

**The distinctive patterns of dynamic learning and inter firm
differences in the Indian pharmaceutical industry**

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Abstract

Technological or institutional change has proven to be a major cause for failure of established firms and history is full of such examples. In a globalised world the capability of a firm to reconfigure existing competencies and create new knowledge for innovation has emerged as dynamic capability to succeed. This paper points out the learning processes involved in the development of innovative R&D capabilities in Indian pharmaceutical firms as a response to the strengthening of patent law. Over the last three decades Indian firms successfully grown in weak patent era and the strengthening of patent law represented a radical regulatory break. This paper shows that the development of new capabilities involved removal of capabilities which were redundant in this new era and acquisition of new knowledge. The analysis revealed that Indian firms are adopting strategies like hiring of Indian scientists educated or working overseas in multinational pharmaceutical R&D and collaborating with Indian and overseas research institutes and universities to acquire capabilities in innovative R&D. However, it also shows heterogeneity in learning processes, thus reinforcing the argument that firm level learning is neither automatic nor linear and requires a deliberate learning strategy. The Indian pharmaceutical firms' responses provide important insights for firms from other developing countries.

1. Introduction

The transition to new technology, science, market or regulatory regime is difficult for any organisation, public or private to manage. The discontinuities forcing these transitions are mostly driven by technology, competitors, regulatory events or significant changes in economic and political conditions. Even when established firms recognise the need to change in response to shifts in their external environment, they are often unable to respond (Tushman and Anderson, 1986; Henderson and Clark, 1990; Utterback, 1994; Christensen, 1997). With the advent of globalisation the pace of these transformations appears to be accelerating and the resulting pressure to change is mounting. Therefore in recent years the ability and efforts of firm, enterprise or countries to develop appropriate understanding and response to change by transforming capabilities has become one of the central areas of research in management science.

In the globalised era, the ability of firms to renew or reconfigure existing competencies and create new knowledge for innovation has emerged as a strategically important capability (Dosi, 1988; Pavitt, 1991, Teece et al., 1997). Several firm level empirical studies of renewal or reconfigurations of capabilities involving mechanisms of learning and knowledge creation have emerged during the past two decades. Some of these studies have drawn on the traditional ‘organisational learning’ literature (e.g. Simon, 1991; Hedberg, 1981; Levitt and March, 1988). These studies argue that knowledge is the foundation of capability and source of performance differences among firms in their industry (see for instance, Nonaka and Takeuchi, 1995; Leonard – Barton, 1995; Kogut and Zander, 1992; Teece et al., 1997; Henderson and Clark, 1990). This literature mainly concentrating on firms from advanced countries competing at the technology frontiers, addresses the firm’s capabilities – and knowledge creation in industrialised economies with reference to maintaining and renewing strategic innovative capabilities that already exist (e.g. Cohen and Levinthal,1990; Prahalad and Hamel,1990; Kogut and Zander,1992; Nonaka and Takeuchi,1995; Spender, 1996).

However this body of literature pays little attention to how those capabilities or knowledge bases were initially accumulated.

In the case of firms from developing countries, transformation of capabilities differs in complexity compare to firms in advanced countries as in developing countries economic, political and social complexities makes the transformation of capabilities a challenging and difficult process.

Literature focused on developing countries has mainly addressed process of capability accumulation in firms and industries (see for instance Dahlman and Westphal, 1982; Bell and Pavitt, 1995; Lall, 1987, 1992; Hobday, 1995). Most of these studies have been based on long-term descriptions of capability accumulation in industries from developing countries. This tradition has concentrated on the learning process involved in building essential minimum knowledge base to engage in innovation activity. Therefore, these studies have not yet paid enough attention to capability transformation or capability renewal in developing countries firms. Also despite the emergence of more comprehensive firm level studies during the mid -1990s (eg. Kim, 1998; Dutrenit, 2000; Figueiredo, 2003) comparative analysis of learning and capability accumulation in firms from developing countries or newly industrialising countries has still been absent in this research stream.

This research takes up that challenge. This research explores the learning processes involved in the transformation of capabilities to develop new competencies by firms from developing country as a response to change in the regulatory environment. More specifically this research investigates approaches used by Indian pharmaceutical firms to move from imitative R&D competencies to innovative R&D competencies as response to the change in patent law. The focus of the research is firm level learning processes involved in reconfiguration or renewal of capabilities for innovation and inter firm differences in learning processes.

Due to the TRIPS (Trade Related Intellectual Property Rights) agreements for the first time in international law, all countries are now required to provide protection to both process and product inventions made in all fields of technology including pharmaceuticals and agro-chemical products. In some developing countries like India and China the absence of product

protection played a crucial role in the development of the domestic pharmaceutical industry and would be severely affected. As a result of this regulatory change, pharmaceutical firms in these countries will have to develop competencies in innovative R&D. Some Indian firms have made transformation towards innovative R&D albeit in small ways and so are used as case studies in this research. These dynamic and complex processes of technological learning in the innovative Indian pharmaceutical firms were explored by developing a theoretical framework drawing on strategic management literature and organizational theory literature focused on knowledge, learning and innovation.

This research contributes to the neglected area of research in developing countries literature by investigating transformation of capabilities and development of new capabilities in firms from developing country. It shows that development of new capabilities involved removal of capabilities which were redundant in new era, acquisition of new knowledge and combination of new knowledge with existing relevant capabilities. The analysis revealed that in case of Indian pharmaceutical firms the main rigidities that emerged are a. imitative R&D organisational routines, b. in-house nature of R&D and c. organisational mindset shaped by short term vision of R&D investments and domestic market approach.

Indian pharmaceutical firms hired product R&D experienced scientists working overseas in MNC pharmaceutical R&D firms or universities to acquire the know-how in innovative product R&D. These firms developed linkages with Indian as well as international research institutes to fill the knowledge gaps and train its scientific workforce. However analysis also shows differences in functioning and implementation of learning processes in each firm suggesting that at firm level learning is neither automatic nor linear and requires a deliberate learning strategy.

Paper proceeds as follows. First relevant background is provided by detailing the effect of TRIPS on the pharmaceutical industries from developing countries along with the main characteristics of the Indian pharmaceutical industry. Then the literature on capability accumulation processes in developing countries and capability renewal in advanced countries is reviewed. Evidence on six Indian firm cases is then examined. This provides basis for

identifying salient features of capability development in Indian firms. The closing discussion develops the broader theoretical and managerial implications of the analysis.

2. TRIPS and the Indian Pharmaceutical industry

World trade agreements, especially the TRIPS agreements, are instrumental in setting uniform standards in intellectual property rights (IPRs) all over the world. The strength of the patent regime plays an important role in knowledge intensive industries and especially in the pharmaceutical industry. The pharmaceutical industry is significantly different from other high tech industries in that the R&D process is stringently controlled by regulation, making it very costly and risky. In the pharmaceutical industry, patents provide strong appropriation and profit maximisation by conferring limited monopoly rights to inventors. As a result the strength of an IPR regime is an important issue for pharmaceutical firms but a sensitive one for countries. Access to technology is also relatively difficult in this sector. New product development in the pharmaceutical industry involves highly professionalized and specialised technological R&D activities. The learning process involved in the development of pharmaceutical manufacturing and R&D capabilities is much more complex. The large multinational firms that dominate this sector develop a significant proportion of knowledge and through patents, effectively control the diffusion of this knowledge. These firms conduct most of their activities at home or in other developed countries and prefer direct investment to licensing when producing abroad. Therefore developing countries have built domestic pharmaceutical industries by adopting weak patent laws which allow them to overcome the patent barriers in acquisition of patented knowledge. Now the pharmaceutical industries from these countries will be severely affected by the TRIPS agreement.

The TRIPS agreement now mandates protection to both process and product inventions made in all fields of technology including pharmaceuticals and agro chemical products. This broad regulatory framework will now guide and control the pharmaceutical industry in WTO member countries. This research focuses on the impact of the strengthening of patent law on

learning processes involved in technological capability development and analyses the mechanisms used by firms to transform their capabilities

The Indian Pharmaceutical industry context

The Indian pharmaceutical industry is a successful high technology based industry, which has witnessed consistent growth over the last three decades. The Indian pharmaceutical industry has developed sufficient capability to ensure the country is self sufficient in addressing health care needs. Furthermore, its export ability makes it a strategic trade sector in the Indian economy. The Indian pharmaceutical industry exports generic drugs to CIS (Commonwealth of Independent States) countries, Africa, and recently to the highly regulated US and European markets. The Indian pharmaceutical industry is characterised by a low degree of concentration; a large number of firms with similar market shares, a low level of R&D intensity ratios with a high level of brand proliferation. The need and incentive for innovation was undermined by low purchasing capability of the domestic market along with the ease of imitation and horizontal product differentiation; features that are representative of industries behind the technological frontier.

The growth of Indian industry was very slow up until 1970. The Patent Act of 1972 and government investment in the drug industry infused life into the domestic pharmaceutical industry. The Act removed product patents for pharmaceuticals, food and agro-chemicals, allowing patents only for production processes. The statutory term was shortened to seven years for pharmaceutical patents and automatic licensing was put in place. It started the era of reverse engineering where firms developed new products by changing their production processes.

During the last three decades the larger private Indian pharmaceutical firms focused their efforts on reverse engineering oriented process R&D, and activity was limited to applying known knowledge, or to making small adjustments in content. A few public laboratories under the Council of Scientific and Industrial Research (CSIR) also operated in pharmaceutical R&D, specifically imitative process R&D. Production technologies were well mastered and the lag period between the launch of a new product in its first market and then

in India was thus reduced, in some cases to as little as two years (Lanjouw, 1996). The Indian pharmaceutical industry represents a successful case of indigenous self-reliant development. But the objective of indigenisation rather than innovation made R&D in Indian pharmaceutical firms insular, with a knowledge base firmly rooted in imitative reverse engineering process R&D. As a result Indian pharmaceutical firms have accumulated extensive knowledge in process R&D (synthetic and organic chemistry) but have severe weaknesses in other scientific disciplines such as medicinal chemistry and biology. The ease of imitation in reverse engineering further resulted in intense competition among Indian firms for market share, hampering the development of a collaborative web of networks of research institutes, academia and industry.

The 1972 Patent Act therefore changed the pattern of competition towards volume / price led competition rather than traditional pharmaceutical competition based on the development of new medical treatments. From 1970 onwards, Indian pharmaceutical firms slowly started dominating the domestic market reducing the market share and influence of Western companies. Today the market share of domestic firms is around 60-70% compared to 10% in 1970. With the signing of WTO agreements, specifically TRIPS in 1994, Indian industry and market structure is poised to change. In a product patent regime, Indian firms will have to look for new future sources of growth and the biggest source will be productive R&D, which can deliver patentable innovations.

The extensive literature that deals with the pharmaceutical industry is focused on the technological frontier firms in the developed world. But not enough attention is paid to the capability acquisition processes of pharmaceutical firms from developing countries and to the changed patent law whose impact will change the scientific knowledge base for firms.

3. Technological capability accumulation in developing countries

Technological capability building is an issue that has been widely discussed in the last 20 years by different theoretical research traditions. Technological capability consists of stocks

of resources needed to generate and manage technical change including skills, knowledge and experience and institutional structures and linkages (Bell and Pavitt, 1993). Research on developing countries is mainly focused on the issue of the long term process of technological capability accumulation in industry. This literature largely discusses the capability development in developing countries with reference to the importance and difficulties associated with various formal and non formal mechanisms of knowledge transfer. It emphasises that firms in developing countries compete on the basis of production capabilities, largely acquired from elsewhere and reinforced by basic to intermediate technological capabilities related to a simple knowledge base (Lall, 1987;).

However the increasing specialisation of knowledge is limiting the existing modes of formal and non formal technology transfer. The widening gap between kinds of knowledge and skill required to imitate or operate a given technology and the kinds of knowledge required to create, generate or change technology, has reduced the possibility of acquiring the latter largely by experience in the former (Bell and Pavitt, 1993). In addition, the fast pace of change in markets, technology and competition are making existing firm and industrial level capabilities redundant. Therefore in this new era, the ability of the firm to create new knowledge for innovation has become a strategically important capability. The area of rebuilding or reconfiguring of capabilities has been addressed by the strategic management literature (SML); however it focuses on innovative firms competing at technological frontiers in advanced countries. This research studies learning and capability building concerned with sustaining, deepening and renewing of the existing innovative capabilities by focusing on most innovative firms competing at the technological frontier in advanced countries (Leonard Barton, 1995; Teece, et al., 1997, Nonaka and Takeuchi, 1995). Therefore there is a flourishing literature on firm specific factors that affect the success and failure of innovation in advanced countries, but there is no literature of equivalent scope and depth for developing countries.

The main difference is in the object of analysis, the firm in a developing country and its external environment as opposed to a firm in the developed world and its environment. In the

case of firms from developing countries, economic, political and social complexities make the transformation of capabilities a challenging and difficult process. Availability and access to technical knowledge for firms from developing countries is an important issue and so literature on developing countries is mostly focused on the technical knowledge dimension of the build-up of technological capabilities. However, Bell and Pavitt (1993) point out that the technical as well as organizational dimension of managing knowledge is crucial in building capabilities for innovation. Research on developing countries has to large extent focused on the accumulation of stocks of technological knowledge and much less on the specialization of knowledge bases and other firm level issues for example coordination and integration of knowledge across organizational boundaries. Thus research focuses on capability development in developing countries and the interaction between organizational and technical dimensions of knowledge; a key issue in the development of technological capabilities which needs more attention.

Researchers such as Kim (1998), Dutrenit (2000) and Figueirido (2003) have explored the organizational and managerial issues involved in the development of innovative capabilities. These researchers mostly focus on firm level learning processes involved in establishing a base of technological knowledge, not previously existent, as opposed to renewing the accumulated knowledge base or using that knowledge base in a different way. The change generating capabilities have become increasingly more complex and specialised as they have differentiated from the capabilities required to use them (Bell and Pavitt, 1993).

This paper presents investigation of these change generating capabilities in Indian firms and contributes to this neglected area of research in developing countries literature.

4. Theoretical Framework

The theoretical framework focuses on both historical and contemporary analysis of processes involved in learning and change in Indian pharmaceutical firms.

The firm's ability to develop new competencies depends upon its learning capacity, that is, its ability to acquire, create and disseminate new knowledge. Cohen and Levinthal (1990) refer to this organisational capacity to generate new knowledge as 'absorptive capacity' and define it as the ability of a firm to identify, assimilate and apply external knowledge. However they suggest that absorptive capacity tends to be cumulative and path dependent as it builds on a prior knowledge base and experience which is firm specific. The prior knowledge base is an essential component of firm learning ability or absorptive capacity as existing knowledge increases the ability to make sense of, assimilate and apply new knowledge. The stock of past capabilities, routines provides the base on which firms develop the capabilities to cope with new technological change. In firm change is certainly possible, but it is conditioned by the past. Patel and Pavitt (2000) shows that firms are heavily constrained by their prior competencies in the extent to which they can accumulate competencies in new emerging fields.

Absorptive capacity also refers to the organisation's ability to exploit externally acquired or assimilated knowledge. An organisation's absorptive capacity does not simply depend on its direct interface with the external environment but also depends on the transfer of knowledge across and within subunits that may be quite removed from the original point of entry. The structure of communication between the external environment and organisation as well as among sub units of the organisation is an important determinant of absorptive capacity (Cohen and Levinthal, 1990:132).

{Fig. 1 Here}

Thus an organisation's absorptive capacity or capability to learn is a function of two separate but interrelated dimensions: a. the firm's ability to acquire the knowledge relevant

to the new technological paradigm, and b. firm's ability to integrate external knowledge into existing capabilities.

This theoretical framework broadly covers practices or mechanisms associated with these two dimensions of absorptive capacity. So its focus is on the transformation of what happens in 'practice' as a response to change in external environment. It covers accumulation mechanisms which govern the content and location of stocks of knowledge in the firm; the transfer mechanisms which govern the balance between, internal and external sources of knowledge; it includes assimilation mechanisms which governs the way in which firms internalise the newly accessed knowledge and is also focused on application or deployment mechanisms such as coordination and integration practices which govern the ways in which the stocks of knowledge or specialized knowledge bases are brought to bear within decision making.

This research also uses learning processes adopted by large pharmaceutical firms in their response to advances in biological science to explore response of Indian firms to change in patent law. It has been widely suggested that the case of biotechnology or advances in biological science made several of the core competencies of existing pharmaceutical firms' obsolete (Henderson et al., 1999). Large global pharmaceutical firms acquired biotech capability by hiring the star scientist, restructuring internal mechanisms of managing research and accessing in new external sources of knowledge. The transformation of technological identity by large pharmaceutical firms as a response to biotechnological innovation provide us better understanding of mechanisms used by incumbent firms to transform in face of an external technological discontinuity. In case of Indian pharmaceutical firms these mechanisms helps in focusing on the areas of investigation and assist development of broader categories in data analysis.

{Fig. 2 Here}

5. Research design

The main research strategy used for the research was a case study method. The research looked at firm level processes and so qualitative methodology like case study design is ideally suited for the exploration of such phenomenon (Eisenhardt, 1989; Yin, 1994).

The patent analysis of Indian firms suggests that only a few numbers of Indian firms (10 to 12) have invested in innovative R&D and have products in advanced stages. For the purposes of analysis only those firms have been selected are those which have filed patents in USA and India for new drug delivery systems or new chemical entities. Some of them have out-licensed their molecule to multinational pharmaceutical firms thereby demonstrating capability in innovative research. Patent data was taken as the indicator of a firm's ability in innovative R&D (Table.1). However this data has some limitations, as publication and patents were not a priority area until 1995 due to lack of trust in the case of the former, and lack of value in the case of the latter.

{Table 1 Here}

Qualitative data collection was carried out in two phases. In the first phase, interviews with academics, consultants and patent experts were conducted. The second phase involved interviews with R&D presidents and pharmaceutical scientists from six innovative firms. In the end, a total of 33 interviews were conducted, of which 10 were conducted in the first phase, and 23 in the second phase.

The semi structured questionnaire used for the study was based on the different learning processes in the organisation as categorised by the theoretical framework. Interviews focused on different organisational learning processes or activities involved in acquisition, assimilation, transfer and integration of knowledge. They also covered the questions regarding how the firms have built the prior knowledge and its relevance in innovative R&D. It referred to the nature of the firm's existing base of technical and organisational knowledge,

processes involved in creation of the existing knowledge base and relevance of the existing knowledge base to innovative R&D.

The analysis of the empirical evidence was carried out by using various analytical techniques like pattern matching (Yin, 1994) and by the building of analytical tables (Miles and Huberman, 1984). In this research, strategy of pattern coding is used to identify the processes involved in transformation of capabilities within and across the firms (Eisenhardt, 1989). In analysis first level coding is used as a device for summarising segments of data while pattern coding is carried out by grouping those codes into a smaller number of overarching themes or constructs. The transcripts were analysed by coding the different internal organisational processes around the transformation issues within each firm. The theoretical framework provided broad categories such as processes involved in knowledge acquisition, assimilation, transfer and integration of knowledge for classification of the data and various pattern codes are classified under those broad categories. Along with that mechanisms adopted by large pharmaceutical firms to acquire biotechnology capability also used in identifying different themes in data analysis. Thus the replicating patterns of internal organisation process representing the learning mechanisms and organisational arrangements adapted by firms' to facilitate the development of competencies in innovative R&D were identified. These patterns were supplemented by secondary data which were collected from industry journals, industry association publications and annual reports of firms.

The differences in firms' learning processes were analysed by comparing each firm on the basis of presence or absence different learning process and the manner in which the firm had organised and implemented a particular learning process.

6. Results

In case of pharmaceutical R&D, the process and product R&D capabilities can be differentiated on the basis of complexities of the knowledge base as basic, intermediate and advance level.

{Fig.3 here}

Traditionally pharmaceutical R&D has two distinct phases; product research and later, process development for production. Process development occurs in parallel with the product development and is responsible for producing the compound in relatively large quantities, in extremely pure form, at an economically feasible cost following all the regulatory requirements. Product development research has two distinct components; discovery and development. In the discovery stage, drug molecules are obtained, screened and promising lead compounds are selected for development. The development stage involves a series of tests to determine safety, efficacy and proper dosage strength and form. The discovery stage represents the innovative phase in the pharmaceutical product R&D.

In the case of process R&D, capabilities in reverse engineering, generics R&D and new drug delivery systems are mapped as basic, intermediate and innovative.¹ In the case of product R&D analogue research, new target or new leads and original NCE research can be characterised as basic, intermediate and advanced level capabilities.²

¹ Reverse engineering involves copying the manufacturing process using indigenous sources of technology while generic R&D includes producing the product with non-infringing and innovative processes. New drug delivery system (NDDS) involves the development of technology to introduce a drug at diseased site in a novel way. New drug delivery system research has definitive and well defined boundaries of complexity. It represents an advanced level of capability in terms of formulation research part of the process R&D.

² Analogue research involves the modification of existing molecule which can provide better efficacy or reduce the side effects of existing molecules. This research involves use of already discovered molecules and targets so the requirements of skills in lead optimisation or target validation are limited in it. The intermediate capability in product R&D represented by new target or new leads requires higher skills than analogue research. The novelty in terms of new leads or new targets will demand deep knowledge about areas like structure activity relationship. Finally the total original research will involve putting up whole new hypothesis about the disease and its treatment. It will require in-depth knowledge about biological and chemical aspect of disease as well as skills in areas like target validation and lead optimisation.

This classification of process and product R&D capabilities assist in tracking the complexities involved in transformation of capabilities to move from imitative process R&D capability (reverse engineering R&D) to innovative process and product capabilities. The difference in the knowledge base, organisational processes and capabilities required in imitative R&D and innovative R&D shows that firms having advance level competencies in imitative process R&D may start with no or basic level capabilities in innovative product R&D. Innovative Indian pharmaceutical firms have developed a basic level of process R&D capabilities through imitative R&D and as a response to changes in patent law, Indian firms are moving towards the development of advance level process and product R&D capabilities. As table 2 shows, this movement involved the integration of existing capabilities with newly acquired knowledge but crucially it also involved the discarding of non-relevant capabilities or rigidities.

{Table 2 here}

6.1 Barriers to change

Reverse engineering experienced scientists in discovery R&D

The success in imitative R&D drew on branches of chemistry such as synthetic chemistry, organic chemistry and basic pharmacology. Firms in their R&D laboratories employed organic and synthetic chemists who could reverse engineer any molecule or develop efficient and cheap processes for any patent protected molecule. However, innovative R&D is about motivating scientists to think ‘out of the box’ or think differently in novel and creative ways. One example would be an anti-diabetic molecule to compete with another already on the market, if it had fewer side effects or better efficacy. The researching skill required in innovative R&D differs from imitative R&D in terms of design and conduct of experiments. Process R&D is about developing scale intensive manufacturing processes, so experiments involve changing solvent temperature, pressure and studying their impact on the output,

safety and cost. Thus chemist in process development lab works on batches of 10 kg or 20 kg whereas work in drug discovery laboratories involves the milligram jobs. This switch requires different levels of laboratory expertise as well as understanding and therefore can be difficult. It is just not the scale but developing new hypothesis regarding disease is also a big challenge for process R&D scientists.

Thus working in process R&D the scientist creates his own routines and ways of working which are suitable for process R&D but becomes irrelevant in innovative product R&D.

Innovative R&D requires scientists skilled in a wide range of disciplines and scientists working in Indian firms lack the knowledge in certain disciplinary areas. Glenmark's strategic planning director explains,

“what you need is innovative chemistry which is not same as reverse engineering. So in fact we do not prefer the people in discovery chemistry to have the experience of reverse engineering. If the scientist has done some non-infringing work or he has done some original work then we will take him but not those with only process development experience because you just can't take a good process chemist and try to make him a good medicinal chemist or a chemist who is able to deliver on an innovative chemistry or chemistry which he is not done before”.

Thus, reverse engineering experienced scientists emerged as one of main rigidity in innovative R&D and therefore Indian firms have not employed these scientists for new chemical entity research.

Ways of managing R&D projects

The reverse engineering method of product development requires relatively little communication of knowledge across the boundaries of the firm or across disciplines or

therapeutic areas within the firm. Innovative R&D requires input from various disciplinary knowledge bases and success is linked with organisational ability to integrate knowledge across disciplines. This need for integrating different disciplinary knowledge bases shows that the organisational practices and routines accumulated in imitative R&D can not be applied in innovative R&D. Thus for innovative R&D, firms have to form forum that will help in creating interaction between different departments. Such need for interactions is much less in reverse engineering. Glenmark's strategic planning director explains,

“ reverse engineering is a individual job, one scientist sitting in the laboratory can do it. Drug discovery is completely team effort so you have to have chemist talking to biologist, biologist talking to the kinetist, kinetist and biologist talking to analytical fellow and things like that. So you need to form a forum and structure where actually these will come together”.

Another important issue is the R&D infrastructure required for innovative R&D. Current R&D infrastructure in Indian pharmaceutical firms is adequate for process R&D research but needs upgrading for innovative product R&D projects. Innovative R&D requires state of the art instrumentation specifically in key disciplines like chemistry and biology. Indian firms still lacks state of art infrastructure required for conducting advanced innovative R&D.

Mindset

The most important issue that has emerged is the mindset to migrate from reverse engineering towards creating and generating innovation led products. Indian pharmaceutical firms have previously gained immediate returns on the R&D investments and mostly competed in domestic markets on the basis of cheap albeit efficient production processes. But in the case of innovative product R&D the product development life cycle is long and takes 10-15 years.

So, firms have to be mentally prepared for committing the resources for 8-10 years without returns on those investments. Former R&D president of Ranbaxy comments,

“it is a mind set problem; those making profits don't want to invest in product R&D. The costs involved in drug discovery and development are really enormous and returns don't come fast. Most of Indian firms have this habit of getting quick returns and so if a firm wants quick return on the investment, its not going to be there”.

Although innovative Indian firms have increased R&D investments since 1995, there is wider consensus that it must be further increased.

In-house nature of R&D

In the reverse engineering era Indian pharmaceutical firms built process R&D capabilities in-house as profits were totally linked to efficient and cheap production processes. The intense competition and lack of trust due to a weak regularity environment shaped the in-house nature of R&D, resulting in a total lack of collaborations between industry and academia. However the areas of innovative R&D require contribution from various disciplinary areas for example medicinal chemistry, biology and pharmacology, which are advancing at an extraordinarily rapid rate. The scientists working in innovative R&D need to be up to date with a wide range of specialised knowledge. The Indian pharmaceutical firms are chemistry based but biological knowledge and talent in India is concentrated in research institutes like the Indian Institute of Sciences and others. Therefore Indian pharmaceutical firms have to change the in-house nature of R&D to access and acquire disciplinary knowledge bases in innovative R&D.

The analysis points out that in the case of Indian pharmaceutical firms the main rigidities that have emerged are: a) imitative R&D organisational routines, b) in-house nature of R&D and;

c) organisational mindset shaped by short term vision of R&D investments and domestic market focused approach.

The difference of knowledge base, organisational practices in imitative and innovative R&D implies that the processes and capabilities that served firms well in the past may not be relevant in this new environment. According to Leonard – Barton (1994) core rigidities are the flip side of core capabilities and represent the gap between current environmental requirements and a firm's core capabilities. The deeply embedded knowledge system sets actively create problems and so the firm has to get rid of these rigidities. In case of Indian pharmaceutical firms the important part of learning is 'discarding' or forgetting past behaviour, which is redundant or unsuccessful. Hedberg (1981) points out that knowledge grows and simultaneously it becomes obsolete as reality changes. Understanding involves both learning new knowledge and discarding obsolete and misleading knowledge. The discarding activity is as important part of understanding as adding in new knowledge and slow discarding is crucial weakness of many organisations in the development of new capabilities. So in the case of innovative Indian pharmaceutical firms getting rid of 'rigidities' accumulated in the reverse engineering era formed an important part of learning in the development of innovative R&D capabilities.

6.2 Processes involved in dynamic learning to develop competencies in innovative R&D

The Indian pharmaceutical firms hired product R&D experienced scientists and developed linkages with Indian as well as international research institutes to fill the knowledge gaps and train its scientific workforce. Firms focused on the creation of an environment which facilitates processes of sharing experiences. Without a shared language and a shared understanding, it is difficult to create a uniform purpose, to construct cohesive meaning, and learn in ways which support innovation across the organisation.

Prior knowledge base:

From the beginning of the 90s these Indian firms started innovating in process development by creating cheaper processes. These firms challenged their scientists to develop a product with an alternative production processes involving less cost or develop processes which would give more yield. This created a strong knowledge base in chemistry and greatly increased expertise in pharmaceutical technologies thus building the foundation for innovative process and product R&D.

Generics product development created understanding about innovative pharmaceutical R&D and helped firms to learn about practices required to operate in advanced markets. These accumulated knowledge bases helped these firms to identify opportunities to move up the value chain in terms of product complexities. This innovative way of developing processes for production forced scientists to think differently, changing the mindset from 'imitative thinking' to 'original thinking'.

Processes involved in acquisition of new knowledge**Hired product R&D experienced as well as fresh scientists**

Innovative Indian firms started building innovative capabilities by hiring Indian scientists working overseas on innovative R&D in the laboratories of multinational pharmaceutical firms (Table 3). The main constraint was lack of scientists trained in areas of medicinal chemistry and biology. To over-come this constraint, firms targeted returning post graduates and post doctorates from overseas universities. These scientists were not influenced by process R&D routines and practises therefore firms employed them in areas of innovative R&D. These firms are mainly trying to fill the knowledge gaps by hiring Indian scientists specialised in medicinal chemistry and biology based in US/UK who work in the R&D laboratories of major pharmaceutical firms.

Currently around 20% of scientists working on innovative research projects have either trained at overseas universities, or have working experience abroad in MNC laboratories.

{Table 3 here}

The number of scientists working in Indian firms has grown considerably in the last decade (Table 3). These firms are heavily recruiting the scientific staff to create a critical mass of innovative R&D experienced scientists and as a result the percentage of staff working in innovative Indian pharmaceutical firms has consistently grown in the last decade. For example, in the case of DRL in just one year the percentage of people working in R&D has grown by 3%.

Increased R&D investment

Indian firms began increasing their investment in R&D from 1995 but this gained momentum in 2000 (Table 4).

{Table 4 here}

The focus of R&D investments in these firms has gradually shifted towards innovative process and product R&D. This has helped firms in creating the innovative R&D oriented knowledge base required for understanding the advances happening at the technological front.

Processes involved in assimilation of new knowledge

Culture of innovation

For Indian firms attracting and retaining good research talent wasn't very easy and firms had to convince these scientists of their commitment by investing in the infrastructure required for innovative R&D. Therefore the Indian pharmaceutical firms' initial effort focused on creating an ideal infrastructure required for innovative R&D and tried to overcome infrastructure limitations with various incentives. These companies are building a culture of innovation by encouraging creativity, providing freedom to work and absorbing mistakes.

Top level commitment played a crucial part in firms efforts to build an innovative R&D environment and is reflected by consistent increase of investments in the innovative R&D.

Changed R&D project management structure

Innovative Indian pharmaceutical firms have changed R&D project management structures to maintain a seamless flow of information inside the R&D department. These firms started using a 'matrix' style of project management for organising and conducting new drug discovery research projects. For each therapeutic area project, there is a project manager, project leader and team members comprising of both chemists and biologists. This has enabled firms to maintain uniform scientific development of the group through better communication among the scientists working on different projects.

Firms have created various forums to increase the interactions among members of different specialised groups. These R&D practises have facilitated the interactions among different parts of the organisation and contributes to the shaping and development of organisational knowledge.

Some of the firms have licensed their molecules to MNC pharmaceutical firms for further development. These licensing collaborations have led to lots of interactions at the scientist level between both firms and that has helped the Indian firms in imbibing some of skills in drug discovery management.

Mechanisms of knowledge transfer

Collaborative R&D

In the case of innovative Indian pharmaceutical firms collaborations have emerged as one of the key mechanisms for accessing and acquiring outside knowledge. These firms didn't have the skills, infrastructure or resources in-house to carry out certain functions and activities in innovative product R&D. Thus they collaborated and interacted with Indian as well as overseas research institutes and universities to get their work done. DRL's R&D president explains the rationale behind the networking,

“drug discovery is very complicated and you may not have everything in house, we can’t and we don’t have everything in house so you have to. It’s a sort of collaborative approach, a collaborative process. We have to really shake hands with the people who have got knowledge in this area, bring them as partner or bring them as a contract research for you, pay definite amount of money required for it and learn in the process”.

This networking approach has changed the nature of R&D in these firms, from an insular in-house R&D to a collaborative R&D model. Indian firms are building research networks by involving themselves in a lot of joint projects with Indian as well as overseas research institutes, and research companies. Most of the innovative Indian pharmaceutical firms have set up special departments of strategic alliances and licensing to scout opportunities for collaboration. The members of these departments move around in different parts of world to find out what is happening and to initiate relationships in specific areas of interest.

During such collaborations innovative Indian pharmaceutical firms give their scientists an opportunity to learn in areas of innovative R&D by sending them to work in collaborators’ R&D departments.

Processes involved in integration of different knowledge bases

Cross disciplinary project teams

Indian pharmaceutical firms realised that it was not enough to just hire the scientists or build new R&D centres, the difficult part was to increase the cross disciplinary understanding of the scientists. In an innovative product R&D project the screening of molecules generates crucial information about the molecule in terms of its structure-activity relationship. All the inputs of biological tests or results of screening have to be communicated to the medicinal chemist or chemistry team in a manner which is meaningful to the chemist. This information needs to be communicated on a continuous basis to minimise the development time and cost. Firms are

using mechanisms such as frequent meetings among project team members for increasing the interactions and communications between different specialised knowledge groups. The sample firms have set up cross-disciplinary teams of scientists from different disciplines for example biology, pharmacology, medicinal chemistry, regulatory affairs for each therapeutic research area. This cross disciplinary team approach is also helping firms to achieve integration of different knowledge bases. The aim of firms is to create a common knowledge base among the scientists working on projects and achieve same level of understanding.

Review of research and Scientific Advisory Boards (SAB)

Periodic reviews of projects, departments and other relevant organisational sub units play an important role in managing knowledge flows across different areas of R&D.

Indian pharmaceutical firms have put emphasis on review of research and institutionalised the process by creating various forums. These review meetings are held quite often and in these meetings each scientist presents research work, which is critiqued, peer reviewed and further action plans are formulated. Firms also use these internal review meetings for increasing the cross disciplinary understanding of scientists, as DRL's former president indicates,

“when chemistry is being discussed, biologists will be present, when biology is discussed, chemists would be present and so a chemist will learn some biology, at least will appreciate what there difficulties are and vice versa”.

Firms have also set up scientific advisory boards (SAB) with well known scientists from overseas as well as Indian academia and industry. This forum gives an opportunity to scientists from these firms to have closer interactions with experts.

7. Inter firm differences in learning processes

Technological learning is a process that permits a firm to accumulate technological capability over time. A diverse set of learning processes are necessary to build and accumulate knowledge or capabilities required to generate and manage improvements in processes and products. Therefore inter-firm differences in operational performances are interpreted as an implication of different paths used for accumulation of technological capabilities (Dosi, 1988).

Firm level differences in mechanisms of knowledge acquisition

The innovative Indian pharmaceutical firms employed mechanisms or processes like learning by hiring scientists, increasing R&D investment and setting up new discovery R&D to acquire knowledge in innovative R&D; however an analysis of these mechanisms reveals the differences in terms of implementation and nature of knowledge access for acquisition.

In learning by hiring scientists, Ranbaxy put more emphasis on hiring senior scientists working overseas in MNC labs than fresh post graduates. Other firms like DRL built a critical mass of scientists by hiring returning post docs and doctorates. DRL's innovative R&D effort was led by Indian based scientists who had worked in innovative research areas in MNC's R&D units, and these scientists built the sub teams. In case of DRL for 90% of scientists working in innovative R&D it was their first job in the industry. Lupin hired the scientists working in other innovative Indian firms like Ranbaxy who had the experience of innovative R&D while Wockhardt recruited scientists working in Indian academia and research institutes. NPIL started its innovative R&D research by acquiring the R&D facilities of Hoechst research centre in India. The Hoechst research centre started operations in 1978 and throughout the period of existence this centre was involved with drug discovery research. Table 5 gives a graphic representation of the data.

{Table 4 here}

Differences have also emerged in the case of R&D investments and establishing R&D set up overseas. It has emerged that all the firms are gradually increasing R&D investment; however the magnitude and focus of the investments are different in each firm. In 2003 DRL invested 10% of its turnover in R&D whereas NPIL investment was only 4% (see Table 4).

In terms of research strategy in innovative R&D all firms except DRL are adopting the cautious approach of analogue research. However, DRL is using an aggressive approach focused on acquiring skills in ‘structure-based drug design’³. This is reflected in DRL’s establishment of a R&D subsidiary in the US. DRL, Ranbaxy and Glenmark have opened laboratories in the US and Europe. However the focus and activities carried out at Ranbaxy’s US R&D laboratory, Glenmark’s R&D set up in Switzerland and Reddy US Therapeutics (DRL’s US R&D subsidiary) differs quite markedly. Ranbaxy and Glenmark overseas R&D set up focuses on clinical research and regulatory filling while Reddy US Therapeutics is focused on developing capabilities in discovering the molecule by using rational drug design strategy.

Firm level differences in mechanisms of knowledge assimilation

All the firms have started new disciplinary and regulatory divisions to foster learning in new areas but firms differ in terms of the internal arrangements needed to support learning in innovative R&D. Table 6 summarises these inter firm differences in knowledge assimilation processes and mechanisms.

{Table 4 here}

³ Structure-based or rational drug discovery involves the determination of a disease causing protein’s three-dimensional structure. Once the structure is known, novel chemical entities are designed to ‘lock-in’ to the protein with the aim of reversing or arresting a disease’s progression. It involves putting up whole new and original hypotheses about the disease and its treatment and requires in-depth knowledge about biological and chemical aspect of the disease as well as skills in areas such as target identification, validation and lead identification, optimisation.

DRL and Ranbaxy have set up supportive arrangements like incentive mechanisms for scientists to upgrade knowledge, training programmes and scientific advisory boards. In case of scientific advisory boards, firms like Wockhardt have not formalised the relationships with experts by setting up scientific advisory boards and instead are informally engaging with these experts on an 'as and when needed' basis.

All firms are putting strong emphasis on patenting any novel research work coming out of the R&D labs. However, the significant differences emerge in firms approaches towards publication strategies. DRL has put equal emphasis on publication and patenting activity, but other firms don't conform to this philosophy and differ in their perception regarding importance of publishing. Therefore except DRL other firms are reluctant to publish the research work in scientific journals or conferences.

Firm level differences in mechanisms of knowledge transfer

Innovative Indian pharmaceutical firms networking and collaboration strategies show differences in terms of their intensity, targeted nature of knowledge and sources of knowledge used for accessing new knowledge. These inter-firm differences in the mechanisms or processes involved in transfer of knowledge are summarised in Table 7.

{Table 5 here}

Ranbaxy and DRL have established strong collaborative relationships with Indian and more specifically overseas research institutes and universities. Other firms like Lupin and NPIL are involved in collaboration with Indian research institutes in various areas of innovative R&D. Some of the collaborations by NPIL and Lupin are also partly financed by the Indian government under the New Millennium Indian Technology and Leadership Initiative (NMILTI). However, Wockhardt has chosen not to collaborate with Indian research institutes as top R&D management in the firm have different opinions towards such collaborations..

According to Wockhardt's anti-infective R&D head many public laboratories had different approach to research programmes; they lacked a focused approach which is required in industrial R&D need. Then issues such as commitment, timelines and performance become very complicated while dealing with Indian R&D institutes. Ranbaxy and DRL are also collaborating with MNC pharmaceutical firms through licensing and research deals. In 2003 Ranbaxy entered into alliance with Glaxo Smithkline (GSK) to discover and develop novel therapies in its four focus therapeutic areas. Ranbaxy's other important collaboration in drug discovery R&D is with Medicines for Malaria Venture (MMV) Geneva, for the development of anti-malarial drugs. Under this collaboration Ranbaxy's team of scientist will work together with the University of Nebraska Medical centre, Monash University and the Swiss Tropical Institute to identify the lead molecule. Also both DRL and Ranbaxy have out licensed molecules to MNC pharmaceutical firms, which give their scientists an opportunity to interact with scientists from MNC pharmaceutical firms.

Firms' innovative performance and implications of differences in knowledge processes

The analysis of different learning processes shows that some of the processes and mechanisms were present and worked continuously in all firms, however their functioning and implementation differed in each firm. The difference in firms' approaches in terms of implementation and functioning have affected firms' access to external knowledge, internal knowledge sharing processes and application of existing knowledge bases.

{Table 1 here}

DRL and Ranbaxy clearly show better performance in terms of innovative R&D although these two firms also started investing in innovative R&D comparatively earlier than other Indian pharmaceutical firms (Table 1). But comparative analysis between these two firms

reflects clear differences in their approaches towards the development of innovative R&D capabilities. For instance, DRL has chosen an aggressive research strategy and has focused on acquiring capabilities in the rational drug design approach to discover new chemical entities. It also adopted a more academic model of pharmaceutical R&D by focusing on publications, collaboration with universities and a strong emphasis on scientists' skill upgrading. DRL internationalised its R&D by establishing its subsidiary in the US to acquire capabilities in rational drug design research. Ranbaxy used a different approach to develop the capabilities in innovative R&D. It built strong complimentary assets in advanced markets by internationalising manufacturing, sales and regulatory functions. Ranbaxy also adopted a cautious strategy of analogue research for discovering new chemical entities and hired senior Indian scientists based overseas working in MNC pharmaceutical R&D rather than fresh scientists to acquire capabilities in innovative R&D.

In follower firms like Wockhardt and NPIL, innovative R&D effort began in the mid 1990s while Lupin and Glenmark started investing in innovative R&D by the late 1990s. Wockhardt started with biotechnology as main research area and building on that firm started developing capabilities in innovative R&D. Unlike other Indian pharmaceutical firms Wockhardt has focused only on one therapeutic area, anti-infective, as its innovative R&D focus and filled the capability gaps through contract research with overseas research companies compared to R&D collaboration with Indian research institutes and universities. Wockhardt created a core team of scientists by hiring scientists from Indian research institutes and academia. The other follower firm NPIL, the youngest firm compared to other innovative Indian pharmaceutical firms, has over the years grown on the basis of using acquisition as means for growth. It thus bought the Hoechst Research Centre to acquire capabilities in innovative R&D. Also, NPIL is not targeting the generics market in advanced countries and has instead chosen the strategy of partnering with MNC and generic pharmaceutical firms for contract manufacturing and custom synthesis.

The late starter, Lupin hired senior scientists from other innovative Indian pharmaceutical firms like Ranbaxy and established strong relationships with Indian research institutes for

collaborative R&D programmes. Lupin is actively promoting joint working and transfer of scientists in collaborating research institutes to train its scientific workforce in innovative R&D.

The other late starter, Glenmark is a small firm compared to other Indian pharmaceutical firms and its innovation R&D learning strategy reflects the limitation of size. Glenmark have small team of scientists working on new drug discovery research programmes which are directly supervised by the firm's managing director.

The analysis of innovative Indian pharmaceutical approaches and performance shows the firm level differences involved in the development of capabilities in innovative R&D. Each firm has adopted a strategy which differs from the other in terms of functioning and implementation of different learning processes. The evidence suggests that functioning and implementation of a diverse set of learning processes plays a crucial role in technology capability accumulation and a continuous effort should be made to improve the learning processes particularly their functioning and implementation.

8. Conclusion

The accumulation of technological knowledge is complex and often a costly process of technological and organisational learning. Bell et al., (1984) point out that absence of sustained efforts to acquire and use the capabilities necessary for continuous technological change often results in failure of learning processes in firms from developing countries.

It is sometimes suggested that firms in developing countries have accumulated technological capabilities in particular sequences, moving through definable stages (Dhalman, et al., 1987). The learning hierarchy model suggests that developing countries progresses from learning to produce, learning to produce efficiently, learning to improve production, learning to improve products and finally culminates in learning to develop new products. It has even been suggested that these sequences and stages can provide guidelines for both firm level strategies and government policies.

In a very general sense, such sequences do reflect realities. For example firms in different industries seeking to improve their technologies generally have to build on what already exists. Beyond such guidelines however rigid ideas about sequences and stages may be misleading, especially at the firm level. This research shows that the learning processes which underlie accumulation and development of knowledge require technical as well as organisational knowledge management capabilities. The important aspect of this learning involves discarding the competencies which might have been useful in an earlier era but not relevant in new environments. The doing aspect (the link to production experience) remains necessary but not sufficient to development of innovative capabilities. Thus this research points out that the move from basic to intermediate and to advance level capabilities is neither linear nor automatic. It requires a deliberate effort from firms to invest in different mechanisms of learning. This finding supports observations made by researchers like Bell and Pavitt (1993), Forbes and Wield (2002) that technological learning is neither automatic nor linear and depends upon the decisions firms make.

Inter firm comparative analysis shows the subtle differences in learning processes in each firm. For example in the case of hiring the product R&D scientists, the nature of scientists targeted for recruitment as well as sources used by firms for recruiting new scientists differed a lot. Similarly inter firm differences emerged in supportive learning mechanisms which influenced the creation of the environment that encourages interaction among distributed knowledge systems and facilitates the development of collective knowledge. The learning mechanisms like incentive policies, top management commitment and emphasis on collaboration and networking differed across the firms. The rate at which a firm moved in accumulating capabilities and the subsequent level of sophistication varied as does the potential sequencing of capability development among different functional areas. Firms need a diverse set of learning mechanisms and reliance on a single mechanism is unlikely to yield any effective organisational learning (Figueiredo, 2003). The evidence suggests that functioning and implementation of a diverse set of learning processes plays a crucial role in technology capability accumulation and a continuous effort should be made to improve the

learning processes particularly their functioning and implementation. Therefore, firms need a consistent and continuous strategy to manage and organise the diverse set of learning processes.

The variability of the technological accumulation patterns suggest that the need for care and clarity in choosing specific strategies for accumulating technologies at firm level. Knowledge acquisition through practice often happens in social contexts (Lave and Wenger, 1991). Much of the knowledge generated through R&D activity is of a tacit nature and located in the specific context in which it was developed (Nelson and Winter, 1982). Chataway et al., (2003) suggest that the challenge faced by social knowledge is that it may not be acknowledged by management. Bell and Pavitt (1993) pointed out that there are few guidelines for firms to follow in designing strategies to move from the basic level to the advanced level of capabilities.

In this regard the findings of this research provide insights for R&D managers in terms of activities involved in creating an environment that facilitate the development of a knowledge creation capability for innovation. This research emphasised the importance of organisational mechanisms in innovative new product development and showed the distinct role of knowledge management strategies in shaping the learning environment that facilitated transformations of technological capabilities in Indian pharmaceutical firms. To larger extent knowledge creation depends on absorptive capacities but as the Indian pharmaceutical industry's example shows some things like firm based strategies, mechanisms of knowledge management and their networks make the difference. The Indian pharmaceutical firms' development of innovative R&D capability suggests that the firms and networks can become more adept at creating learning environments which enhance sense making and sourcing capacities.

The importance of these internal activities in the capability development process raises an important implication for firms in Indian industries as well as other developing countries. The limited resources typical in many firms in developing countries hinders their ability to provide necessary environments in terms of recruitment of talented personnel, extensive knowledge

sources, training and organisational mechanisms to facilitate capability development. Hence in the future, emphasis of the technology policy should be on providing mechanisms that will help firms increase their awareness and access to external knowledge. Technology policy should assist firms in creating linkages between their internal capabilities and external knowledge and help in assimilating these associations into business opportunities.

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Figures and Tables

Fig. 1 Model of sources of firm's technological knowledge (Source: Cohen and Levinthal, 1990)

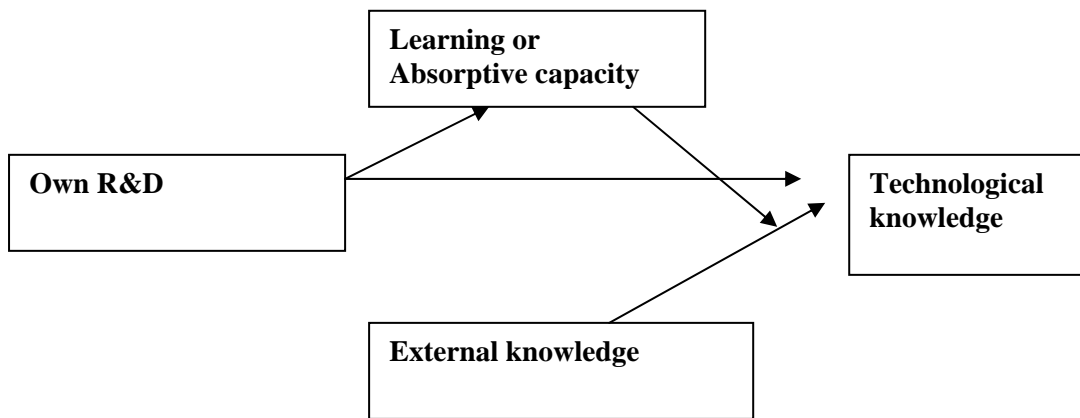


Fig. 2 Theoretical Framework

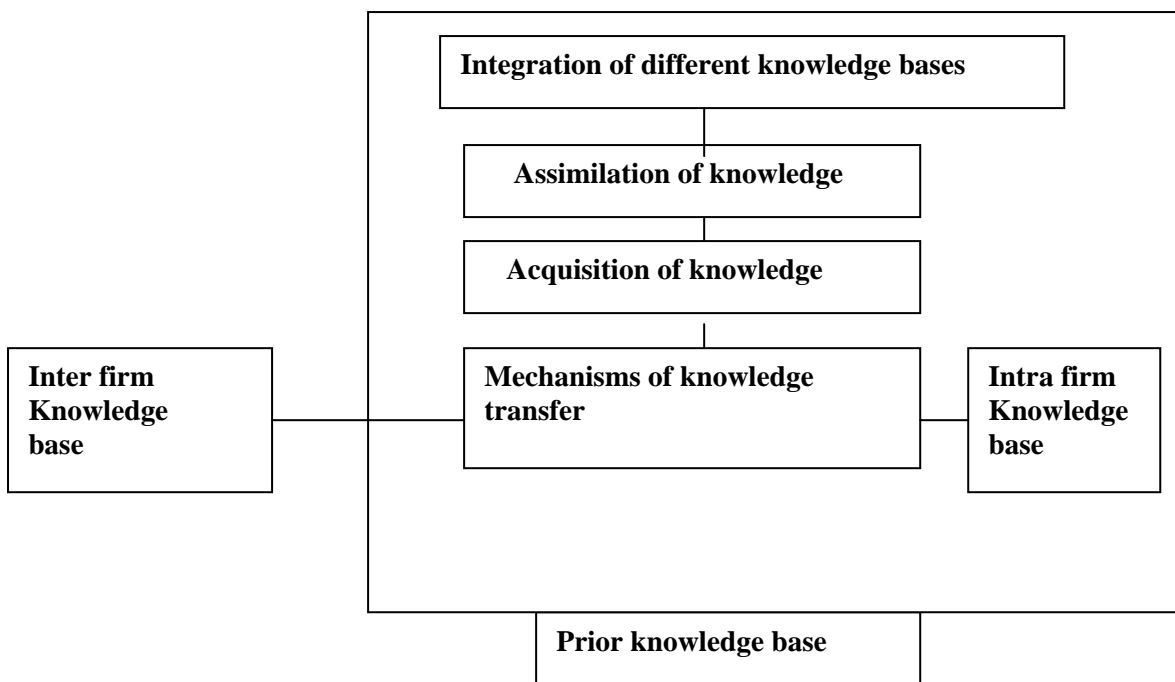


Fig. 3 Changing skills and capabilities in the Indian pharmaceutical industry (Kale and Wield, 2006)

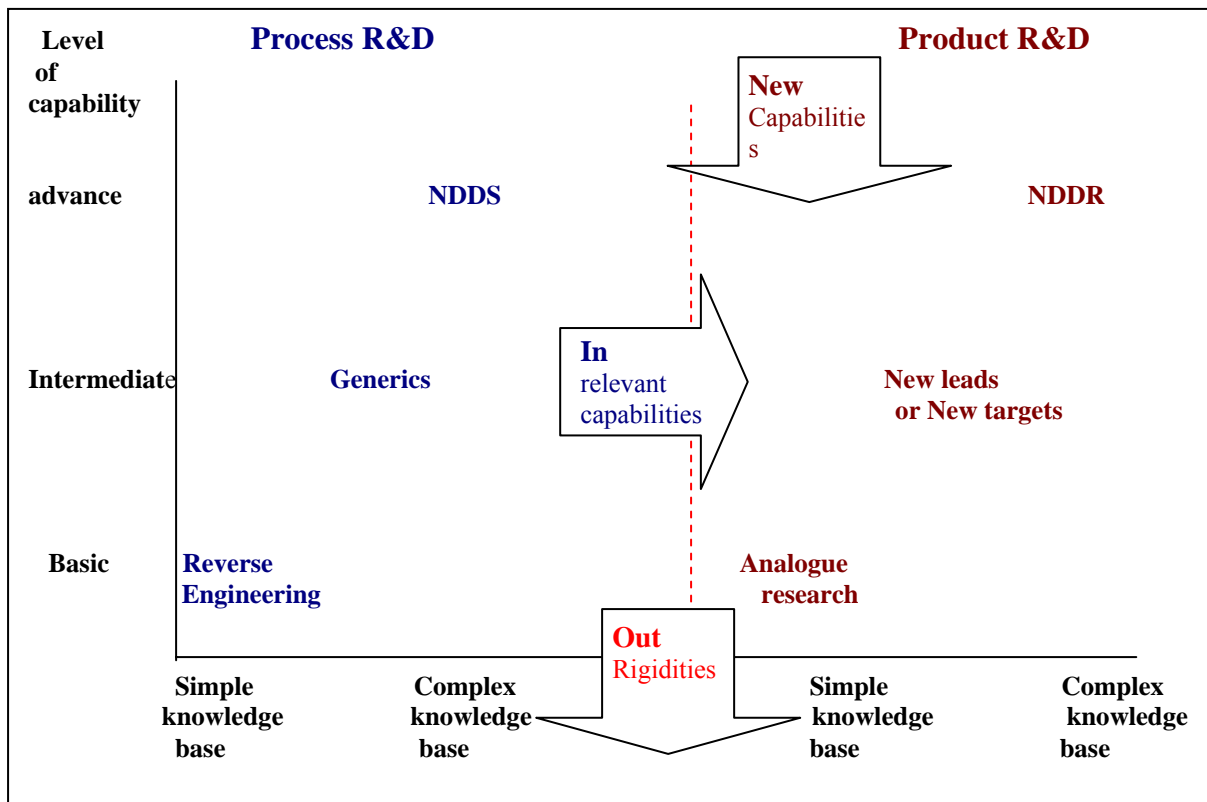


Table 1: R&D performance of innovative Indian pharmaceutical firms (Source: Annual Report, 2003)

No.	Firms	Innovative R&D performance			
		DMF (Drug Master File)	ANDA (Abbreviated New Drug application)	NCE patents (New Chemical Entity patents)	New drug delivery systems patents
1	Ranbaxy	44	127	6	4
2	DRL	56	35	8	
3	Wockhardt	17	32	3	1
4	NPIL			1	
5	Lupin	12	5	3	1
6	Glenmark	4		4	

Table 2: Rigidities, relevant capabilities and new capabilities

IN	OUT	NEW
<p>Understanding of the pharmaceutical R&D</p> <p>Complimentary technological assets: Skills in pharmacology, analytical chemistry, process R&D (for development phase) - Sources of knowledge created through distribution, marketing routes in overseas markets</p> <p>R&D Infrastructure</p> <p>Existing relationships with research institutes</p>	<p>Mindset a. Short term vision of R&D b. Domestic market focused thinking</p> <p>Reverse engineering experienced scientists in discovery R&D</p> <p>R&D management practises a. Resource allocation b. Project review</p> <p>In-house nature of R&D</p>	<p>Culture of innovation R&D management mechanisms</p> <p>Research talent a. expertise in medicinal chemistry and biology ; b. scientists with experience in product R&D c. incentive schemes for scientists</p> <p>Product R&D infrastructure</p> <p>Networking and collaboration capabilities</p>

Table 3: Percentage of R&D staff to total staff and R&D intensity (R&D spend % of sales) (Source: Annual Reports)

Firms	No. of R&D labs	% of R&D staff / Total staff and R&D intensity							
		2000		2001		2002		2003	
DRL	5		4.22	9.09	6.29	12.39	7.7		10
Ranbaxy	3	8.85	4.2	9.02	3.8	11.11	5.2	13.52	6.1
Wockhardt	2	9.57	7.2	11.11	6.2	12.47	6.2	13.66	7.9
NPIL	3	2.66	1.80	3.38	2.16	4.53	1.63	4.33	3.9
Lupin	1				2.41	5.45	2.30	6.11	3.09
Glenmark	2		1.45	5.55	3.50	6	4.41	10	6.52

Table 4 Inter firm differences in knowledge acquisition and assimilation processes

No.	Knowledge acquisition processes and mechanisms	RAN	DRL	WOC	NPIL	LUP	GLE
1	Hiring senior Indian scientists from MNC R&D overseas	Present	Weak	Absent	Present	Absent	Absent
2	Hiring fresh Indian post graduates, doctorates and post doctorates from overseas universities	Absent	Present	Present	Present	Absent	Absent
3	Increasing investment in R&D	Present	Present	Present	Present	Present	Present
4	Setting up new disciplinary units and regulatory department	Present	Present	Present	Present	Present	Present
5	Setting up discovery labs abroad	Weak	Present	Absent	Absent	Absent	Weak
6	Acquisition of R&D labs in India or abroad	Absent	Absent	Absent	Present	Absent	Absent
Inter firm differences in knowledge assimilation processes and mechanisms							
1	Scholarships to upgrade scientist's skill level	Present	Strongly present	Present	Absent	Strongly present	absent
2	Training programmes	Strongly present	Strongly present	weak	Present	weak	weak
3	Scientific advisory boards	Strongly Present	Strongly Present	absent	Present	weak	Present
4	Encouragement for Publication	absent	Present	absent	absent	absent	Absent
5	Encouragement for Patenting	Present	present	Present	Present	Present	Present

Table 5 Inter firm differences in processes and mechanisms involved in transfer of knowledge

No.	Knowledge transfer processes	RAN	DRL	WOC	NPIL	LUP	GLE
1.	R&D collaboration with Indian research institutes, universities	Present	Present	Absent	Present	Strongly Present	Absent
2.	R&D collaboration with overseas research institutes and universities	Present	Strongly Present	Absent	Absent	Absent	Absent
3.	R&D collaboration with MNC	Strongly Present	Strongly Present	Absent	Absent	Absent	Absent
4	Cross boundary movement of scientist	Present	Strongly present	Absent	Present	Present	Absent

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