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DIMENSIONS OF TECHNOLOGY TRANSFER: TRANSFER COSTS AND TECHNOLOGICAL CAPABILITY

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ABSTRACT

Countries frequently rely on successful assimilation of foreign technology to achieve indigenous growth. But success depends on various factors. The factors include technological capability of the country, transfer costs, government policies, political structure, patent laws etc. In our paper we focus on two of these factors namely, technological capability of the country and transfer costs. We explore technological capability through the "capability creation model" given by Kale and Little (2010). To test the theory empirically, we took data from the Indian pharmaceutical industry. We find that post the year 2005 (i.e., post TRIPs) there is strong IPR regime i.e. reverse engineering is restricted. Because of strong IPR regime there will be more technology transfers because of increase in the royalty payments. We also find a positive and significant relationship between increasing technology transfers post 2005 and firms own R&D expenditure.

KEYWORDS: *Royalty Payments, R&D, TRIPs, Technology Transfers, Indian pharmaceutical industry*

1. INTRODUCTION

Countries frequently rely on successful assimilation of foreign technology to achieve indigenous growth. But success depends on various factors. The factors include technological capability of the country, transfer costs, government policies, political structure, patent laws etc. In our paper we focus on two of these factors namely, technological capability of the country and transfer costs. Transfer costs in our paper will essentially refer to the resources which must be utilised to transfer technological know-how but we do not take into account the royalty costs or rents which must be used to secure access to technology. Transfer costs will be dealt with respect to both the transferee and transferor's characteristics. This is discussed in the next section of the paper.

Cohen and Levinthal (1990) gave the term "absorptive capacity" which we can interpret as the technological capability of a country. Technological capability assumes paramount importance when it comes to developing countries like India. It's not just enough to bring technology at home but one requires knowledge and effort to understand the same. This knowledge base is captured by the technological capability of the country. As technological capability builds up it leads to imitation and as the capability keeps on building up one moves towards basic research or innovation. We explore technological capability in Section 3 of our paper using the "capability creation model" given by Kale and Little (2010).

At this juncture, one also has to emphasize the role of patents. If a country has weak IPR regime then firms have an incentive to imitate and this acts as a disincentive for foreign firms to transfer the technology. In the case, having a strong IPR regime prevents foreign firms to face any threats of imitation. India implemented TRIPs effectively from year 2005 which restricts the imitative of research and development.

We shall understand these in the perspective of Indian pharmaceutical industry. The Indian pharmaceutical industry is the world's second largest by volume and is likely to lead the manufacturing sector of India. The industry is characterised by a low degree of concentration, a large number of firms with similar market share, low level of R&D intensity ratio and with high level of brand proliferation.

To test what the theory suggest we have made a conscious attempt to test it empirically by taking data on various parameters of 548 pharmaceutical firms. Since the conscious effort is our original work it is open to faults and criticisms. This is discussed in Section 4 of our paper.

2.DEFINITION OF TECHNOLOGY TRANSFER

Robert Krull (OECD Seminar, 1990) defined technology transfers as "Technology transfer is a process by which existing technology is transferred or transformed to fulfil the user's needs".[1]

A more complete definition was given in a National Co-operative Highway Research Programme (NCHRP) Synthesis (Hodgkins, 1989): "Technology transfer is a process by which research and other new technologies are transferred into useful processes, products and programmes. Another way of saying the same thing is: technology transfer is the process by which a better way of doing something is put into use as quickly as possible." We shall note that every part of this definition has some significance:

- "The process" defines technology transfer as a methodology and not a "thing"
- "Research findings" suggests that research is the genesis of new technologies
- "Other new technologies" suggests that new technologies can emerge from other fields of endeavour.
- "Are transferred into" does not simply imply the use of the technology but implies its adoption
- "Processes" are techniques for accomplishing tasks
- "Products" are actual tools, materials, and other hardware or software
- "Programmes" means the institutional setup to accomplish the given task.

Types of Technology Transfer:

Edwin Mansfield, the noted American economist, makes a useful distinction between **vertical** technology transfer and **horizontal** technology transfer: "Vertical technology transfer occurs when information is transmitted from basic research to applied research, from applied research to development, and from development to production. Such transfers occur in both directions and the form of the information changes as it moves along this dimension. Horizontal transfer of technology occurs when technology used in one place, organisation, or context is transferred and used inanother place, organisation, or context."

The various ways in which technology transfer can take place:

- Licensing or sale of Intellectual Property.
- Foreign Direct Investment.
- Cooperative Research and Development
- Technical Assistance
- Public exchange of information (e.g. conference, publication, networking, etc.)

Technology transfers can take place at two levels: Cooperation and Non-Cooperation. Under cooperation, transferors willingly give technology to local firms. Here transferors and recipients experience problems pertaining to partner dynamics and to adapting the technology to local conditions. In non-cooperation case, firms imitate the products of the MNCs without the latter's permission or assistance.

Costs of Technology Transfers:

We focus on the resources which must be utilised to transfer technological know-how but are not taking into account the royalty costs or rents which must be used to secure access to technology.

The conventional neo-classical view is that the transfer of technology from one site to another is an effortless and costless activity. This view is based on the following argument: Innovation occurs in industrialized countries and is then gradually diffused to developing countries (Khan, 1951). Developing countries choose technologies from the existing 'shelf' created by industrialised countries given their local labour and capital endowments (implying technology itself is static). It implies that technology operates the same regardless of a change in geographical location, operate skills, inputs etc. The neo-classicals then assumed that after adopting a given technology developing countries were *automatically* capable of operating this technology at its *optimal efficiency*. What follows from this perspective is that developing countries could avoid considerable costs of innovation and still enjoy benefits from diffusion of technologies from industrialised economies. In the process the developing countries could catch up or converge with the industrialised economies by importing technology.

Empirical evidence and studies show that the transfer of technology is not costless but is hard and costly. It was mainly Teece (1977) who in his examination of 26 international technology transfer projects observed that transfer costs varies within a range of 2 percent to 59 percent, with an average of 19 percent of total project costs. From the case studies of Mueller and Peck, Arrow (1962) we infer that transfer costs may be high. From the Hall and Johnson (1970) study of the transfer of aerospace technology from the US and Japan, it is not clear that this is true. Robinson (1973) believes that economists' views on transfer costs are exaggerated while Mansfield (1973) and Freeman (1965) take the opposite view.

Teece defines costs of technology transfer as the costs of transmitting and absorbing all of the relevant un-embodied knowledge. There are many skills which are needed for success of a project; all such skills cannot be transferred to the transferee. These skills entail costs which can be divided into four categories:

- **Pre-engineering technological exchanges**: During such exchanges, the basic characteristics of the technology are revealed to the transferee along with the necessary theoretical insights.
- **Engineering Costs:** In case of process innovations, the process design and associated process engineering are transferred and in case of product innovations, product design and production engineering are transferred. The difficulty is in the process of absorption which requires the utilisation of consulting or advisory resources. The case where technology is already commercialised, transmission may involve transferring existing drawings and specifications with minimum modifications.
- **Cost of R&D personnel:** These costs are borne during all phases of transfer process. These costs include costs of solving unexpected problems, adaption, modifying the technology, salaries etc.
- **Pre-start-up training costs and excess manufacturing costs**: These costs represent the operating losses which are incurred during the initial phases of production, i.e. there is a possibility that no marketable output will be produced during the initial phases of the start-up but still costs of normal labour, materials, utilities, depreciation costs, extra supervisory personnel to assist in the start up must be incurred.

Understanding Transfer Costs through Transferor Characteristics:

- **The number of Manufacturing Start-ups or Applications already Conducted:** This is an index of the transferors' knowledge. With each start-up additional knowledge about the technology is acquired and this lowers the transfer costs. This provides the firms with an opportunity to assess the effects of different operating parameters and differences in equipment design. If similar plants exist already, experienced operators from these plants can be used in the start-up of the new plant and untrained people can be sent to the existing plants for the pre start-up training.
- **Age of the Technology**: Teece (1977) defines age of the technology as the number of years since the beginning of the first commercial application of the technology anywhere in the world and at the end of technology transfer programme. The stability of the engineering designs and the transferors' knowledge of the manufacturing procedure are positively related to the age of the innovation. The un-codified information – the "relevant art" is carried out by supervisors, engineers and operators and with time that can assist better the technological transfer process. With time, problems stand a better chance of being ironed out and drawings are more secure. Teece points that "when the length of stay of corporate personnel begins to be outstripped by the age of the technology then the non-codified dimensions of the design knowledge may be lost to the firm. Therefore after a certain point in time, transfer costs will begin to rise with the age of the technology.
- **Number of Firms Utilising the Technology:** Diffusion of a technology plays an important role in determining the costs of technology transfer. The greater the no. of firms with the similar and competitive technology, greater is the likelihood of availability of technology and hence lowers the cost. We associate the "leading-edge" technology by hard and high transfer costs since the engineering drawings are constantly altering and is characterised by lower diffusion, age and application. In contrast, the "state–of–the art technology" involves lower transfer costs due to the greater likelihood of finalising engineering drawings and is characterised by higher diffusion, age and application.

Understanding Transfer Costs through Transferee Characteristics:

- **Number of Years of Manufacturing Experience**: A firm skilled in the manufacturing process is likely to have better absorptive capacity (Cohen and Levinthl, 1990) even when it has no previous experience in the same. They are in better situation to understand and apply codified knowledge to the manufacture of a new product, or utilisation of a new project.
- **Size of the Transferee**: Larger the firm, wider the spectrum of technical and managerial talent which can be used for assistance during the transfer. A smaller firm places extra demand on its scarce managerial and technical manpower, thereby making it difficult to absorb new technology and may have to hire consultants to perform tasks that are handled internally in larger firms.
- **R&D Activity**: In index of R&D capability is its R&D to sales ratio and an inverse relationship between this index and transfer cost is postulated. An in-house R&D capability is of value when unexpected technical problems occur.
- **Level of Infrastructure:** The level of skill formation in the host country will influence the amount and type of training that the labour force requires. Suppose a new venture is to acquire its inputs domestically, the quality of inputs available will influence the level of start-up costs. The better the infrastructure the host country offers, the lower are transmission and absorption cost.

Transfer costs will be lowered once the first production run has been commenced and more likely is the international transfer. This is consistent with the Product Cycle Model of Vernon (1961).

There is a widespread consensus that a technology with a large *tacit* component is more difficult to transfer than one with a large *codified* component. As Teece (1981) observes,

"Transmission and receiving costs are lower the greater the similarities in the experiences of the transmitting unit and the receiving unit; for the greater these similarities, the easier it is to transfer technology in codified form such as blueprint, formulas or computer language. Furthermore, there appears to be a simple but powerful relationship between codification of knowledge and costs of its transfers. Simply stated, the more a given item of knowledge and the experience has been codified, the more economically it can be transferred. ... This is a purely technical property that depends on ready availability on channels of communication suitable for the transmission of well codified information. Un-codified or tacit knowledge, on the other hand, is slow and costly to transmit."

In our empirical work we have taken technical know-how fees as a proxy for transfer costs of the transferee, which shall be discussed in detail in Section 4 of the paper.

3.TECHNOLOGICAL CAPABILITY AND IMITATION – AN ANALYSIS OF THE INDIAN PHARMACEUTICAL INDUSTRY

The Indian Pharmaceutical industry has been following a trajectory that started with duplicative imitation followed by creative imitation, rising up the value chain of pharmaceutical R&D and finally as a result of change in patent law industry achieving the learning required to develop capabilities in innovative research and development. The imitative R&D activities followed by the Indian pharmaceutical industry helped them acquire basic and intermediate technological capabilities. The industrial and regulatory policies followed by the Indian government resulted in the development of self-sufficient pharmaceutical industry. The evolution of Indian pharmaceutical industry can be described in three phases:

1. The first period was prior to 1970, when the industry was relatively small in terms of its production capabilities.
2. The second period is the decade and a half spanning from the 1970s to the beginning of the 1990s, a period during which the output of the industry grew remarkably.

3. In the third phase of expansion, from 1990s onwards, the pharmaceutical
   Industry grew more than three times faster than it did during the 1980s. However the third phase also witnessed major regulatory policy change for the Indian industry. In 1992 the Indian government signed the TRIPS agreement, which led to the introduction of strong patent laws which became effective from 2005 which restricted reverse engineering R&D by Indian firms.

Before 1970s foreign firms had a disproportionately high share in total domestic pharmaceutical production. In 1960, close to 90 percent of market share was with multi-national corporations (MNCs) and 10 percent with Indian companies. The adoption of new weak patent act was an attempt by the Indian policy makers to improve the terms of assessing international IP, this act was passed in 1970 and became effective from 1972. The FERA reduced MNCs holding to 40 percent.

We can broadly outline the measures taken by the state for achieving competency in the pharmaceutical industry:

1) The state only recognized process patents so that local firms could legally copy the drug innovations of foreign firms.
2) Local firms entered at the formulation manufacturing stage because of its relatively low entry barriers. (formulation manufacturing stage follows the active ingredient stage)
3) Public sector drug firms accelerated the growth of local pharmaceutical industries by training a cadre of employees who would later play prominent role in private sector drug firms.
4) Government tariffs on important pharmaceutical products provided local firms with protection as they learnt the basic of pharmaceutical manufacturing.
5) The state imposed price control on drug products. Thereby stimulating local firms to improve their manufacturing skills, so that they could remain profitable under this policy.

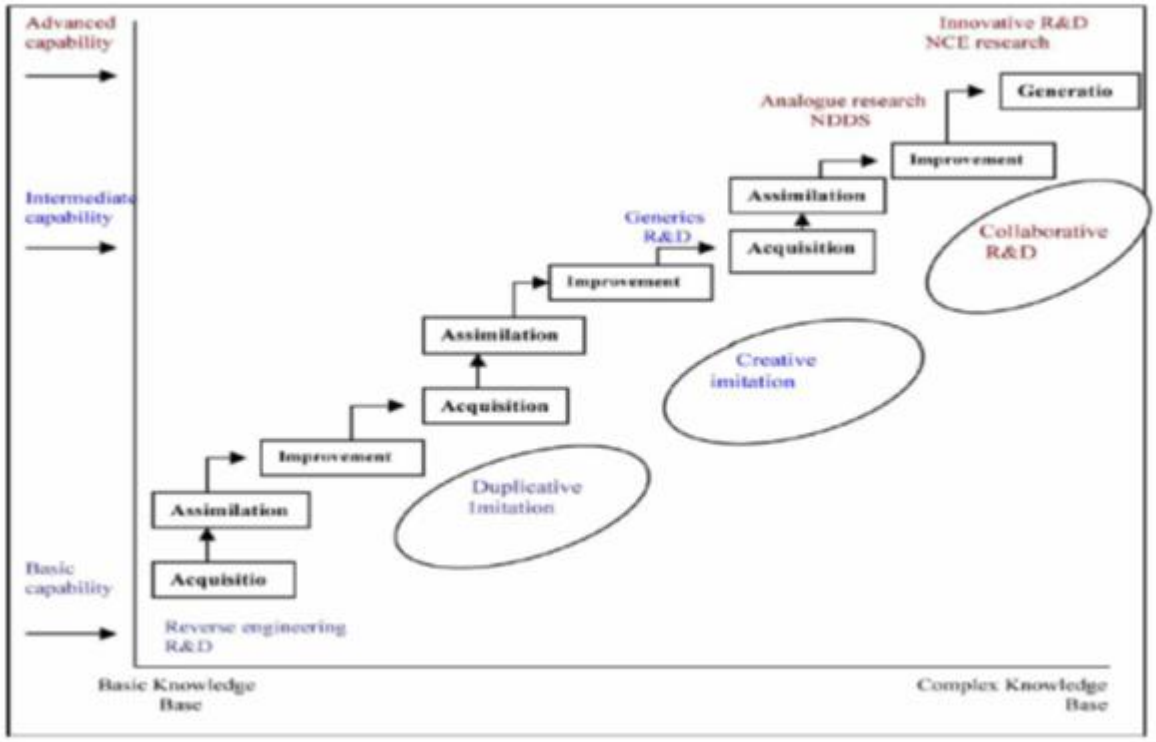
The intersection of these five factors led to local firms quickly moving down the pharmaceutical learning curve and challenged the MNC's dominance in the domestic market.

Industry-Academia Linkages: Industry and Institutes had different research focus and due to this, complementary linkages between them never evolved. The focus of Indian R&D institutes was on *indigenisation* i.e. if something was imported then the process or mechanism to develop it locally was found. Due to the protected environment given to the industry, it restricted completion and reduced incentives for innovation.

Capability creation model

Capability creation model helps us to understand the link between imitation and technological capability. The model is given by Dinar Kale and Steve Little (2010). In the capability creation model a *basic level of capability* is taking as the ability to make my minor adaptations to production and to assimilate technology into a firm's environment.

Figure 1: Capability Creation Model



Source: Kale and Little (2010)

Intermediate innovative capability is the ability to generate incremental technical change in product design, quality and production processes, including ability to search and evaluate external sources of technology. *Advanced innovation capabilities* refer to the ability to generate new products and new process innovations. This classification of level of capabilities is given by Haque et al. (1996). When these definitions are applied to the Indian pharmaceutical industry, basic capability would include the ability to do reverse engineering i.e. to develop products by copying the process. Generics R&D involve incremental change which is intermediate capability whereas advanced capabilities would represent new chemical entity research i.e. creating new drugs and innovative therapy.

Stage 1: Duplicative Imitation and Basic R&D Capabilities

Taking the benefit of the weak patent law, the Indian pharmaceutical firms used reverse engineering or duplicative imitation to acquire knowledge and build the basic capability in R&D process. After 1970s the Indian firms saw great opportunities in the pharmaceutical sector wherein they could develop drugs by copying or using known processes to produce at lower costs. Scientists in these firms developed skills in reverse engineering R&D through trial and error experimentation or 'Learning by Doing'.

What does Reverse Engineering R&D involve?

According to Kale and Little (2010), it involves purposive searching of relevant information, effective interaction among technical members within a project team and with marketing and production department within the firm, effective interaction with suppliers and customers and trial and error in reaching a satisfactory result. In case reverse engineering pharmaceutical R&D firms need to have tacit knowledge to complement and interpret disclosed knowledge since publically available knowledge in the patent is not always sufficient to produce a reverse engineered product.

The focus of Indian pharmaceutical firms in the context of reverse engineering R&D was not based on the number of patents a firm had filed but on the number of products a firm could reverse engineer and the time required for imitative process development. Because of the fierce completion in the pharmaceutical industry, the domestic firms put intensive in-house effort to improve their efficiency that led to a lower cost of production. The firms across the industry developed an expertise in reverse engineering processes. This also resulted in a lack of collaboration between industry and academia. By the end of 1980s, Indian firms were manufacturing practically every new molecule which was commercially viable without access to process details from the innovator company. 1980s was the era when Indian pharmaceutical firms consolidated their position in the domestic market. The following table gives an idea of the growth of the industry during 1980s:

Table 1: Growth in Indian Pharmaceutical Industry during 1980s

	Year	Bulk drugs (Rs million)	Formulations (Rs million)	Total
1	1980–1981	2400	12,000	14,400
2	1981–1982	2890	14,340	17,230
3	1982–1983	3450	16,600	20,050
4	1983–1984	3550	17,600	21,150
5	1984–1885	3770	18,270	22,040
6	1985–1986	4160	19,450	23,610
7	1986–1987	4580	21,400	25,980
8	1987–1988	4800	23,500	28,300
9	1988–1989	5500	31,500	37,000
10	1989–1990	6400	34,200	40,600

Source: OPPI, Pharmaceutical Compendium, Mumbai, Organization of Pharmaceutical Producers of India, 2001

The era of protected environment, intensive competition and strong emphasis on reverse engineering led to the development of insular technical knowledge base, for e.g. Indian firms built strong capabilities in organic and synthetic chemistry, but other areas of innovative pharmaceutical R&D like medical chemistry and biology remained neglected. The weak patent law led to negligible publications and patenting activities by the Indian pharmaceutical firms thereby, preventing the development of basic IPR management capability.

The weakening of the patent act and the drug price control order of the 1970s forced MNC pharmaceutical firms to reduce their operations in India. This provided Indian firms with a domestic market which was large in volume but small in value. The lack of enough value in the Indian market proved detrimental to the emergence of innovative R&D in Indian pharmaceutical firms.

Stage 2: Creative Imitation and Intermediate R&D Capabilities

Creative adaptations are innovative as they are inspired by existing products but are still different from them. Creative imitations are aimed at generating facsimile products but with new and better performance features. It also involves activities like substantial investment in R&D to create imitative products. According to Kim and Nelson, design copies, creative adaptations, technological leapfrogging and adaptation to another industry are different forms of creative imitation.

Some Indian pharmaceutical firms entered the export market and specifically the generic market in advanced countries after the liberalisation in 1990's. A generic drug is produced by a different process but with same chemical compound as the original product. The strategy adopted by these firms was one of 'creative imitation' to manufacture products by developing non-infringement processes. These non-infringement processes can be converted into a patent, which creates a value for firm in the market.

Two distinct stages comprise the pharmaceutical manufacturing process, active ingredients[2] (also known as bulk drugs) and formulations[3]. The production process of active ingredient is highly volatile, requires expertise and high capital investment and exhibits economies of scale, whereas the production process for formulations is relatively straight forward (typical steps involves: mixing, granulating and drying) as it requires low capital investment and economies of scale is not as important for theses as it is for the active ingredients. Generally developing countries attempting to build pharmaceutical capabilities choose to enter at the formulation stage because of the fewer resources and less cost at this stage. By producing generics, formulations that contain the same active ingredient as the branded MNC drug, local firms are focussed on a strategy which requires only limited resources and yet is very effective in reducing MNC market share in the domestic market.

Of all the developing countries, only India and China have significantly back integrated into active ingredients because large number of local pharmaceutical formulation firms enables them to exploit economies of scale profitably and the presence of local chemical equipment manufacturers lowers the capital investment requirement. The R&D expenditures for generics are minimal and are solely focussed on developing a cheaper process to produce the brand drug. Also the associated risk is negligible because the target drug already exists. Because of these features generic are priced low and thus very quickly erode the revenues of the original patented drugs. For example, those drugs whose patents expired in the 1991-92 period lost 72% of their prescription to generic completion worldwide after only 18 months (PhRMA 1998).

Table 2: Comparison of drug prices in India and US

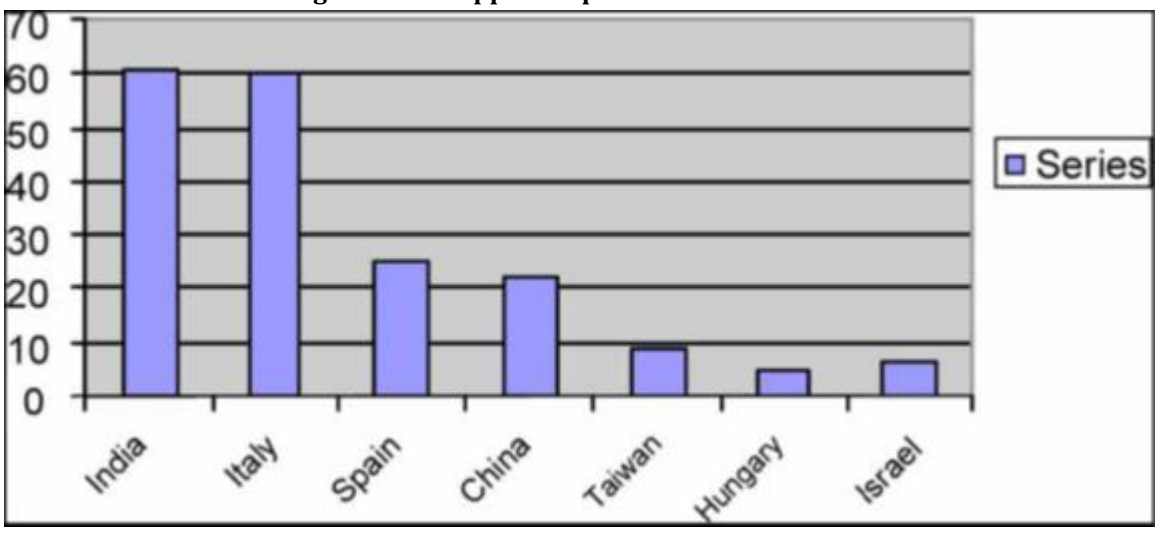
Drug Name	Price in India ($)	Price in US ($)
Ranitidine	0.26	14
Ciprofloxacin	2.42	40
Diclofenac	0.18	9.11
Famotidine	0.20	27.75

Source: Badr, 1995; The Drug Index, 1997; The Red Book, 1995

Until the 1970s, Italy, Spain and Eastern Europe were the primary 'alternatives' for active ingredient suppliers but when these countries instituted product patents, the developing country firms requiring raw ingredient switched their supply lines to India and China. TRIPS protects on patent active ingredients resulted in no alternative suppliers for materials beyond 2005 and thus the local firms have to r estrict their generic formulation activities to off-patent drugs only.

Indian pharmaceutical industry has even entered the US generic drug market by setting up marketing infrastructure and forming alliances with US generic firms. By 2003, India had the highest number of FDA (Food and Drug Administration) approved plants outside USA followed by Italy.

Figure 2: FDA approved plants outside USA



Source: USFDA.

Success in generic R&D involves strong interaction and coordination between IPR, marketing and R&D departments and requires the presence of organisational mechanisms to facilitate these interactions.

Nelson and Winter reflecting on imitative learning suggest that 'an imitator working in an extremely sparse set of closed about the product might well adopt the more prestigious title of "innovator", since most of the problem is really being solved independently'. Creative in form of generics R & D has increased Indian pharmaceutical firms awareness of opportunities in the new drug delivery system (NDDS) and NCE Research. Thus many skills and activities required in generic R & D are applicable in the innovative process R & D.

Stage 3: Collaborative R&D and Advanced R&D Capabilities

Advanced R & D capabilities involved new chemical entity research either by using research strategies like analogue research or rational drug design and new drug delivery systems (NDDS). But the movement from intermediate R & D capabilities to advanced R & D capabilities varies due to differences in knowledge based and organizational capability.

Large Indian firms started investing in new drug discovery research as a response to the emerging post TRIP scenario. Initially Indian firms faced major constraints such as financial and infrastructural resources, an insular knowledge-base and lack of scientists trained in innovative R&D. To leverage the financial cost, Indian pharmaceutical firms started investing the revenue generated from generic business into innovative R&D. The alternative strategy to cover these financial costs was to partner with MNC pharmaceutical firms through licensing of molecules or drug delivery system technology. These licensing agreements usually involve milestone payments and limited marketing rights. For example, Torrent pharmaceutical licensed its anti diabetic molecule to Novartis at a preclinical stage. According to the agreement, initially Torrent will receive a payment of US$0.5 million and it will develop the molecule to a predefined stage. At this stage Novartis will have the option to acquire rights for further development. If Novartis exercises this option then Torrent will receive an initial payment of US$3 million and subsequent milestone payments depending on progress. If the product is commercialised Torrent will get royalties and will also lead the co-promotion of the product in India.

The financial constraint associated with a new drug discovery can be overcome by the low cost of research. The cost is estimated to be one-tenth in India vis-a-vis advanced countries in development of a new molecule. Indian pharmaceutical firms are filling the knowledge gaps in the new chemical entity research by hiring Indian scientist experienced in drug discovery finding and by adopting strategy of collaborative research with Indian and overseas research institutes.

Because of these initiatives many research laboratories have taken up industry sponsored research and established strong partnerships with industrial firms on a long-term basis for product and process development projects. In the past, academic research meant publishing journal papers, not releasing technologies into the market place. Now CSIR laboratories are becoming more market oriented and collaborating with industry to bring the inventions into the market place. Because of these initiatives many research laboratories have taken up industry sponsored research and established strong partnerships with industrial firms on a long-term basis for product and process development projects.

4.EMPIRICAL ANALYSIS

To see how the transfer of technology affects the R&D decisions of the firms in the Indian pharmaceutical industry, we did an econometric analysis (using our little knowledge of applied econometrics learnt in third semester). We are taking R&D expenditure of a firm as a measure of its technological capability; a highly capable firm would invest more in R&D as compared to a low capability firm. So the technological capability of firm that we talked about in Section C is actually captured by its R&D expenditure. We postulated the R&D expenditure of the firm in Indian Pharmaceutical sector should be related to:

1) Technology Transfers
2) Size of the firms
3) Transfer Costs
4) TRIPS Agreement

Technology transfers which can be in form of imported technology are reflected by the amount of *royalty payments*. As mentioned in the paper "R&D and Technological Learning" by Bhaduri and ray (2004), the import of disembodied technology is measured by the royalty payments. Therefore, in our study we have taken data on *forex spending on royalty* from the CMIE Prowess data.

Size of the firm is captured by the *annual sales* of the firms.

Costs of transfers for the transferee as discussed in section B is taken to be reflected by the amount of *technical know-how fees*. As technology is not always codified but tacit, firms must hire technicians for their know-how. In this way technical know-how fees is taken as a proxy for transferees' costs of transfers.

After the implementation of TRIPS agreement in 2005, the R&D behaviour of the firms is expected to change. The Indian pharmaceutical firms have for long followed reverse engineering processes, but after the implementation of TRIPS in 2005, such activities shall be restricted, therefore we anticipate the firms' R&D behaviour to undergo a change. To capture the effect of TRIPS we used a time dummy variable Dt, such that Dt = 0 for the Pre-TRIPS regime (base category) and Dt = 1 for Post-TRIPS regime.

Also we have included an *interactive dummy* for the technology transfers and the time which is an interaction between the royalty payments and the time dummy variable Dt.

Methodology

Data on the above variables was collected from the CMIE's Prowess database. We did our regression analysis using panel data techniques using data on 548 firms listed with Prowess for the period 2000-2009. We have taken the period 2000-2005 as the Pre-TRIPS regime and the period 2006-2009 as the Post-TRIPS regime. The regression equation estimated is as follows:

$$R\&D = \beta 0 + \beta 1\, Royaltyit + \beta 2\, Salesit + \beta 3\, Know - how\ feesit + \beta 4\, Dt + \beta 5\, Dt * Royaltyit + uit$$

where i refers to the firms and t refers to the time period.

Table 3: Estimation Results

R&D	Coefficient	Std. Err.
Royalty	-2.364032***	.7752784
Sales	.069922***	.0010342
Know-how Fees	-.1005689	3.209225
D_t	-.8355824*	.4671724
D_t* Royalty	2.346444***	.8691373
Constant	-3.221182***	.5158815
R-Squared	.6887	
N	548	

Source: Authors' calculations

The coefficient of royalty payments is negative and statistically significant at one percent level of significance, meaning that as royalty payments that the firms have to give to the transferor go up, its own R&D will decrease. This could mean that if the amount spent on foreign technology increases, firms will have fewer resources to do own R&D. This could also mean that firms who are technologically less capable would invest less in own R&D and spend more on getting it transferred from the foreign countries.

The coefficient of the sales of the firms is positively related and statistically significant, implying that R&D expenditure of a firm increases with its size.

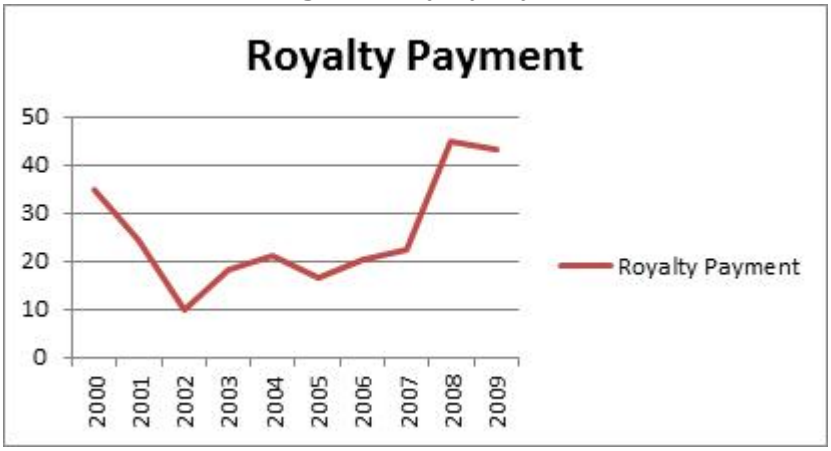
The coefficient of know-how costs is negative meaning that as costs of transfer increases, firms' own R&D falls, which is not in line with our supposition that if it becomes more and more costly for a firm to absorb the transferred technology, a firm should rather increase its R&D *both* to be better able to understand the outside technology as pointed by Cohen and Levinthal (1990) and to be more self-sufficient in the light of increasing costs of transfer for the transferee. However, the coefficient though negative is statistically insignificant.

The coefficient of time dummy variable D_t is negative meaning that R&D expenditure has gone down in the Post-TRIPS regime, which is against our belief that firms would invest more in their own R&D after the implementation of TRIPS as reverse engineering activities would be restricted. The negative coefficient could mean that as it has not been much time after the implementation of TRIPS, not all firms who only had reverse engineering capabilities will invest in basic research R&D. These firms will now not in invest in reverse engineering R&D leave alone basic research and depend completely on transferred technology, leading to decline in own R&D expenditure. However, the coefficient is statistically insignificant.

The coefficient of interactive dummy on time and royalty payments suggests that post 2005 (post TRIPs) there is strong IPR regime i.e. reverse engineering is restricted. Because of strong IPR regime there will be more technology transfers (since foreign firms do not face the threat of imitation) because of increase in the royalty payments but since firms can't do reverse engineering they will invest in their own R&D. Hence there is a positive and significant relationship between increasing technology transfers post 2005 and firms own R&D expenditure.

The trend of royalty payments can be shown as below, where the horizontal axis presents the years from 2000-09 and the vertical axis gives the royalty payments.

Figure 3: Royalty Payments



The trend suggests that while royalty payments were falling in the period 2000-2003, they rose sharply after 2005, suggesting the fact the Post-TRIPS period actually saw Indian pharmaceutical firms paying more royalties as a response to the strong IPR policy.

5.CONCLUSION

The Indian pharmaceutical industry is the world's second largest by volume. During last few decades Indian Pharmaceutical industry has emerged as a rapidly growing industry. From the "capability creation model" we know that the industry initially focused on duplicative imitation and followed creative imitation in its second stage of development. The imitative R&D activities followed by the Indian pharmaceutical industry helped them acquire basic and intermediate technological capabilities. To protect the Indian pharmaceutical industry from competition in the initial stages, the Indian policy makers used weak patent laws to infuse life into the industry. Finally as a result of change in patent law in

2005, industry is on its way to achieve the learning required to develop capabilities in innovative research and development.

Indian firms are now focusing on drug discovery research. Firms will have to create an environment that will motivate 'out of the box' thinking. These firms will use collaborative R&D approaches to develop advanced capabilities in pharmaceutical R&D and fund these investments through formulations and bulk generics business.

Enforcement of product patents increases the likelihood of foreign firms investing in developing countries particularly in industries where patents are important since foreign firms will be assured that local laws will protect their proprietary technology from 'pirates' (Mansfield 1994). However, throughout the TRIPS negotiations, the developing countries contended that they had not yet attained a sufficient level of industrial development and thus to switch over to a product patent regime is unfair.

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END NOTES

[1] *As cited by Irwin, H. L., Technology Transfer (2005), pp. 1-6,http://onlinepubs.trb.org/onlinepubs/millennium/00114.pdf*

[2] *Active ingredient is the essential raw material of a drug which can be extracted from animal or vegetable sources prepared by fermentation or synthesized chemically.*

[3] *Formulations are the end products seen by customers and entail combining the active ingredient with excipients, raw materials that aid in the absorption or administration of the active ingredient.*