones.

Thus APPLE has surrounded its iPod with many IPR protections thus making it difficult for any body to break through this cordon ! The knowledge delivery can only be on its commercial terms.

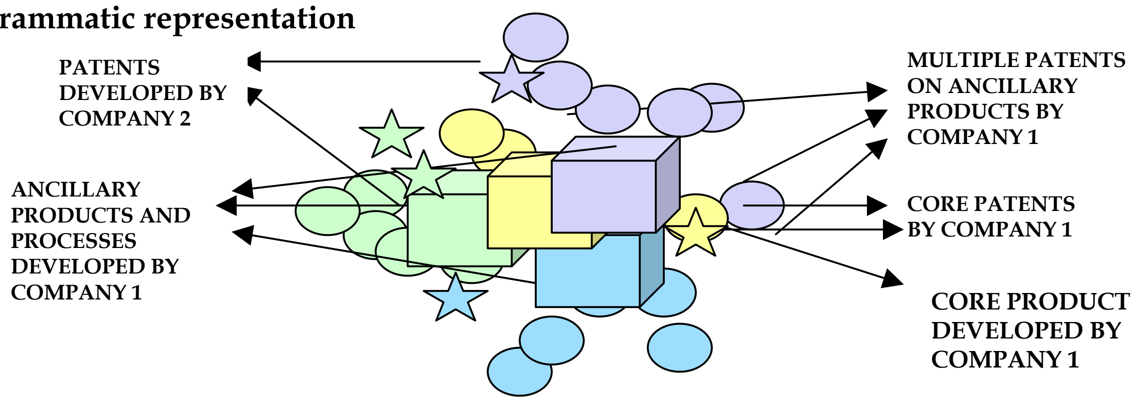
Category 2 : Multiple patents for single product by multiple firms or organization

Instead of a single company, two or more companies together may hold many patents to protect a single product thus keeping the competitive edge within them only.

For example, Mitsubishi Digital Electronics America and Sharp have signed up licence agreements for the digital television (DTV) reception technology developed by Zenith. Zenith developed the 8 – VSB digital transmission system which is the core element of the FCC's adopted ATSC DTV Standard. The FCC DTV Tuner Mandate, which began July 1, 2004 requires 8 – VSB tuners in 50 per cent of 36 in and large sets sold in USA. Effective July 1, 100% of 36 inch and larger sets and 50% 25 – to 35 – inch sets, sold in the USA will be required to incorporate 8-VSB demodulators. The rule will apply to all TV's 13 inch and larger in 2007. (Note here the role of standards and national rules we have discussed in an earlier section of this paper.) In addition to addressing the core standards, Zenith has several patents essential to the operation of over-the-air digital television receivers compliant with ATSC DTV Standard. Thus Zenith has a near total control and the licence agreement empowers Mitsubishi Electronics America and Sharp.

It is difficult for others to get into this segment without agreement with these firms.

Case 3: **Defensive/ Futuristic Patent Portfolio**
Diagrammatic representation



The company 1 develops a core technology and protects it with core patents. To protect its core technology, the company 1 develops ancillary technology and protects it by way of patents on various products and processes. Company 2 may also cover the core or related technology and ancillary patents / processes.

This opens scope for cross licensing between company 1 and company 2 on the use of the patented technology.

A good example of this is the MPEG-2 technology. **MPEG-2** is the industry standard for "the generic coding of moving pictures and associated audio information". The technology pertains to a combination of lossy video compression and lossy audio compression (audio data compression) methods that allow storage and transmission of movies using available storage media and transmission bandwidth.

The MPEG-2 technology is covered by approximately 640 “essential patents” held by over 20 companies and 1 university located in different countries including Mitsubishi, Matsushita, Hitachi Ltd., Toshiba, Fujitsu, Sony, Sanyo, Sharp, Nippon Telegraph & Telephone Corporation, Canon, Samsung, LG Electronics, Robert Bosch GmbH, France Telecom, Philips, Alcatel-Lucent, British Telecommunication, Thomson Licensing SA, General Electric, Motorola. The patent pool is managed and administered by MPEG Licensing Authority, a private organization. Where software patentability is upheld, the use of MPEG-2 requires the payment of licensing fees to the patent holders via the MPEG Licensing Association. Other patents are licensed by Audio MPEG, Inc. The development of the standard itself took less time than the patent negotiations.

<u>Category 4 : Beyond and Around the Horizon Possible</u>

Products: These are really futuristic ones like advanced sensors (bio, electro optical, magnetic etc) nanotechnology, neurosciences with possible products in computing, medical etc., second generation biofuels, etc. Certain countries/companies take advance IPR's even before a full product is visible thus practically taking the full control of new areas. For example, 74% of IPR in renewable energy are from USA.

There are futuristic technologies such as areas of application of nanotechnology where a number of companies have already filed and obtained patents. Figures in the USPTO reveal that there are 2,738 patents in total, covering 52,148 relevant claims that cross seven application categories of the eight classes of nano materials namely carbon nanotubes, metal nanoparticles, aerogels, ceramic nanoparticles, dendrimers, quantum dots, fullerenes and nanowires.

Similarly in areas such as biofuels, there has been a marked jump in the number of patent applications filed in this area. The USPTO figures show applications have jumped 150% in the last couple of years. Since 2001 to January 2008, the number of patent applications filed at the USPTO have been 2081 of which 1024 applications were filed in 2007alone.

According to reports, the patents published in technologies such as biodiesel (299), agricultural biotechnology (110), ethanol and other alcohols (42), enzymes (35) and biomass (41) in 2006 to 2007 were 57 percent owned by corporate entities, 11 percent owned by universities or other academic institutions and 32 percent undesignated, where the patent applications do not list the patent owner.

IPR OWNERSHIP IN IMPORTANT TECHNOLOGY BUSINESS AREAS

We have discussed in the earlier section about the approaches of the global firms towards IPR’s and standards and their conscious efforts to imbed them in their planned and potential products, with a few examples.

Here we explore the matter further. These are about two products in which inventors from developed countries have a clear lead and these products appear to hold a great future in global market.

Product 1 : Algal Biodiesel

Biodiesel is defined as the alternative fuel to the conventional petroleum based diesel engine fuel which uses a biological source material. Biodiesel is being manufactured from vegetable oils or animal fats by the process of transesterification or alcoholysis. The biological source material is catalytically reacted with a short chain aliphatic alcohol.

A variety of oils used in the process include rapeseed, soybean, mustard, flax, sunflower, plam oil, hemp and jatropha. Vegetable oils as the source for biodiesel is losing its point as a cost viable option because of its rising food prices. Non food grade oil source like Jatropha has become quite controversial as the source material for biodiesel because of is exaggerated claim as high yielding source. Algae which can be grown using waste materials as sewage (algae ponds of waste water treatment plant) and without displacing land used for food production seems to be having a very promising future as the source material for biodiesel. Algae were also found to be growing next to power-plant smokestacks where they digest the pollutants. Algae have been reported to have natural oil content greater than 50% of traditional oilseeds. This is because there are algae types that are comprised up to 40% of their overall mass by fatty acids. It is this fatty acid (oil) that can be extracted and converted into biodiesel. The yield thus is higher as compared to conventional oilseeds. According to some estimates, the yield (per acre, say) of oil from algae is over 200 times the yield from the best-performing plant/vegetable oils.

The product developmental stage and potential market size

- Feasibility studies have been conducted by US Department of Energy (DOE) to project a possible yield estimate. The production of algae for biodiesel extraction has not yet been undertaken on a commercial scale. Though no large scale plant has been built yet, many companies are pursuing algae bio-reactors for scaling up biodiesel production to commercial levels. HR Biopetroleum has joined with Shell on a company, Cellana that is one of about 20 worldwide looking to commercialize algae technology. Cellana has a leg up on the competition because it already has a patented process and research expertise from HR Biopetroleum that has been developed over nearly two decades. Cellana's pilot plant is producing oil now and that a demonstration plant is being built in Kona to scale it up. Within three years it hopes to have its first commercial plant operating and within six years, another five plants.

Boeing and Air New Zealand recently announced a joint project with a New Zealand company to develop an algae-based jet fuel. Canrex Biofuels Ltd. is currently developing and refining its technology that will see algae production and the supply of biodiesel expand worldwide. Inventure Chemical and Seambiotic announced this week a joint venture to create biofuels from algae fed by a coal-fired power plant. Dr. MGR Algae Biofuel Research Center – Sivakasi, Chennai, India have launched a biodiesel project from micro algae. Above 1 hectare land in Sivakasi is selected to do research on Algae Biofuel. Though algal biodiesel has not been tested at commercial scale, biodiesel from other sources is rapidly replacing diesel as a more efficient, cheap, and clean alternative. Biodiesel in India is being used for Railway engines and experimentally to run state transport corporation buses in Karnataka. Biofuels from algae is being tested for use in transport, including jets. The fuel also can be used in power plants.

Patent status

About five crucial patents have been filed on different aspects of biodiesel processing from algae. US Publication No. **20080160593** relates to process for production of biofuels from algae by cultivating an oil-producing algae by promoting sequential photoautotrophic and heterotrophic growth. Conversion of the algal oil to biodiesel is by direct hydrogenation or transesterification of the algal oil. US Publication No. **20080090284** discloses a system for processing oil from algae. US Publication No. **20080155888** relates to methods and compositions for producing purified oil from algae. Purification is done by using nanomaterial. US Publication No. **20070048848** discloses methods, apparatus, compositions and systems relating to closed bioreactors for algal culture and harvesting. Biodiesel from algae in this case is reported to be produced by transesterification. US Publication No. **20080086937** provides a system and method for producing algae with high oil content.

The five crucial patents are held by :

1. Two stage process for producing oil microalgal
   Inventor : Oyler James (Salt lake City, UT, USA)

2. Photosynthetic oil production with high carbondioxide utilization
   Inventor : Hazlebeck, David A (ElCajon, CA USA); Dunlop Eric H (Paradise AU).

3. Methods and compositions for production and purification of biofuels plants and microalgae
   Inventor: Vick Bertrand (Berkeley, CA USA); Caspari; Matthew (San Francisco, CA); Guido; Radaelli (Berkeley, CA)

4. Method, apparatus and system for biodiesel production from algae
   Inventor : Sears; James T. (Boulder, CO, USA)

5. Photosynthetic oil production in a two-stage reactor
   Inventor: Hazlebeck; David A (El Cajon, CA, USA); Dunlop; Eric H (Paradise, Australia)

It can be seen from the above that the really most advanced Biofuel technology are covered by patents by persons in two countries. Almost any further knowledge development or delivery has to take this reality into account.

Let us look at another biomedical, biotechnology product.

Product 2: Blood Chip : DNA microchip for blood grouping and genotyping

Blood chip is a DNA chip (oligonucleotide genotyping microarrays). It has been developed by BloodGen Consortium and is at commercialization stage by Progenika Biopharma, Spain. BioArray Solutions in Warren, New Jersey, has developed another genotyping product called BeadChip that tests for 11 blood groups but not A, B, and D.

Blood chip does a comprehensive blood genotype profiling of both donor and the recipients and thus help in safe transfusion. Blood chip aims to focus on clinically relevant antigens and will be able to determine 9 blood groups and 65 predicted phenotypes.

The Blood chip kit consists of reagents for labeling the sample DNA. The sample DNA is amplified and the PCR product is added to the Blood chip where it is hybridized and washed. The final step is analysis, where the Blood chip is scanned and the intensity signals are automatically interpreted by the software which provides a final report with the genotypes and the predicted phenotypes for each of the blood groups.

Blood chip has applications in the following areas of:

- Blood transfusion (sickle cell anemia, thalassemia, leukaemia, chemotherapy patients)
- Testing for pregnant woman
- Identify fetus at risk for hemolytic disease of the newborn
- Reliably determine RhD especially partial D, weak D and D negative
- Screen for antigen-negative donors
- Confirm serology for weak antigens
- Determine complete blood group profile of frequent donors

Observations

Clinical stage of development and potential market

- Validation studies of blood chip in different countries have shown it to have a higher precision than serology and the ability to determine weak antigens, which are not detected by serological techniques.
- Clinical trials in a large multi-site international study have been conducted and have shown high precision of analysis.
- So far around 3000 samples have analyzed as a clinical validation.
- To come to the Indian markets they would have to study a few thousand Indian samples as well.
- The Blood chip has received CE mark status in Europe for use as a clinical diagnostic.
- It will take another 1-2 years to launch as product.
- Presently Blood chip is targeting the European and USA market.
- Eventually plans to capture all the Blood Banks and Blood services worldwide.

Patent status

Five patents filed on the genotyping of blood cell antigens have been found relevant to the Blood chip product. US publication No. **20080050727** and Publication No. WO **2005095650** relates to a method of genotyping of blood cell antigen and a kit for genotyping of blood cell antigens. Publication No. WO **2006032897** relates to genetic analysis of blood cell antigen gene. The patent with the Publication No. EP **1047777** has been granted and discloses a novel nucleic acid molecule correlated with the Rhesus D phenotype. A similar patent on the molecular structure of Rhesus D negative locus has been published with the Publication No. **EP 1780217.**

Conclusions on Blood Chip

The Blood chip has been developed mainly with the aim of replacing the conventional serological technique for blood typing to achieve safe transfusion. The market it is presently targeting is European and US market. However

Progenika Biopharma has already installed the first platform devoted to blood genotyping in the Middle East in the Sharjah Blood Transfusion and Research Centre, the main blood bank of the United Arab Emirates. This indicates its initial step in foraying into Middle East and Asian region. This however will be possible only after blood sample testing of populations of this region.

The crucial core patents in this area are :

1. **Method of genotyping blood cell antigens and kit suitable for genotyping blood cell antigens**
   Inventor : Beiboer; Sigrid Herma W.; (Hoogvliet, NL);Wieringa-Jelsma; Hendrika; (Almere, NL); Den Dunnen; Johannes Theodorus; (Rotterdam, NL); De Haas; Maschenka; (Koog Aan De Zaan, NL)

2. **A method of genotyping blood cell antigens and kit suitable for genotyping blood cell antigens**
   Inventor : Beiboer Sigrid Herma Wilma (NL); Wieringa-Jelsma Hendrika (NL); Den Dunnen Johannes Theodorus (NL); De Haas Maschenka (NL)
   Assignee: Sanquin Bloedvoorziening (NL); Beiboer Sigrid Herma Wilma (NL); Wieringa-Jelsma Hendrika (NL); Den Dunnen Johannes Theodorus (NL); De Haas Maschenka (NL)

3. **Gene Analysis**
   Inventor : Olsson Martin Lennarth (SE); Storry Jill Rosalind (SE); Avent Neil David (GB); Madgett racy Elizabeth (GB)
   Assignee : Univ Briston (GB); Universitetssjukhuset I Lund B (SE); Olsson Martin Lennarth (SE); Storry Jill Rosalind (SE); Avent Neil David (GB); Madgett Tracy Elizabeth (GB).

4. **Novel Nucleic acid molecules correlated with the rhesus weak d phenotype**
   Inventor : Flegel Willy A (DE); Wagner Franz F (DE)
   Assognee: DRK Blutspendedienst Baden Wue (DE)

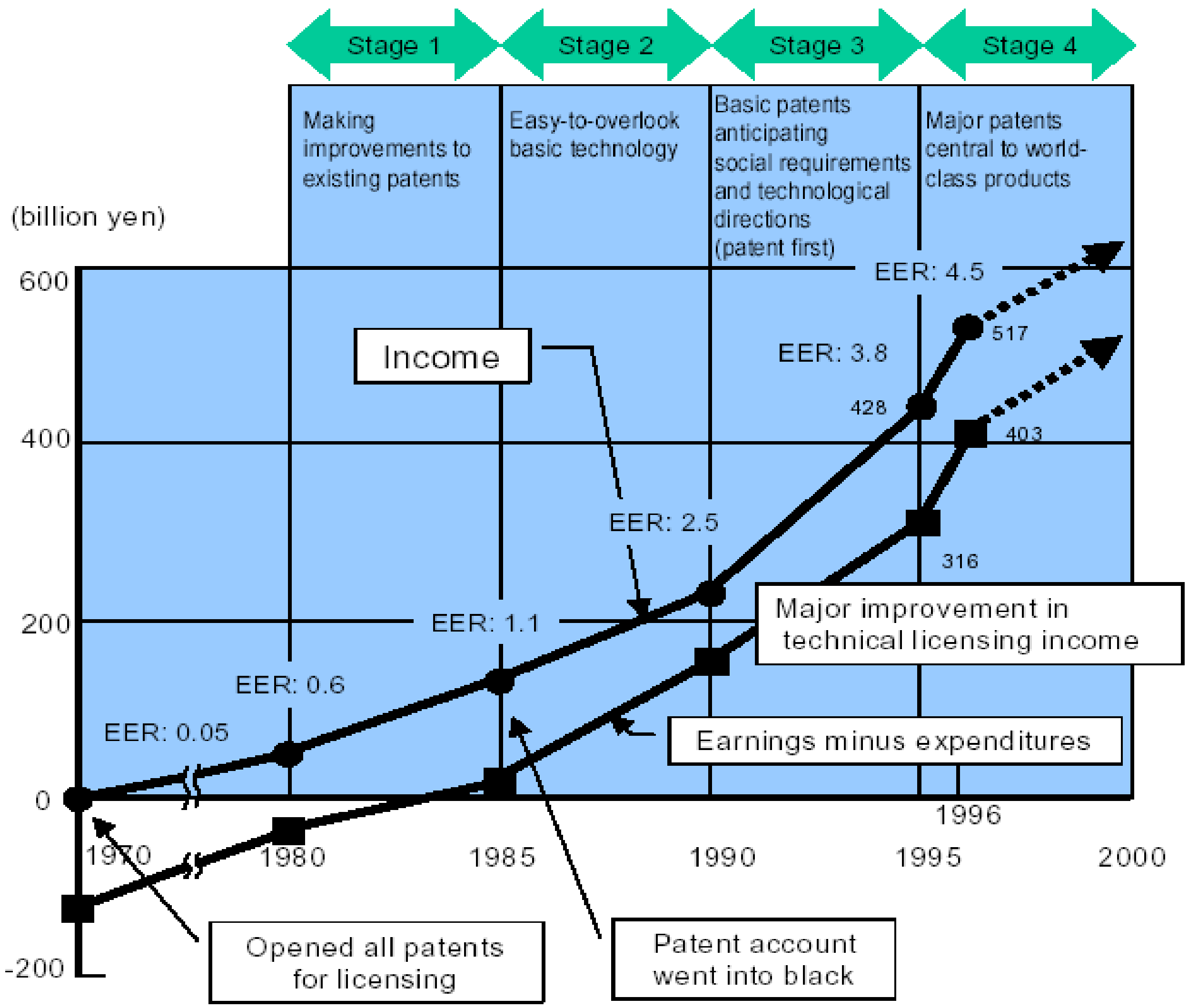
5. **Molecular structure of RHD negative locus**
   Inventor: Flegel Willy a (DE); Wagner Franz F (DE)
   Assignee : DRK Blutspendedienst Baden Wue (DE)

Again one can note that this advanced technology with huge application and market, has the crucial patents from inventors from a very few advanced countries.

HITACHI’S PATENT STRATEGY

Company’s patent strategy from 1970 – 2000. This is true of many companies which have grown up into global leaders from their earlier follower stage. The information and the graph given here may be seen in the context of the discussion in earlier sections.

Hitachi’s Patent Strategy



Note: The earnings:expenditures ratio (EER) is calculated by dividing patent license earnings by patent license expenditures.

Source: http://www.wipo.in/about-ip/en/studies/publications/wipo_pub_489/pdf/wipo_pub_489_ch4.pdf

PATENTING IN INDIA

In addition to the global status of patenting in various areas, it is also important to look how patenting situation in India. It determines how global and domestic firms have decided to use the domestic market in India. Without patent registration in India, the firms cannot have the IPR's operating in India though they can export to India, products manufactured from outside. For domestic production, it is safer to have IPR. Therefore the patents registered in India by foreign firms and entities indicate their business plans in India.

Let us look at the applications filed from residents and non-residents (foreigners) through various routes from 2000 – 20007.

Applications filed from Residents and non-Residents through various routes :

2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	Applicants
2179	2371	2693	3218	3630	4521	5314	Indians(Residents)
2160	1870	1723	1678	3165	1008	693	Foreign/ordinary
-	-	-	-	-	3509	3165	Convention
4164	6351	7049	7717	10671	15467	19768	PCT
6324	8221	8772	9395	13836	19984	23686	Foreigners Total

Source: Patent Facilitating Centre, TIFAC, DST, New Delhi

NEW FORMS OF CONSOLIDATION OF IPR'S: PATENT POOLS

We have so far surveyed how companies approach IPR's around a single product; how companies join to strengthen their grips of IPR's; how certain advanced technologies have been captured through patents by inventors in a few developed countries; also about the need for compliance to standards to enter into market etc. And also about increased foreigner patent activity in India. On the whole, it is important to note that though there is severe competition between firms in developed countries, as far as IPR's in advanced emerging areas of technology businesses are concerned, they have near global monopoly through patents and through their ability to satisfy crucial conditions of standards and regulation in the developed and developing countries. (Most of the developing countries follow the regulations and standards from the developed world for their domestic markets as well. This was so even in 70's and 80's albeit with some time lag).

A new feature of patent pooling may re-emerge partly in view of the fact that a single product has several patents behind it and often the crucial ones are held by a few major firms (or organization). This feature needs a close watch by those interested in global knowledge development and delivery.

A "patent pool" is an agreement between two or more patent holders (owners) to license one or more of their patents to one another or third parties. A patent pool can also be defined as a consortium of at least two companies agreeing to cross license patents and other IP rights relating to a particular technology.

Although the first reported patent pool was formed in 1856 in the USA; the first in the recent time was formed in 1997 in USA with the approval of the Department of Justice in respect of MPEG-2 standard. We have briefly touched on this product in an earlier section in a different context.

MPEG-2 video standard defines how to represent a digital video data stream used in digital cable television systems, digital satellite for televisions and DVD players. If a company wants to sell equipment that will be capable of decoding a digital video stream on a DVD, it must make its product compliant with MPEG-2 standard. As of January 2002, there were at least 14 separate companies owning 75 US patents that have been determined to be essential to the MPEG-2 standard. Can a company start manufacturing MPEG-2 compliant systems with out infringing the above patents? The chances of infringing the above patents would be quite high because these patents among them would cover practically all aspects of the technology for it to be utilized in true sense. No one company, perhaps, would be in position to have expertise in all aspects. Therefore, it becomes imperative on the part of the company to have these patents licensed to it. If one were to deal with these 14 companies for patent licensing, the transaction cost and inconvenience in establishing and completing separate license agreements would be enormous. In addition, a licensee not having a strong legal back up would always live in a fear of possible infringement. Therefore, patent pool does provide a better comfort zone to licensee and also help in keeping the transaction costs low. Small or new manufacturers can enter DVD player market after performing no research and development in respect of MPEG-2 and DVD technology. The effect of such an arrangement may be seen in the low prices at which DVD players are available today in the market even after paying royalties to the MPEG-2 and DVD patent pools. In terms of the terminology ‘knowledge delivery’, this arrangement helps ‘knowledge delivery’ even to a firm which does not have a patent and may not have a R&D base.

Prima facie, it would appear that patent pools would lead to monopoly which is restrictive and anti-competitive and thus may be discouraged in the interest of trade and commerce. Further, they could inhibit future innovations and entry of new players. It is the same argument which was advanced by many against a strong patent regime in India and other developing countries. Limited monopolies have been allowed by law in the field of patents to promote innovations and wider utilization of innovations. Similarly, when it comes to patent pools necessary legal mechanisms and instruments need to be built to avoid situations going out of hand as there could be a very small gap to be traversed from a competitive state to a monopoly state. MPEG-2 patent pool was allowed by the Department of Justice, USA with the above in mind. Taken together they are comprehensive :-

1. A patent pool can only be formed in respect of patents dealing with a technology which is covered by well defined and definite technology standards.

2. The patent pool must integrate complementary technologies and competitive technologies are not candidates of the patent pool. If patents related to competitive technologies are allowed to form patent pool, it may lead to overpricing and profiteering leading monopolistic alliances.

3. Companies spend extensive resources to develop industry standards in order to implement new technology.

4. An independent evaluator / independent expert should be engaged to determine which patents are essential to the implementation of the standard and define a group of essential patents.

5. A patent pool administrator should be appointed by the essential patent holders to handle signing up licensees, collecting royalties from licensees and distributing share of royalties to essential patents holders.

6. The essential patent holders retain the rights to license patents outside of the patent pool.

7. A license agreement should be so designed and drafted by the essential patent holders that it allows technology to be licensed on a reasonable and nondiscriminatory basis.

8. It reduces transaction costs.

9. It avoids costly infringement litigation

10. It promotes dissemination of technology.

11. The pool agreement must not disadvantage competitors in downstream product markets and

12. The pool participants must not collude on prices outside the scope of the pool, e.g., on downstream products.

Patent pools conforming to above features should be approved and promoted by government, industry, and the public; otherwise they will not stand on a good foundation. What happens if any of the above element(s) is missing or not clearly established? Does it mean that a patent pool cannot be established? The answer, perhaps, would be no. However, it would be necessary to scrutinize the patent pool arrangement more carefully.

History of patent pools

The first patent pool was formed in 1856 in USA involving sewing machine manufacturers. Before this arrangement the manufacturers namely, Grover, Baker, Singer, Wheeler and Wilson used to be engaged in accusing each other of patent infringement. In 1917, an aircraft patent pool was privately formed encompassing almost all aircraft manufacturers. The creation of such an outfit was considered essential as two major patent holders, the Wright Company and the Curtiss Company had effectively blocked the building of new airplanes which were desperately needed by the USA to enter World War I. 1924 saw setting up of another pool which merged the radio interests of American Marconi, general Electric, AT&T and Westinghouse leading to standardized radio parts, airway's frequency locations and television transmission standard. MPEG-2 patent pool was set up in 1997 and is almost the first one in recent times and it was formed by the Trustees of Columbia University, Fujitsu Limited, General Instrument Corp., Philips Electronics N.V. Scientific Atlanta Inc., and Sony Corp. Sony, Philips and Pioneer formed a patent pool in 1998 for inventions that are essential to comply with certain DVD-Video and DVD- ROM standard specifications. Hitachi Ltd., Matsushita Electric Industrial Co. Ltd, Mitsubishi Electric Corporation. Time Werner Inc., Victor Company of Japan and Toshiba Corp. formed a patent pool in 1999 for products manufactured in compliance with the DVD-ROM and DVD-Video formats. More recently, RFID Consortium has announced its intent to form a patent pool in August 2005 and also announced that MPEG LA, LLC will act as the administrator for the licensing purposes. The latter announcement was made in September 2005. Official members of the RFID Consortium are Alien Technology, Applied Wireless Identifications Group, Avery Dennison, ThingMagic, Tyco Fire & Security and Zebra Technologies. The proposed pool is to manage the intellectual property required for UHF RFID standards from EPCglobal and ISO.

Some functional aspects of patent pools

The patent pool created in 1998 for DVD-ROM and DVD-Video Format I envisaged a royalty rate of 3.5% of the net selling price for each player sold and $ 0.05 for each disc sold. In addition, the portfolio license requires an initial payment of $ 10,000, half of which is creditable against the per unit royalties. In this arrangement Sony and Pioneer licensed essential patents to Philips to enable Philips to grant license the package to third parties.

The arrangement in the patent pool created in 1999 for DVD-ROM and DVD-Video Formats II has a difference in royalties rates.(It may be noted that partners in Formats I and Formats II are different.) The royalty rate is 4% of the net sales price of each DVD player and $0.075 for each DVD disc sold. The formula for royalty considers how often a licensor's patent is infringed and age of patent.

The patent pool often called 1394 Standard Patent Pool deals with 1394 standard (IEEE 1394-1995, IEEE P1394a, IEC 61883-1 and IEEE P 1394b) is very fast bus standard that supports data transfer rates up to 400 Mbps. Products supporting 1394 standard are sold in different names by different companies. The original partners in the pool were Apple Computer Inc., Compaq Computer Corp., Matsushita Electric Industrial Co. Ltd. (Panasonic), Royal Philips Electronics, Sony, STMicroelectronics and Toshiba Corp. It is now reported that Cannon Inc. and Hitachi have also joined the pool which comprises 34 patents and portfolio is licensed to 56 licensees. The royalty is $0.25 upon the sale or manufacture of each system that implements 1394 standard regardless of the number of 1394 ports per system.

In case of MPEG-2 patent pool, the expert reviewed about 8000 US patent abstracts and over 800 patents owned by about 100 different patentees. Any one could submit his/her patents for the review, meaning thereby that the expert was supposed to look at all patents and not limit himself only to patents owned by companies which opted for a patent pool.

Regulators have to closely monitor the functioning of patent pools to ensure that basic principles of founding such pools are not violated and absolute monopoly is avoided under all circumstances. A patent pool was created by VISX and Summit Technology, manufacturers of FDA approved lasers used in photo refractive keratectomy. It was complained that both the manufacturers had intellectual property to enter the market independently. In other words patents of the two companies were not complementary. One of the terms of the pool was a $ 250 license fee each time laser eye surgery was performed using standard equipment covered by either company's patents. As a result of this level of royalty, the cost of surgery was higher than if VISX and Summit Technology remained competitors. It was estimated that consumers paid over $30 million in 1997 to cover licensing fees. The Federal Trade Commission of USA decided to put all patents in the patent pool and made them available to third parties on non-exclusive and royalty free basis.

Nature of technology

Patent pools formation calls for a long experience of development of standards and associated technologies. Intricacies of available technologies and their interrelationship involved in the process of forming patent pools are to be understood. The exercise of identifying essential patents demands high level of understanding of technology and the concerned standards on the part of all the players wanting to be a part of the pool as making such an assessment would involve study and interpretation of a few hundred patent documents.

Further questions are posed here for enquiry and research : Is it possible to extend the concept of patent pool to other areas such as drugs and chemicals? Would all the above features be satisfied in respect of these areas? Do we have standards for drugs which have to be met by all the drugs and no one else can sell drugs which don't meet such standards? Is it possible to conceive of complementary technologies in this area? Considering the common platform in respect of diseases which the world is confronted with complementary technologies may provide a solution which is acceptable to many and may be the most cost effective solution.

Such pools can be anticipated in new technology areas such as nanotechnology and biotechnology. Although no such example is reported but realms of possibility has been discussed in a few quarters.

'Patent pooling' need not be looked with a negative approach by firms and institutions in developing countries, as a 'cartel'. If they understand the rules of the game of global knowledge development and delivery (for example new product development and marketing globally and also finding local producers for such products), it is possible that some of them can do a few crucial inventions which need not be for the full product but can fit in the pool as a necessary risk minimization for a later producer. In addition for those who do not aim at being ‘knowledge developer’ but only want ‘knowledge delivery’ from others at a price, the pool become a single point source for negotiation of technology transfer etc and thus reduce transaction costs and legal risks.

DISCUSSIONS

In this paper we have pointed out that knowledge development and delivery of old and mature segments of technology, can take the traditional routes of sale of technology, license production, merger and acquisition, joint venture etc. Even in these areas when a firm or a product line of the firm graduates to a point when it can attempt to be in the leader league, then questions of IPR’s arise. The recent example by a major stock take over of Ranbaxy by a Japanese company Daichii highlights the needs of original IPR’s in possession of the firm to enter into the leader league.

Even for creation of new original IPR’s (new knowledge development at the global scale), it is no longer the situation as it was in 1970’s, 1980’s and 1990’s. In the twenty-first century with WTO regimes under way, it is no longer a matter of a knowledge developer doing R&D first and then going for a patent filing later. One has to study the whole status of IPR in a particular product line (current and future possibilities) before embarking on new Knowledge Development. Even for those who are keen only on Knowledge Delivery to them from some other firms or institutions, it is important to look at all the IPR’s connected with the intended product line. If arrangements for all of them are not done, the knowledge purchasing firm may have risks by possessing rights in one set of IPR’s only. Especially when the purchasing firm plans to grow big in domestic or global markets, the legal risks are high; under WTO regimes even for domestic sales, there are legal risks. When a firm is too small, those who possess other IPR rights, may not bother ! Let us not forget that e-commerce is making everything transparent !

In the emerging areas in biomedical fields, renewable energy, advanced electro-optics, biotechnology, nano-technology etc., the firms from the developed countries have positioned themselves very well with IPR's well in advance of actual commercial global operations, making it very difficult for a new comer to enter. The knowledge delivery will be on their terms. If a developing country firm or institution plans new knowledge development, they have to study the IPR situation around the intended or potential product line very well so that their invention will become a crucial IPR around the product in the midst of already crowded encircling of patents from developed country firms. One of the authors used to refer this phenomenon as "Chakravyuha" borrowing an term from ancient Indian military strategy; it is a formation which is difficult to enter for the enemy and if he enters it is difficult to get out without being killed !

This does not mean that knowledge development by developing countries will be impossible due to WTO regime. The fact is that it is going to be difficult. Only those who master the IPR's and standards around a potential (or intended) product can venture into the game of new knowledge development. In which case their IPR's may also become a part of a pool and gain much more value as the investor would not like to risk infringement fo IPR's. Or armed with new IPR, the firm would be in a position to bargain for better terms with other global actors owning other crucial IPR's as described in earlier sections.

Similar precautions should also be taken for those who merely receive knowledge from others at a price. The receiver has to take care of the delivered 'Knowledge' (from others) is risk free from other IPR's. Even to assess it, considerable degree of technological knowledge is required at that product level (not just generic !). In addition, one has to be careful about existing global and / or national standards at the target export markets.

We thus find that global knowledge development and delivery are no longer the usual form of "free trade" studied and dealt with by the economists. The price of knowledge development and delivery, is not that easy to determine as only a few firms (or country institutions) are the possessors of rights over the knowledge and its utilization. The terms they will set up, need not follow the usual forms of trade we are accustomed to, so far. Also many other considerations including political relations between countries may come into play.

In view of such complexities of global knowledge development and delivery, it may not be possible to leave these processes (be it IPR management described above, IPR pools, or even certain critical merger and acquisition etc) to a firm or an institution alone, especially in a developing country like India and expect them to succeed in the global market place. Let “the markets decide”, the usual phrase of policy makers, is not simple for countries having firms and R&D institutions, which are still laggards or followers.

Firms or institutions may not have all the wherewithals even though they may be big sized within their countries. Governments in developing countries without the past role of control and inspection, have to play a new facilitating role to help the firms and institutions of the countries. It is possible to do so within the current WTO regimes also provided that they are done with creative innovation. Similarly the usual Govt. grant giving mechanisms for promotion of scientific research can no longer follow their usual “peer review” mechanisms, without taking into account the new global realities.

The authors suggest that these emerging new possibilities may be researched by multi-disciplinary teams. It may enable better global transactions of knowledge.

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