

# Strong Medicine? Patent Reform and the Transformation of the Indian Pharmaceutical Industry

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## 1 Introduction

Can a shift to strong intellectual property rights induce higher levels of inventive activity in developing countries? This question has acquired increased salience in recent years as developing country governments, international agencies, and economists have all struggled to understand the impact of the worldwide movement to stronger IPR on developing countries. The existing evidence on this question appears to be inconclusive at best.<sup>1</sup> Perhaps because of the lack of strong dispositive evidence, IPR continues to be a flashpoint of disagreement in international trade negotiations.

The debate on these issues is especially intense when it comes to the question of product patent protection for pharmaceuticals. The provision

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<sup>1</sup>Maskus (2000) provides a masterful overview of the critical issues. See also Fink and Maskus (2004) for a focused discussion of the role of intellectual property rights in the economic development process. Lerner (2002) presents evidence based on a very long, comprehensive set of patent reforms. The literature is quite extensive, and we make no attempt at a comprehensive review.

in the TRIPs agreement requiring such protection was one of the most hotly contested provisions of the agreement, and opposition to its inclusion and enforcement remains widespread. Developing country representatives claimed during the debate over TRIPs –and continue to claim, more than a decade after its ratification – that stronger patent protection for pharmaceuticals in developing countries would have no positive effect on innovation or technological upgrading in the local industries; the only effect would be to raise prices and reduce access to medicines. This skepticism has received powerful empirical backing from recent research. Qian (2007) provides persuasive evidence that the general effect of stronger pharmaceutical patent protection on local innovation is indistinguishable from zero; only in relatively advanced countries can one find any evidence of a positive effect.

The Indian pharmaceutical industry provides a particularly interesting context in which to explore these questions. From the early 1970s through 2005, India’s pharmaceutical industry operated under a legal regime that nearly nullified patent protection for pharmaceutical products. Indian firms were effectively free to sell imitations of patented Western medicines without sanction in their own country (and in other countries that did not enforce product patents for pharmaceuticals). This business model was gravely threatened by the ratification of the TRIPs Agreement in the mid-1990s.

Indian industry leaders and their advocates in the Indian government asserted that the creation of pharmaceutical product patents in India would force up prices for essential medicines without generating any positive benefit in the form of increased FDI and innovation or through multinationals shifting R&D to India. These concerns led Indian government officials to sharply criticize TRIPs. Several recent academic papers have echoed these concerns, using theory and/or empirics to forecast the potential welfare losses affecting current and future consumers, especially in countries like India, through the higher drug prices a stronger patent regime might bring. These papers include Chaudhuri, Goldberg, and Jia (2006), McCalman (2001), and Cockburn and Lanjouw (2001). A common feature of these papers is that they completely ignore or heavily discount the possibility stronger patents might

actually induce increases in R&D in developing countries. However, theoretical work such as Grossman and Lai (2004) emphasizes the reality that, in economic terms, the Indian pharmaceutical market is a fairly small one. Accession of a small market such as India to the strong patent bloc should have relatively limited impact on the incentives for pharmaceutical firms to conduct R&D – the large markets were already protected by strong patent laws.<sup>2</sup> Recent empirical research, such as Qian (2007), tends to strengthen pessimism regarding the likelihood that stronger patents in pharmaceuticals would induce more R&D in India. Qian only finds evidence of an increase in R&D in countries that are relatively rich, possess a well-developed innovative capacity, and have a high degree of "economic freedom" as measured by the Fraser Institute's economic freedom index. At the time it ratified TRIPs, India was a poor country with limited evident innovative capability. In terms of "economic freedom," a variable emphasized in Qian (2007), India scored below the mean – roughly at the same level as Namibia and below such countries as Zambia, Guyana, and Paraguay.<sup>3</sup>

Despite these concerns, we have found evidence of a striking increase in the R&D intensity of Indian pharmaceutical firms since the ratification of TRIPs. In a companion paper, Arora, Branstetter, and Chatterjee (2008) – hereafter ABC – find that absolute R&D expenditure, R&D intensity, and measures of research output have all increased substantially since India ratified the agreement. Furthermore, the stock market valuation of Indian firms' investment in R&D has also increased sharply. More detailed investigation of the data suggests a concentration of the increase in innovative activity in a small group of local firms with especially well developed research capabilities; this also appears to be the same group of firms in which the rising stock market valuation of R&D investment is concentrated. Press accounts, industry analysts, and the statements of Indian pharmaceutical executives all seem to point to a development once widely viewed as improbable – the

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<sup>2</sup>This point has been well understood for some time and was part of the basis for opposition to the TRIPs agreement. See Maskus (2000).

<sup>3</sup>The Fraser Institute's economic freedom index is available on the internet. We examined India's ranking in the year its ratification of TRIPs went into effect.

emergence of a domestic, research-driven pharmaceutical industry. The timing of this shift is so strongly coincident with important changes in India's patent regime that it is hard not to view the shift to stronger patents as having played a causal role in this transition.

This sets up the central puzzle that this paper attempts to resolve. The logic behind the theoretical argument that patent reform in a small market should have little impact on incentives to do R&D seems hard to refute. Yet, this apparently irrefutable argument is directly contradicted by some inescapable facts. How shall we reconcile the two? We do so by employing a mixture of theory, empirical analysis, and process of elimination.

In theory, TRIPs could push Indian firms into innovation by foreclosing the traditional option of simply imitating Western firms' inventions in the Indian market and in other markets with weak patent protection for pharmaceuticals. Under the old patent regime, Indian firms may have voluntarily foregone potential profits earned through sales of innovative products because of the high investment costs required and the limited technical capabilities of the Indian firms. Later in the paper, we sketch out a preliminary model in which this ceases to be an equilibrium if the "protected home market" adopts stronger patents. In essence, firms are forced to adopt a more research-intensive strategy because the former business model is no longer viable. The modelling logic portrays the new style of innovation protected by patent reform and the previous product development activities of the Indian firms as strategic substitutes in the sense of Milgrom and Roberts (1990). We find some empirical support for this story. It is clear that some Indian firms have gone to considerable effort to develop their own new patented products, and the top firms now have products in clinical trials. Nevertheless, these efforts have yet to yield a single new product that is a major commercial success. The efforts of the Indian firms have cast their technical limitations into sharp relief. Statistically, we find little evidence that the rise in R&D output or the market valuation of R&D inputs is primarily driven by these efforts toward "independent innovation." This may be the future of the Indian industry – or at least its top firms – but it is not the dominant

theme of the industry's recent past.

In theory, TRIPs could push firms into R&D collaboration with Western firms rather than into a strategy of independent drug development. Stronger patent laws could make it relatively more attractive for Indian firms with limited technical capability to eschew imitation and specialize in particular stages of the production process that play to their strengths in process engineering, low-cost manufacturing, and basic chemistry. Elsewhere in the paper, we sketch out a (very) preliminary model that has this implication. Public statements by industry leaders in both India and the U.S. bear witness to the strong interest in both countries in the potential benefits of collaboration, and we do find in the data a sharp growth in alliances and collaborations between Western pharmaceutical and biotechnology concerns and their Indian counterparts. Wadwha et al. (2008) has claimed that Indian firms are now playing a key role in an increasingly globalized innovation value chain within the pharmaceutical industry.<sup>4</sup> Unfortunately, these bold assertions do not bear up well under close scrutiny of the available data. A careful inspection of the data from on strategic alliances between Indian and foreign pharmaceutical companies show that only a small number of these alliances focus substantively on real R&D collaboration. Furthermore, this trend has been quite recent, and only a small fraction of the R&D output of the leading firms can be reliably ascribed to the fruits of international R&D collaboration. We also find limited evidence that the established pharmaceutical and biotechnology firms in the West have begun to outsource significant amounts of R&D to Indian subsidiaries or partners. This is another story that is likely to figure prominently in the future of the Indian industry, but it can only explain part of the industry's recent past.

Our analysis in this paper emphasizes a different explanation. A detailed analysis of the content of Indian pharmaceutical firms' innovative activities over the last ten years reveals that relatively little of it has been focused on the kind of new product innovation that one might have expected fun-

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<sup>4</sup>This paper, funded by the Kauffman Foundation, generated extensive comment in the business press.

damental patent reform to encourage and reward. Instead, R&D efforts have remained (largely) focused on process innovations, manufacturing improvements, and refinements of existing products pioneered elsewhere. The principal mechanisms by which Indian firms have appropriated the returns to their expanding R&D investments have been sales of generic products, exports of bulk drugs and active ingredients, contract manufacturing rather than new drug development or R&D services to Western firms. India's domestic patent reform played a role in the expansion of this activity, but other reforms and external market developments coincident in time with key steps of the patent reform process were also quite important. These other developments had the combined effect of opening up to Indian firms a foreign market for "TRIPs-legal" imitations – the generics market – that had not been sufficiently attractive before the mid-1990s. Exploiting the Western market for generics and related products required investments in process innovation and technological upgrading that were costly for Indian firms but well within the range of their technical capabilities.

The plan for the rest of the paper is as follows. Section 2 provides a brief overview of the recent history of the Indian pharmaceutical industry. Section 3 reprises the main empirical findings of Arora, Branstetter, and Chatterjee (2008), and sets out the "puzzle" of industry transformation in further detail. Section 4 presents evidence documenting the degree to which Indian pharmaceutical R&D efforts have focused on process, rather than product innovation. This section also describes the role that regulatory and market developments other than TRIPs may have played in the growth of R&D activities in the Indian pharmaceutical industry. Section 5 examines the (limited) extent of fundamental product innovation in the Indian pharmaceutical industry to date, and offers up a sketch of a model by which TRIPs and related Indian patent reforms could have contributed to growing product innovation. Section 6 examines the growth of R&D collaboration between the Indian pharmaceutical industry and foreign producers. Section 7 concludes.

## 2 The Evolution of India's Pharmaceutical Industry

India began its history as an independent nation with relatively strong intellectual property rights for pharmaceutical products. India adopted the British Patents and Design Act of 1911 after independence in 1947 and kept this law in place until 1972. Under this statute, firms could patent all the processes by which a given drug could be manufactured, they could obtain product patents, and patents lasted for 14 years. This relatively strong patent regime allowed multinational companies to translate their research strength into high market shares. Foreign drug companies dominated the Indian drug industry throughout the period during which this law was in effect, collectively holding a 68% market share in 1970. It was widely believed, at least in India, that the strong IPR regime effectively prevented the development of an indigenous drug industry.<sup>5</sup>

In response to these concerns, the Government of India enacted a fundamentally different law, the Indian Patent Act of 1970, which was implemented in 1972. This law shortened the life of a patent to 5-7 years and allowed a manufacturer to patent only one method of production for a drug. Other producers were free to produce the same product, so long as they used a different production process. This dramatically weakened patent protection – in many cases, it effectively nullified it – and the market position of the multinational firms. Indian firms could now legally imitate newly introduced drugs without sanction in their own country, so long as they did not use patented processes. By 1980, the market share of the multinationals had fallen to 50%, and it would continue to fall over the next two decades as these new, weaker patent laws remained in place.<sup>6</sup> Indian firms that had been founded prior to the Patent Act of 1970 grew, and large numbers of new firms entered the market over time.

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<sup>5</sup>See Chaudhuri (2005) for a comprehensive history of the intellectual property rights regime for drugs in India. Many of the key facts presented in this section are drawn from this source.

<sup>6</sup>Chaudhuri (2005) emphasizes this point.

Indian pharmaceutical production grew rapidly after the implementation of the new patent act, as is shown in Table 1. The table divides production into bulk drugs (the raw materials used in pharmaceuticals) and formulations (mixtures of substances ready for human consumption). Both categories grew substantially. Given the weak patent regime, little effort was devoted to drug discovery, but the manufacturing capabilities, reverse engineering skills, and imitative capacity of domestic firms became steadily more advanced. Indian firms were able to produce and sell drugs initially invented in the West within only a few years of their introduction into major markets. Low costs of production increasingly provided Indian firms with a competitive edge outside India, particularly in product categories or markets in which patents were not an issue. By 1988-89, India had become a net exporter of pharmaceutical products, exporting more than 75% of its bulk drug production and about 25% of its production of formulations.

Early formulations exports tended to be concentrated in developing countries with weak patent laws. India's price controls limited profit margins in the domestic market, so Indian firms began to look for opportunities elsewhere. A limited devaluation of the rupee in the 1980s arguably reinforced India's competitiveness in these poorer markets, although it also raised the prices Indian firms paid for raw materials. One of the most significant reforms in terms of the industry's future came in 1984, with the passage of the Hatch-Waxman Act in the United States. This widened the market for generic competitors to off-patent branded medicines, and India's Ranbaxy had the foresight to pursue this opportunity early on, but it took years before Indian firms would realize significant success in the U.S. generics market. In 1991, India succumbed to a balance of payments crisis that required it to seek financial assistance from the IMF, which forced a thorough trade liberalization and further devaluation of the rupee. This coincided with a delicensing of the domestic industry. A liberalization of international financial transactions, completed by the mid-1990s, made it much easier for Indian firms to invest abroad and vice versa. Indian firms continued to refine their manufacturing capabilities in the 1990s.



Meanwhile, the Indian intellectual property regime for pharmaceuticals was about to undergo fundamental change. In 1986, the Uruguay Round of international trade negotiations was launched. It would drag on for nearly a decade. One of the most divisive issues in these negotiations was the demand of the developed countries for developing countries like India to substantially strengthen their patent laws by ratifying the Trade Related Intellectual Property Rights (TRIPs) Agreement that would eventually become part of the WTO charter. Western countries insisted that India adopt strong patent protection for pharmaceutical products, a demand that appeared to pose a grave threat to the Indian pharmaceutical industry. Product patents would protect a chemical entity, not a manufacturing process. All conceivable manufacturing processes that produced a chemically identical substance would be effectively covered by such a patent regime, making the kind of reverse engineering practiced by Indian firms illegal. Indian industry leaders and their advocates in government asserted that the creation of effective patent protection for pharmaceutical products in India would force up prices for essential medicines without generating any positive benefit in the form of increased R&D and innovation.<sup>7</sup> Despite strong Indian objections, however, a TRIPs Agreement incorporating relatively strong patents for pharmaceuticals survived the negotiating process. If India wanted to be a part of the newly created World Trade Organization, it would have to ratify the TRIPs Agreement along with the other components of the WTO Charter. Reluctantly, the Indian government did so, signing the TRIPs treaty in late 1994.

When the Indian government took this step, it effectively committed itself to a path of reform that would eventually produce a patent statute consistent with the standards outlined in the new TRIPs Agreement. However, the treaty allowed developing country member states a number of years in which to come into full compliance with the treaty. India stetched out its patent reform process for more than a decade, and the domestic debate that raged

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<sup>7</sup>Opposition to stronger patents was not universal within the Indian pharmaceutical industry. Bhandari (2005) claims the leadership of Ranbaxy took a more positive view of stronger patent rights.

within India over exactly how to honor its WTO obligations complicated the reform process in some ways. Table 2 provides a summary of the key steps in the reform process.

This evolution of the patent regime suggests that the years since 1990 can be divided into three parts. In the years 1990-1994, there was considerable uncertainty regarding the outcome of the Uruguay Round negotiating process. Only by 1994 was it clear that the Indian government would sign the TRIPs Agreement. We therefore consider this to be a period in which knowledgeable industry observers and the stock market would discount the probability of a substantial change in the Indian IPR regime for pharmaceuticals.

That changed significantly in the period from 1995 through 1999. The Indian government began accepting and processing applications for product patents and exclusive marketing rights. However, national legislation was required to provide a legal basis for these product patent applications. While a patent amendment was introduced in 1995, it was not fully enacted for another 10 years. Disputes continued, both within India and between India and its trading partners, regarding the exact contents and timing of this legislation. Patent reform was now inevitable, but the exact nature of that reform was still not completely clear to market participants. This suggests a different sort of discount factor being applied by the market. Indian patent law was amended in 1999, but this amendment fell short of India's obligations under TRIPs.

At the end of the 1990s, India requested and was granted an extension by the WTO for additional time to complete its institutional reform process. The WTO gave India until Jan. 1, 2005 to complete the process. We believe that, in this final period, the "end game" was increasingly evident to all market participants and observers. This view is supported by conversations with industry practitioners and a reading of the contemporary business press. The final amendment legally authorizing product patents was passed just before the deadline, and came into force in 2005.

If our reading of the policy reform process is correct, then we should be

able to identify discrete shifts in market behavior corresponding to the three subperiods outlined above. Working with a panel of 315 Indian pharmaceutical firms from 1990 to 2005, ABC found evidence of a shift in behavior that parallels changes in India's pharmaceutical patent regime. This are discussed in the next section.

### **3 The Transformation of India's Pharmaceutical Industry after TRIPs**

The raw data on R&D spending and inventive output in the Indian pharmaceutical industry suggest there was significant change as the IPR reforms were phased in. Table 3 and Figure 1 illustrate the rise in R&D intensity within the Indian pharmaceutical industry. One sees a surge that is roughly coincident with the ratification of TRIPs and an even more striking increase as the implementation of a product patent law approaches. This latter movement reflects both an increase in absolute levels of R&D spending and a decline in sales by less R&D-intensive firms in the industry.

Given the movements in R&D spending, it is not surprising that one also sees a substantial increase in R&D outputs. Table 4 lists illustrates rapid growth in U.S. PTO patent grants, grants of pharmaceutical product patents by the Indian patent office, and applications to the FDA for the market offering of generic drugs as measured by ANDAs (abbreviated new drug applications). At a later point in the paper, we will discuss the degree to which the introduction of generics into the U.S. market requires innovative effort. For now, we stress that these different indicators all affirm the same story.

Table 5 illustrates the central result of ABC, showing what is obtained when one uses stock market data on the 315 publicly traded pharmaceutical companies to estimate the stock market's valuation of R&D spending. Following a long line of empirical research inaugurated by Zvi Griliches (1981), ABC calculate the ratio of the market value of the firm to the replacement

cost of its tangible assets and regress this on a measure of the ratio of intangible assets (R&D spending) to tangible assets.<sup>8</sup> The specification is

$$\ln\left(\frac{V_{it}}{A_{it}}\right) = \ln q_{it} + \beta_t \left(\frac{R_{it}}{A_{it}}\right) + \epsilon_{it}$$

Sales and firm effects are included in the regression. In order to allow for a change in the market valuation of R&D spending, ABC estimate separate coefficients on the knowledge stock to tangible asset ratio for the periods 1990-1994, 1995-1999, and 2000-2005. As Table 5 indicates, the point estimates of these valuations increase dramatically over time, and the increase is clearly concentrated in firms that *ex ante*, had superior technical capabilities. ABC measure "technical capabilities" in three different ways – possession of a recognized R&D or product development center ("modern firms"), recognition by stock market analysts as being a technologically progressive firm ("analyst firms"), or having a production facility inspected and approved by the U.S. FDA. Regardless of the measure used to identify them, the technologically progressive subset of firms shows a rise in market valuation of R&D that is of greater magnitude and is statistically significant at conventional levels. ABC demonstrate that these results are robust to the imputation of missing R&D data, the use of various different rates of depreciation for R&D expenditure, and to various other changes in specification.

This shift stands in stark contrast to the typical effect tightening pharmaceutical patent laws has had in poor developing countries, especially on the indigenous firms that developed under weak patent systems. Qian's (2007) comprehensive study of the strengthening of pharmaceutical patent laws cites and builds on a long series of papers which show, at best, no positive effect and, at worst, a seriously negative effect on the domestic indigenous industry after reform. Qian's results suggest that only relatively wealthy countries with highly developed institutions stand much of a chance of benefiting from these patent law changes. At the time of its patent reform, India was not wealthy and its institutional quality was not terribly high. India would seem to be an unlikely candidate to realize large gains in indigenous research

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<sup>8</sup>ABC present a derivation of this equation, cite numerous related studies, and report the results of several robustness checks.

inputs and outputs after the passage of a stronger patent law.

## **4 The Post-TRIPs Innovation Surge in the Indian Pharmaceuticals Industry: Did TRIPs Really Matter?**

### **4.1 India's Invention Boom: Process Innovation, not Product Innovation**

We begin our investigation of the post-TRIPs innovation surge with a close inspection of the innovative outputs it has produced. To the extent that Indian firms are creating useful inventions, they will have an incentive to patent them in the U.S., and these data are easily accessed by the researcher. By mid-2008, Indian assignees had been granted about 620 U.S. patents. The majority of these can be linked to the listed Indian pharmaceutical companies in our data set, and Figure 2 depicts the growth over time in these patents. The post-TRIPs surge in patenting is clear.

However, this rising tide of patents and R&D has yet to yield a single new product that has yielded major commercial success. Table 6 provides data culled from a variety of sources on the development of NCEs (new chemical entities) by Indian firms.<sup>9</sup> Only one compound – Dr. Reddy's Bagliatazone, coded as DRF-2593, is close to a commercial launch, and that particular compound has been developed through an outlicensing agreement with Denmark's Rheoscience. Eight Indian firms have new products in various stages of the clinical trials process, but the numbers are quite modest. Leading Indian firms have had some success licensing manufacturing processes or drug delivery systems to Western firms, but the creation of new drugs – the kind of innovation for which domestic patent reform strengthened legal protection

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<sup>9</sup>We thank Matt Higgins of Georgia Tech for steering us to PharmaProjects data on Indian drug firms' drug development efforts.

the most – has yet to be successfully accomplished. This meager record of fundamental product innovation raises the question of exactly what the stock market is valuing – how could rational investors place such a dramatically rising premium on investments that have yielded so little, at least so far?

One reason may be because very little of India's post-TRIPs innovation surge has focused on product innovation, per se. A complete reading of the patent abstracts and claims for a sample of these patents suggests that the vast majority of these patents describe process innovations. This impression is confirmed when we seek to broadly categorize inventions into product and process inventions based on keyword searches of the text of the patent documents. Even an extremely expansive, generous definition of "product patent" yields relatively small numbers. This is evident in both Figure 2, which tabulates flows of patent grants by grant year, and Figure 3, which depict trends in cumulative patent stocks.

A significant fraction of the process inventions can be directly linked to existing compounds the Indian firms are currently selling in Western markets. Business press accounts have emphasized that the most financially successful Indian incumbents have derived an important fraction of their global revenues from sales of generic products in Western markets. We do not (yet) possess data that break down our sample firms' sales by product, but we can use publicly available data from the FDA Orange Book to identify Indian firms that have been granted approval to sell generic products in the U.S. market, which is the most important single generics market by a considerable margin. The publicly traded Indian firms in our sample had been granted approval for 143 Abbreviated New Drug Applications (ANDAs) by 2005, when our stock market data end. This marked the beginning of a surge in ANDA applications and approvals – by mid-2008, Indian firms had been granted more than 400 ANDAs. For the firms in this particular generics market, it seems that the majority of their inventive output can be linked to their generic product offerings. 12 Indian firms have both approved ANDAs and U.S. patents. For these firms, more than 52% of their U.S. patents describe processes or modifications related to the active ingredient contained in their

ANDAs. If we restrict our purview to process inventions, the fraction rises to about 60%.

While the number of Indian firms with approved ANDAs remains limited as of the end of our sample period, a much larger group have received FDA approval for the manufacture of particular compounds and active ingredients for the U.S. market. Ongoing research is attempting to link process inventions to the compounds for which FDA inspectors have granted approval. We anticipate computerized text searches will plausibly link a large fraction of Indian drug patents to these compounds.

## 4.2 Does the Market Value Product Innovation?

It is possible that the number of product innovations could be small, yet still account for a very large fraction of Indian firms' total R&D investment and the stock market's valuation of that investment. To formally test this hypothesis, we re-ran the baseline regressions in ABC, inserting stocks of product patents, divided by assets, as an alternative measure of knowledge capital. If the market is placing disproportionate value on that fraction of R&D that is connected to product innovation, then this additional regressor should be positive and statistically significant. It is not. Table 7 summarizes the results of various specifications suggested by this line of reasoning. The regression results suggest that there is no premium attached to product innovation, even in the broad way we have measured it. The regression coefficient is statistically indistinguishable from zero.

A related specification employs data generated by the Indian patent reform itself. Upon ratification of the TRIPs agreement, the Indian patent authority began accepting applications for pharmaceutical products that would be eligible for protection under a TRIPs-consistent patent regime. We can track, by firm and year, the number of Indian patent applications generated by Indian and foreign firms. In principle, a patent stock constructed from these data offers the most direct possible measure of invention that is directly

impacted by the patent regime change. Yet, as we see in Table 7, patent stocks do not function well as a proxy for intangible assets. In a market value equation, Indian patent stocks are not statistically insignificant. Further analysis (not shown) revealed no trend of a rising valuation of Indian patent stocks over time. That is, even as the legal underpinnings for protection of these particular inventions were strengthened, the market failed to react.

The implication of this seems clear: the rising valuation of R&D spending is not closely tied to the kind of fundamental product innovation directly targeted by India's pharmaceutical patent reforms. Instead, it is much more driven by the incremental, process-oriented invention Indian firms had engaged in before TRIPs, and for which India's pre-TRIPs patent regime offered at least some degree of protection. More confirmation of this comes from the results of an additional specification (not shown), in which we separate our sample into Indian firms with ANDAs and the rest. The tendency for the market valuation of R&D spending to rise over time is no longer statistically significant in the non-ANDA sample, but it remains statistically significant – despite the small sample size – in the ANDA subsample.

### **4.3 The Evolution of Indian Invention: Firm Capabilities and Market Opportunities**

That Indian firms would make only limited progress in fundamental product innovation is a reasonable outcome, given their constraints. India is not well endowed with many critical scientific and technical skills required for drug discovery research. At the front end, there is a serious shortage of well trained molecular biologists and molecular geneticists, and limited capability for high throughput screening and combinatorial chemistry. At the back end, relatively few organizations have a strong clinical research capability. Indian scientific strengths are in the middle stages: It is well endowed with organic and medicinal chemists. Moreover, there are a number of well established



and very large firms in America and Europe (and perhaps also Japan) that are already in the market, frequently allied with smaller startups to get technology and the compounds to be developed. Thus, patent protection should not be expected to increase NCE R&D significantly in India.

Viewed at the firm level, there are additional reasons why one would not expect to see Indian pharmaceutical firms investing much in NCE research. The most important reason is that change is difficult. Firms accustomed to imitating existing products could evolve towards discovering new ones, but this is fraught with difficulties. The first is the organizational challenge of blending reverse engineering research with true discovery.

*"What you need is innovative chemistry, which is not the same as reverse engineering. So in fact we do not prefer the people in discovery chemistry who have the experience of reverse engineering. If the scientist has done some non-infringing work or he has some original work then we will take him... For innovative R&D, you need to form a forum in a way that there is interaction between different departments, whereas reverse engineering is an individual job... Drug discovery is a completely team effort so you have to have chemists talking to biologists, biologists talking to the kinetist, kinetist and biologist talking to (the) analytical fellow. .. So you need to form a forum and structure where these will actually come together...*

*(Glenmark executive, cited in Kale.)*

The second, and perhaps more formidable, difficulty is that drug discovery (and development) is very expensive and very risky. Even if managers were willing to take the plunge, shareholders would (correctly) be loath to risk a profitable franchise, namely the production of pharmaceutical intermediates and, more recently, generics.

These difficulties manifest themselves in a number of ways. First, existing firms have moved only slowly into NCE research. <sup>10</sup>Those that have, have

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<sup>10</sup>Ranbaxy and DRL were the pioneers, investing in R&D starting in the late 1980s. Drug discovery R&D came later, in the 1990s. Many of the firms that began R&D later hired away R&D managers from Ranbaxy and DRL. In addition, some R&D labs were

tended to separate their NCE research into separate organizations. This ameliorates the organizational challenges of combining businesses with very different risk-reward profiles, and correspondingly different models for recruiting and compensating skilled employees. It also insulates investors, allowing private equity investors the possibility of investing in NCE research, with its much bigger upside gains. This separation also facilitates the tapping of the scientific talent pool overseas. Dr Reddy's Labs (DRL) and Sun Pharmaceuticals have adopted this route, and Ranbaxy was reportedly planning to do. DRL's drug discovery organization is called Aurigene. Unlike most Indian efforts, it uses a structural approach (rational drug design) to drug discovery.<sup>11</sup> Similarly, Sun has set up a drug discovery unit, SPARC, which is itself publicly listed. A more recent report indicates that more firms are planning to follow suit by hiving off their drug discovery efforts in a separate organization.<sup>12</sup> However, none of the efforts have succeeded as yet, although a number of compounds are in various stages of clinical trials, underscoring the wisdom of separating drug discovery from the main business.

These difficulties also imply that new firms, not burdened with having to change an existing organization and without a profitable business to protect, are more likely to be the ones investing in NCE research. A rough and ready way to illustrate this point is to look at the share of "product" patents filed at the US PTO by unlisted Indian firms in their total pharmaceutical patents. This share has steadily risen between 2000 and 2007, from about 29% to over 50%. The corresponding share for listed firms (which are typically larger and older) has slipped from about 35% to below 20%. This is a crude test in a number of ways. Our measure of product patents is rough, and some publicly

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seeded by personnel from Hoechst's R&D labs, the only MNC with an R&D initiative in India of any size (and subsequently acquired by Nicholas Piramal). A significant number of scientists were earlier working in the United States or the U.K. See Kale for more details.

<sup>11</sup>DRL has also formed Perlecan Pharma, whose business model is to in-license molecules developed by DRL. Since clinical development is the financially most demanding, the inference is that the separation is to manage risk rather than organizational diseconomies of scope.

<sup>12</sup><http://www.expresspharmaonline.com/20080215/market01.shtml>, last visited 16 July 2008.

listed firms are of recent vintage. Nonetheless, the data are consistent with the anecdotal accounts. For instance, GVK Bio was set up by the ex-CEO of Ranbaxy, whose business model is to in-license compounds from overseas firms, and develop them through the phase II clinicals and then outlicense back to established pharmaceutical firm.<sup>13</sup> In some cases, this could also be provided as a contracted service.

Advinus, a part of the Tata group, is another start-up focused on drug discovery, and also offers drug development services to Western pharmaceutical firms. Its drug discovery efforts are targetted to small molecules (i.e., not large proteins). It has entered into a joint venture with Merck in metabolic diseases, with Merck owning the right to in-license compounds in late stage clinicals. Avasthagen, founded in 1998, focuses on biotechnology. One of its division develops the generic version of large molecule (biotech) compounds, but has also launched drug discovery programs and programs in agrobiology.

It should also be emphasized that much of drug discovery research in Indian firms has tended to be “analogue” research. Working with validated targets or with compounds whose activity is well understood, firms can search for molecules that are more effective or have fewer side effects. In other words, these are not the “first in class” compounds, which target the disease in a new way. Kale (2005) provides a good example. Sanyo had discovered a molecule that sensitizes the body to the action of insulin. DRL scientists developed two other molecules in the same class that had better properties and licensed those to Novo Nordisk.

But NCE research is not the only type of “genuine” or “creative” technical activity available. Firms can innovate by improving an existing drug, such as a more desirable dosage form. This was the case when Ranbaxy developed a “once a day” dosage form for an important antibiotic, ciproflaxacin, which was licensed to the original innovator, Bayer, for \$65 million in 1999. Firms can innovate by developing better ways to deliver the drug, such as through

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<sup>13</sup>As Ranbaxy’s head of R&D noted in 2003 (cited in BusinessWorld, cited in Kale, PhD thesis) there are a number of drugs with a potential market size of \$100 - \$200 million, too small for the major pharmaceutical firms but large enough for the Indian firms.

a skin patch or through an inhaler. Firms can also develop cheaper ways to produce an existing drug, using new intermediates. Such process innovation may also accompany new dosages or drug delivery systems. Finally, even plain reverse engineering is seldom so. The established pharmaceutical firms surround their products with a bevy of patents, some of which remain in force even after the principal patent expires. A firm that seeks to launch a generic version of the now off-patent drug must be skilled enough to avoid tripping up on the cluster of unexpired patents. In many cases, this may require developing new processes to avoid using patent protected intermediates. These types of innovative activity draw more directly on the capabilities that Indian firms developed during the time when pharmaceutical products did not enjoy patent protection.

*What was happening was a more innovative way of producing the drug; if you would look at what Pfizer did, what DRL did and what Ranbaxy did for various products. Example, Prozac which is Fluoxetine used to be sold in particular dosages and strength. DRL not only developed the new process to make Fluoxetine but also they developed new dosage form and therefore got exclusivity in the US. ...”*

(Ranbaxy head of R&D, cited in Kale, 2007, p 127).

Moreover, many of these innovative activities naturally lead to collaborative alliances with Western firms. As Ranbaxy’s then CEO put it, “*We moved through a maze of over 70 process patents around Cefaclor (commercialized by Eli Lilly) to produce a non-infringing version of the molecule*” (cited in the Company Annual Report, 1993). This led to a joint venture with Lilly to produce this improved version of Cefaclor!

## 4.4

#### 4.5 *Could TRIPs Have Driven a Surge In Process Innovation?*

The previous section argues that the accumulated skills and labor endowments of Indian firms made a major transition to product innovation costly, risky, and therefore unlikely. Given these constraints, the direction of R&D effort over the last ten years seems to make sense. But can we explain its scale and the degree to which this scale has expanded over time? We began the paper by noting that the increase in R&D spending and patenting appears to be broadly coincident in time with the domestic patent reforms mandated by TRIPs. However, the incidence of these reforms was greatest for product innovations, where the Indian R&D response has been relatively modest. Is the association between patent reform and the innovation surge purely coincidental? If not, then how could the two be logically connected?

Part of the answer could lie in the implications of TRIPs-mandated patent reforms for process innovations. While the incidence of these reforms was surely greatest for product innovations, they also measurably strengthened protection for process innovations. In theory, the pre-TRIPs Indian patent statute protected process patents, but drug producers were only allowed to patent a single process per drug, and the length of patent protection was limited to 5-7 years. India's patent amendments lengthened patent protection considerably (to 20 years from the filing date), and allowed for the patenting of multiple processes related to the same drug. In principle, this could broaden the scope of process patent protection as well as the length, since trivial modifications of existing processes could be anticipated and patented by the innovator. But these additional protections for process innovations would only apply in the Indian market. That brings us back to the Grossman-Lai point: the Indian market was and is still too small to constitute a meaningful source of demand pull for innovation. The results of Table 7 are instructive here. The market does not appear to place much weight on Indian patents taken out under the new law, which applies to both product and process innovations. These considerations would appear to constitute, at best, a weak link between TRIPs and the innovation surge.

The real impact of TRIPs almost certainly came about through a very different mechanism: by foreclosing the opportunity for Indian firms to continue to grow through simple imitation of Western products in weak patent markets. Contemporary press accounts suggest a broad realization throughout the industry that TRIPs meant the eventual obsolescence of the historical business model. Since the 1970s, India and much of the developing world had been a preserve in which Indian firms were reasonably free to infringe on Western patents. That preserve was going to shrink rapidly, forcing Indian firms to pursue other business models. This effect can be modeled in a number of ways and, in the next section, we present a sketch of one such model. The broader point, though, which goes beyond the particulars of our theoretical specification is this: to the extent that TRIPs really mattered, it mattered not as a carrot but as a stick.

When we look for the carrot, it becomes clear that factors other than TRIPs mattered, and some of these other factors were broadly coincident in time with TRIPs-mandated patent reforms. Among the most important of these has to be the evolution of the market for generic drugs in Western countries, especially the United States. An extensive literature has described how the Hatch-Waxman Act of 1984 dramatically widened this market in the United States by reducing the regulatory hurdle firms faced when introducing products to compete with off-patent drugs.<sup>14</sup> It was no longer necessary to go through an expensive and lengthy clinical trials process with the rival compound; it was sufficient to prove bio-equivalence. This dramatically lowered the market entry hurdle facing firms with limited drug development capability; in effect, the fixed costs of product development dropped sharply. The high prices prevailing in the U.S. market for patented drugs created strong market incentives to substitute to lower-priced generics when the latter became available. The Act allowed this low regulatory hurdle apply to products that competed with patented drugs, so long as the producer could certify both bioequivalence and non-infringement of the patent(s) still in force. Generic drugs introduced through this feature of the Act (so-called

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<sup>14</sup>See Morton (2002).

paragraph four certifications) could face a legal challenge from the patent holder, raising the costs of introduction and increasing the uncertainty of future revenue flows, so the Act provided a benefit to compensate such producers for the additional risk: a half-year of market exclusivity is granted to successful paragraph four entrants. The generic producer competes with the patent-protected product but is itself protected from additional generic competition for 180 days.

Drug producers in the West quickly realized the significance of this reform, and the FDA was flooded with so-called applications for new drug approvals (ANDAs). Access to this market was temporarily interrupted by a scandal at the FDA in the late 1980s in which officials were found to have taken bribes in order to certify generic products. The adoption of more stringent controls over the certification process dramatically slowed the rate of generic approvals and created a backlog of applications which only began to clear in the early 1990s. Generally high drug prices in the U.S. created demand for generic products, so the size of this market steadily expanded. The market also grew in Europe, but its growth was limited by the fragmented nature of the European pharmaceutical industry in general, the absence of a central European authority or a common set of standards and procedures for the certification of generic products, and the fact that European drug price controls kept prices for branded medicines – even those with patent protection – at relatively low levels, indirectly suppressing the market for an alternative product. Over the last 10 years, European generics markets have reached significant size. In the mid-2000s, the generics market began to expand globally as a series of blockbuster drugs lost patent protection in the major Western markets.

As we have already indicated, a large fraction of Indian patent output can be linked to the generic products Indian firms sell in the U.S. market. The owners of the patents for successful drugs have a strong incentive to patent processes and other ancillary aspects of their inventions in order to prolong their period of monopoly rents.<sup>15</sup> So, successful entry into the generics

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<sup>15</sup>This is extensively discussed and convincingly documented by Graham and Higgins

market can require strong process engineering skills and considerable R&D investment. This is even more true for paragraph IV product introductions, where the original patent holders have an incentive to resort to patent infringement litigation. The business press notes that many of the major milestones in the financial growth of leading Indian firms like Ranbaxy and Dr. Reddy's were linked to successes in the U.S. generics market, including successful paragraph IV certifications. Part of the sharp increase in Indian R&D intensity observed in Figure 1 is surely related to the explosion of Indian ANDAs filed in the last 3-4 years.<sup>16</sup>

But while Indian pursuit of the generics market is widely acknowledged today, the initial response of Indian producers to the Hatch-Waxman Act was relatively muted. Why is it that Indian firms appear to have vastly intensified their pursuit of this market after TRIPs? It is plausible that it could have taken some time for the significance of this new market to be realized by all leading firms. The FDA's generics scandal and the resulting backlog of applications also may have played a role. But it is also true that, in the 1980s, the attractiveness of foreign markets was limited by a significantly overvalued currency and a restrictive trade and FDI regime.

That changed sharply with India's fundamental trade and FDI reforms in the early 1990s. These reforms have been extensively described in Panagariya (2005, 2006) and are the subject of a large literature in their own right. For our purposes, it is sufficient to note the following facts. In 1991, India suffered a major balance of payments crisis and was forced to seek financial assistance from the IMF. The IMF required a substantial liberalization of India's trade and FDI regime, which was phased in over the course of the 1990s. The rupee depreciated substantially, losing about two-thirds of its value vis-a-vis the U.S. dollar. This dramatically raised the rupee value of overseas sales. The trade, FDI, and foreign exchange restrictions limiting the ability of Indian firms to access overseas markets were substantially

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(2007).

<sup>16</sup>See Graham and Higgins (2007). We thank Matt Higgins for further discussions on these issues.



reduced by the mid-1990s, allowing Indian firms to purchase marketing organizations and FDA-approved manufacturing facilities that already existed in their major target markets. These liberalizations impacted not only the generics producers but also firms that exported bulk drugs or were willing to engage in contract manufacturing (often on behalf of cost-sensitive generic producers based in more advanced countries). The collapse of the rupee left India-based manufacturers with a strong cost advantage in the major Western markets.

This helps resolve the second dimension of the Grossman-Lai paradox. Domestic patent reform intensified protection, but in a market that was too small to induce much additional R&D spending. The patent policies protected fundamental product innovation in the Western markets did not change, but the fundamental attractiveness of those Western markets for Indian producers did change in the early 1990s, thanks to devaluation and trade/FDI reform. Meanwhile, the generics market – which Indian firms could access even without significant new drug development capability – grew steadily over time, as did the interest of foreign producers in outsourcing drug manufacturing. TRIPs may have supplied a stick, but there was also a carrot, and the carrot came through the confluence of India’s opening to trade and the Western countries opening to generics and related products.

## **5 The Growth of Product Innovation in India: A Role for TRIPs?**

### **5.1 Product Innovation in India: Limited, but Growing**

In the previous section, we have characterized the innovation surge of India’s pharmaceutical industry as having been largely focused on processes rather than new products. As we suggested, that requires a reconsideration of the role played by TRIPs in promoting the large increase in numbers of

R&D dollars (or rupees) and numbers of patents generated since TRIPs ratification. We also that Indian efforts to produce truly new drugs have had limited success to date. But it is also true that Indian firms, including the most financially successful, are making nontrivial investments in new drug development, in spite of the costs and the risks. The aggregate size of these investments is increasing over time. And the Indian industry has seen a more recent wave of new entrants whose business models are much more tied to new drug development – or at least particular phases of the drug development process – than has been the case for the established incumbents. While we want to avoid the mistake of ascribing too much importance to this phenonemon, it still calls for an explanation.

Why are Indian firms increasingly investing in product innovation after TRIPs? Efforts to tie even this relatively small component of India's innovation surge to domestic patent reform in the conventional way founder on two inconvenient facts. First, the Indian market is too small to matter. Second, it is abundantly clear that the product development efforts in India are not principally focused on tropical diseases or India-specific maladies; instead, they are focused on drugs with markets in the Western world. Yet, the timing of this increase in investment and the statements of the investing firms themselves suggest a strong link to patent reform, especially its most recent stages. And we cannot appeal to alternative driving forces, as we did in the previous section. The gap in time between fundamental trade/FDI reform and the growth in product innovation efforts is to great for their to be a plausible strong linke between the two. The evolution of the generics market is even less relevant.

So we have been forced back to the Grossman-Lai paradox. Our efforts to resolve this paradox bring us back to the role of TRIPs as a stick rather than a carrot. This was a point we made in the previous section, but did not develop in terms of a formal model. In this sectoin, we introduce a model of domestic IPR reform as a "stick." To put this in more professorial language, one way to reconcile theory and fact is to consider the possibility that Indian firms were not pulled into innovative activity by the lure of a

newly protected domestic market; rather, they were pushed into innovation by the foreclosure of a domestic haven for imitative activity. This loss of the opportunity for imitation increased the payoff to research. In other words, imitation and research must be strategic substitutes (Milgrom and Roberts, 1990). This strategic substitutability could arise directly from the cost function, due to budget constraints or limited managerial resources. However, we consider another form of substitutability below, arising from demand. We do not intend to provide here a complete theoretical exposition – the following analysis presents a sketch model that illustrates how strategic substitution could arise for a deliberately simplified example.

## 5.2 The Model

Suppose there are two firms:  $h$  and  $f$ , where  $f$  is the foreign firm and  $h$  the home firm. Firm  $h$ 's production options are a function of its investment choices, of which it has four. It can invest in: (a) imitation of good  $x$ ; (b) innovation which leads to a new/differentiated good  $y$ ; (c) both innovation and imitation; or (d) neither innovation nor imitation. Imitation requires a fixed investment  $F_m$  and it is successful with probability  $1 - k$  whereas innovation requires fixed investment  $F_n$  and it succeeds with probability  $\alpha$ . In what follows, we will consider two different proxies for the degree of IPR enforcement: (a) the fixed cost of imitation  $F_m$  and (b) the likelihood that imitation is detected by local authorities and therefore fails, which is captured by the parameter  $k$ .

The timing of decisions is as follows. First firm  $h$  makes its investment decision. Next, firms compete in prices in the product market. Firm  $j$ 's profit in good  $i$  is denoted by  $\pi_i^j(n_x, n_y)$  where  $i = x, y$ ;  $j = h, f$ ; and  $n_i$  denotes the number of competing firms that have the ability to produce good  $i$ . When only firm  $j$  produces good  $i$ , its profit in good  $i$  is written as  $\pi_i^j(1)$  and when it is the sole producer of both goods, its profit over both goods is given by  $\pi_{xy}^j(1)$  where we must have  $\pi_{xy}^j(1) > \pi_i^j(1)$ . We assume that the local firm has a sufficient cost advantage over the foreign firm in producing good  $x$

such that post imitation it can limit price the foreign firm out of the market while charging its optimal monopoly price. This implies that if the home firm invests in imitation its profit equals  $\pi_x^h(2, 0) = \pi_x^h(1, 0)$  whereas if it invests in both imitation and innovation, it becomes a multi-product monopolist and collects  $\pi_x^h(2, 1) + \pi_y^h(2, 1) = \pi_{xy}^h(1)$  in the product market.

Now consider firm  $h$ 's investment decisions. If firm  $h$  invests in neither activity, its profits equal zero. If it invests only in innovation, it collects

$$v_I \equiv \alpha\pi_y^h(1, 1) + (1 - \alpha).0 - F_n = \alpha\pi_y^h(1, 1) - F_n \quad (1)$$

whereas if it invests only in imitation, its payoff equals

$$v_M(k) \equiv (1 - k)\pi_x^h(1, 0) + k.0 - F_m \quad (2)$$

If firm  $h$  invests in both imitation and innovation, its payoff is given by

$$v_{IM}(k) \equiv -F_m - F_n + \alpha(1 - k)[\pi_{xy}^h(1)] + \alpha k\pi_y^h(1, 1) + (1 - k)(1 - \alpha)\pi_x^h(1, 0) + k(1 - \alpha).0 \quad (3)$$

To simplify calculations, suppose  $\alpha = 1$ . Using  $\alpha = 1$ , equations (1) through (3), firm  $h$ 's profit maximizing investment strategy can be illustrated graphically. However, to do so we first need to describe when each investment option is profitable as well as when it is profit maximizing. First note from (1) that innovation is profitable as a stand alone activity iff  $F_n < F_n^* \equiv \pi_y^h(1, 1)$  and that imitation alone is profitable iff  $F_m < F_m^*$  where  $F_m^* \equiv (1 - k)\pi_x^h(1, 0)$ . Finally, investing in both activities is profitable iff

$$v_{IM}(k) > 0 \Leftrightarrow F_m + F_n < \pi_y^h(1, 1) + (1 - k) [\pi_{xy}^h(1) - \pi_y^h(1, 1)] \quad (L_B)$$

In the  $(F_m, F_n)$  space,  $F_m^*$  is a vertical line;  $F_n^*$  a horizontal one; while line  $L_B$  is downward sloping. Note also that the horizontal intercept of line  $L_B$  exceeds  $F_m^*$  because  $k\pi_y^h(1, 1) + (1 - k) [\pi_{xy}^h(1) - \pi_x^h(1, 0)] > 0$ . Similarly, the vertical intercept of line  $L_B$  exceeds  $F_n^*$  because  $(1 - k)[\pi_{xy}^h(1) - \pi_y^h(1, 1)] > 0$ .

Note further that innovation is more profitable than imitation iff

$$v_I > v_M(k) \Leftrightarrow \pi_y^h(1, 1) - F_n - [(1 - k)\pi_x^h(1, 0) - F_m] > 0$$

which is the same as

$$F_n < F_m + \pi_y^h(1, 1) - (1 - k)\pi_x^h(1, 0) \quad (L_{IM})$$

When inequality  $L_{IM}$  binds, it can be plotted as an upward sloping line in the  $(F_m, F_n)$  space with a vertical intercept of  $\pi_y^h(1, 1) - (1 - k)\pi_x^h(1, 0)$  and slope equal to 1. Note that since  $(1 - k)\pi_x^h(1, 0) > 0$ , the vertical intercept of line  $L_{IM}$  is below  $F_n^*$ . Finally, note also that the point  $(F_m^*, F_n^*)$  lies on line  $L_{IM}$ .

Furthermore, investing in both activities dominates investing in imitation alone iff

$$v_{IM}(k) > v_M(k) \Leftrightarrow -F_m - F_n + (1 - k)\pi_{xy}^h(1) + k\pi_y^h(1, 1) > (1 - k)\pi_x^h(1, 0) - F_m$$

which is the same as

$$\begin{aligned} F_n < F'_n &\equiv (1 - k)\pi_{xy}^h(1) + k\pi_y^h(1, 1) - (1 - k)\pi_x^h(1, 0) \quad (L_{BM}) \\ &= k\pi_y^h(1, 1) + (1 - k)[\pi_{xy}^h(1) - \pi_x^h(1, 0)] \end{aligned} \quad (4)$$

Similarly, investing in both activities dominates investing in innovation alone, iff

$$v_{IM}(k) > v_I \Leftrightarrow -F_m - F_n + (1 - k)\pi_{xy}^h(1) + k\pi_y^h(1, 1) > \pi_y^h(1, 1) - F_n$$

which is the same as

$$F_m < F'_m \equiv (1 - k)[\pi_{xy}^h(1) - \pi_y^h(1, 1)] \quad (L_{BI})$$

where  $F'_m < F_m^*$ . It is easy to establish the following: (i) lines  $L_B$  and  $L_{BI}$  intersect at  $(F'_m, F_n^*)$ ; (ii) lines  $L_B$  and  $L_{BM}$  intersect at  $(F_m^*, F'_n)$ ; and (iii)  $L_{IM}$  and  $L_{BI}$  intersect at  $(F'_m, F'_n)$ .

The simple investment model described above can be made more concrete by assuming that the representative consumer's utility is a function of the consumption of the two differentiated goods ( $x$  and  $y$ ) and a numeraire good  $m$  and is given by

$$u(q_x, q_y, m) = a(q_x + q_y) - (q_x^2 + q_y^2) / 2 - sq_xq_y + m, \quad 0 \leq s \leq 1 \quad (5)$$

where  $q_i$  is the total consumption of good  $i$  and  $p_i$  its price,  $i = x, y$ . Utility maximization gives rise to the following demand system

$$p_x = a - q_x - sq_y \quad \text{and} \quad p_y = a - sq_x - q_y \quad (6)$$

The parameter  $s$  represents the degree of substitutability between  $x$  and  $y$ : the goods are perfectly homogeneous if  $s = 1$  and completely differentiated when  $s = 0$ . Note that an increase in the degree of product differentiation (a decline in  $s$ ) shifts the demand curves for *both* firms outward.

If firm  $h$  invests only in imitation, good  $y$  is not invented, and both firms compete in the market for good  $x$ . Due to its cost advantage over the foreign firm, post imitation, the home firm monopolizes the market for  $x$  and chooses  $p_x^h$  to maximize

$$\max_{p_x^h} (a - p_x^h)p_x^h$$

Solving this problem yields

$$p_x^h(1) = a/2 \quad \text{and} \quad \pi_x^h(1, 0) = \frac{a^2}{4}$$

If the home firm invests in only innovation and succeeds, then firms produce differentiated goods: the home firm produces  $y$  and the foreign firm  $x$ . At the product market stage, firm  $j$  chooses its price  $p^j$  to solve

$$\max_{p^j} \frac{p^j(-p^j + a(1-s) + sp^{-j})}{1-s^2}$$

Standard calculations show that the equilibrium price of each firm and the associated profits levels are given by

$$p^j(1, 1) = \frac{a(1-s)}{2-s} \quad \text{and} \quad \pi_i^j(1, 1) = \frac{a^2(1-s)}{(s+1)(2-s)^2}$$

Finally, if the home firm invests in both activities and succeeds, it becomes a multi-product monopolist and solves

$$\max_{p_x^h, p_y^h} \left[ \frac{p_x^h(-p_x^h + a(1-s) + sp_y^h)}{1-s^2} \right] p_x^h + \left[ \frac{p_y^h(-p_y^h + a(1-s) + sp_x^h)}{1-s^2} \right] p_y^h$$

which gives

$$p_x^h(1) = p_y^h(1) = \frac{a}{2}$$

and

$$\pi_x^h(1) = \pi_y^h(1) = \frac{a^2}{4(s+1)} \text{ so that } \pi_{xy}^f(1) = \frac{a^2}{2(s+1)}$$

Given these relationships between the different investment options and the profitability of each option, we are now ready to describe how the strengthening of IPR protection. Suppose first that stronger IPR enforcement makes it more difficult for the home firm to imitate the foreign firm, i.e., the cost of imitation  $F_m$  increases. How does this increase alter the investment choices of the home firm?

### 5.3 Empirical Implications and Discussion

Suppose IPR protection is quite weak initially so that imitation is rather cheap (i.e. we are to the left of line  $L_{BI}$ ). In this region, the home firm always finds it profitable to imitate good  $x$ . Whether or not it also finds innovation profitable depends on the magnitude of  $F_n$ . When  $F_n$  is low (i.e. less than  $F'_n$ ), the home firm undertakes both activities, as indicated by the pair  $(I, M)$  in Figure 4. But if  $F_n$  exceeds  $F'_n$ , it undertakes only imitation to the left of line  $L_{BI}$ , which is indicated by  $M$  in figure 1. Prior to India's patent reforms, imitation of foreign pharmaceuticals was fully legal so that Indian firms did not really face any significant costs of imitation. Furthermore, during the early phase of its development, the industry was somewhat limited in terms of its innovative capacity and likely faced intermediate (or maybe even high) costs of innovation so that it invested only in imitating foreign products. By making imitation illegal and therefore subject to high costs (that would result from being prosecuted for example) Indian IPR reforms had the potential to substantially encourage local innovation by moving local firms from an  $M$  region to an  $I$  region in Figure 4. Note, however, that if local innovative capacity is rather limited (i.e. when  $F_n > F_n^*$ ), a sufficient strengthening of

IPR reform would shut down local imitation (a profitable activity) without leading to any local innovation – i.e. the home firm could move from a region where it invests only in imitation to a region where it invests neither in imitation nor innovation (to the right of  $L_M$  and above  $L_I$ ). Critics of TRIPS would contend – and did contend – that the real world situation is much closer to latter scenario than it is to the former.

Fortunately for many Indian firms, the real world situation did not turn out to be that grim. Some Indian firms have managed to develop the capabilities for production innovation and are investing accordingly. That is the real world phenomenon that may most directly reflect this model. And a model like this could help explain a link between TRIPs and the rising degree of product development in India. In this particular theoretical specification, the strategic substitution between imitation and innovation comes through the demand side. Substitution could also arise through the cost function, due to internal resource constraints. We intend to explore this alternative possibility in ongoing research.

This kind of model may also shed some additional light on the claims of the previous section. In effect, the global market for generics (and the related market for bulks and APIs) represents an intermediate place in the product space between pure innovation and pure imitation. Our existing model lacks such an intermediate step, but the language of the model helps us envision what role such an intermediate step could and possibly did play. The fixed costs of entering this intermediate market declined before TRIPs, because of relaxed regulatory hurdles. The profitability of entering this intermediate space expanded thanks to rupee devaluation and trade/FDI reform that was broadly coincident with TRIPs. And this intermediate market grew substantially just as TRIPs or the prospect of TRIPs was endangering the traditional business model. Indian firms did not all have to progress quickly from pure imitation to drastic innovation. There was an intermediate step to which they could move first.

And this may help explain why indigenous Indian producers have fared better as a group than indigenous producers in other countries where patents



were weak prior to some reform event. Not only did Indian producers have a relatively long transition period, but they were well set up to profitably serve this intermediate market. Countries like Taiwan and South Korea had reasonably advanced domestic engineering capacity, but both countries instituted stronger patents before the generics market had fully emerged, and their post patent reform currency appreciations and wage growth limited their competitiveness as commodity manufacturers.

## **6 Increasing Indo-Foreign R&D Collaboration in Pharmaceuticals: A Role for TRIPs?**

### **6.1 Indo-Foreign R&D Collaboration: Limited, but Growing**

Just as Section 4 downplayed the importance of product innovation, it also downplayed the importance of R&D collaborations between Western and Indian firms in which Indian and Western firms cooperate to develop drugs. At this point in the paper, though, we wish to focus on precisely this phenomenon. A number of commentators in the business press have suggested that few Indian firms will compete directly with the likes of Merck and Pfizer. A larger number of Indian firms will focus their "inventive" activity on tasks that are, broadly speaking, complementary to the strengths of the Western giants. In this view, Indian firms will specialize in particular components of the drug development process that reflect India's comparative advantage – contract research (especially in the labor-intensive parts of the research process), clinical trials, contract manufacturing under license, or outlicensing of promising compounds to Western firms for further development and marketing. Under this hypothesis, a large component of Indian R&D activity will take eventually place explicitly within formal collaborations with Western firms, or it will be undertaken with an eye toward selling what

amounts to an intermediate input to Western firms. In the analysis below, we sketch out a model that illustrates how a strengthening of the local IPR regime could "push" firms out of imitation and into collaboration.

## 6.2 The Model

Innovation in the pharmaceutical industry has a substantial development component that arises from the need to conduct clinical trials etc. Since such development is distinct from basic research and indeed can be carried out in an entirely separate location, it is useful to consider how local IPR enforcement matters when innovation is a two stage process that comprises of basic research ( $R$ ) and drug development ( $D$ ). Of course, such vertical separation creates the possibility that the foreign firm may wish to delegate the development part (i.e. the  $D$ ) of its R&D for a new drug to the local firm so that the innovation activities of the local firm are complementary to the research conducted by the foreign firm. Whether or not such a vertical arrangement of R&D can arise depends upon a variety of factors but the crucial consideration for our purposes is the role played by the local IPR regime. Our basic idea is that whether such a collaborative arrangement is acceptable to the local firm will depend upon the profitability of other options available to it – in particular, on the profitability of pursuing a go-it-alone option under which it imitates the foreign firm's technology and develops the drug on its own.

In most discussions of the pharmaceutical industry, "development" refers to clinical trials and related activities. In our usage, "development" is meant to refer more broadly to various stages of the R&D process in which an Indian firm could possess (or attain) a comparative advantage. The text of the paper has cited numerous examples. It need not be closely connected to clinical trials and, in fact, to date, the development of clinical trials in India has perhaps lagged expectations.

To capture the trade-offs involved, consider the following simple game and restrict attention to the market for the new drug (call it  $y$ ). At the first

stage, the foreign decides whether or not to outsource development of the new drug to the local firm (we assume that the basic research  $R$  for the drug has already been done by the foreign firm and that the investment in such research is sunk). If the local firm agrees to undertake  $D$  on a collaborative basis, it incurs the fixed cost  $\theta F_d$ , where the parameter  $\theta$  measures the degree to which knowledge transfer from the foreign firm lowers the development cost for the local firm. In addition, collaboration eliminates the need for imitation on the part of the local firm since results of the basic research are provided by the foreign firm. As will become clear, this illustrative model is most reasonable when viewed in the context of a drug targeted at the developing country market. We fully acknowledge that most R&D collaborations have tended to focus on drugs with substantial Western markets, and we plan to incorporate in future work theoretical specifications that will be more natural in that setting.

Under collaboration, post drug development, the local firm becomes the sole producer of the drug and the two firms split the total profit: the home firm gets  $v_D(k)$  where  $v_D(k) \equiv \pi_y^h(1)/2 - \theta F_d$ . If, however, the home firm rejects the foreign firm's offer it then has two options: invest in both imitation and drug development (both of which are necessary to bring the drug to market) or invest in neither activity. Since the home firm's cost advantage is assumed to be large enough for it to be able to limit price the foreign firm out of the market while charging its optimal monopoly price, post imitation the foreign firm's payoff equals zero while that of the local firm equals  $v_{MD}(k) \equiv (1 - k)\pi_y^h(1) - F_m - F_d$ . Also, suppose that if IPR enforcement is completely lax (i.e.  $k = 0$ ), the local firm finds imitation and development profitable – i.e.  $v_{MD}(0) > 0$ .

Since imitation drives the foreign firm out of the market, it also leads the foreign firm to *not* develop the drug itself. If, however, the home firm undertakes neither imitation or development, the foreign firm finds it profitable to undertake development and collects  $v_D^f \equiv \pi_y^f(1) - \theta F_d > 0$ .

At the first stage of the game, the foreign firm chooses whether or not to collaborate with the local firm. This choice clearly depends upon whether or

not imitation is profitable. Suppose that it is: i.e.  $v_{MD}(k) > 0$ . Then, the foreign firm prefers to collaborate with the home firm – local imitation and development would occur if it chooses not to collaborate and its profit would then equal zero. By engaging the local firm in a collaborative arrangement, the foreign firm can deter imitation. The issue is whether or not the local firm finds it profitable to undertake drug development under a collaborative arrangement with the foreign firm. The home firm prefers collaboration to going solo iff

$$v_D(k) > v_{MD}(k) \Leftrightarrow \pi_y^h(1)/2 - \theta F_d > (1 - k)\pi_y^h(1) - F_m - F_d$$

which is the same as

$$\frac{\pi_y^h(1)}{2}(2k - 1) + F_m + (1 - \theta)F_d > 0$$

It is clear from above that if  $k \geq 1/2$  (i.e IPR enforcement is strong), then the home firm prefers to undertake drug development under a collaborative arrangement to imitation and development on its own. However, if  $k$  is small enough (i.e. IPR enforcement is sufficiently weak), then the local firm may not be willing to give up imitation and undertake drug development. For example, when  $k \simeq 0$ ,  $\theta \simeq 1$ , and  $F_m \leq F_d$  the above inequality necessarily fails since  $v_{MD}(0) > 0$ . This suggests that prior to IPR reform in India, one reason we did not see much outsourcing of drug development to local Indian firms is because these firms found imitation to be much too lucrative to be willing to enter into partnerships with foreign firms under which they would agree to undertake development and forego the opportunity to imitate. Thus, the binding constraint may not have been that the foreign firms were reluctant to collaborate but rather that the Indian firms were not interested in doing so. By shutting down the profitable imitation channel (i.e. by lowering  $k$ ), the patent reform in India indirectly nudged Indian firms to agree to conduct drug development on a collaborative basis.

When local imitation and development is not profitable, i.e., when  $v_{MD}(k) < 0$ , the foreign firm may still prefer to outsource drug development due to the

local firm's cost advantage and this happens iff

$$\frac{\pi_y^h(1) - F_d}{2} > \pi_y^f(1) - F_d \Leftrightarrow \pi_y^h(1) + F_d > 2\pi_y^f(1)$$

i.e. development costs and/or the home firm's cost advantage is sufficiently large.

### 6.3 The Evidence

Having outlined a theoretical rationale for an impact of IPR reform on collaboration, we can then seek to assess the extent to which this channel of influence is operative in the Indian pharmaceutical industry. The popular press has emphasized this channel quite strongly and, at first glance, it seems to have a certain plausibility. Major Western pharmaceutical companies, including Merck, Eli Lilly, Bristol Myers Squibb, Wyeth, and Pfizer have all entered into well-publicized research collaborations with Indian firms. Relatively new entrants into the Indian pharmaceutical industry, such as Glenmark Pharmaceuticals, have explicitly based an important component of their business strategy on research collaborations with foreign partners. The industry trade press has pointed to a small number of prominent out-licensing deals between Indian and foreign firms that could be a leading indicator of future developments. India's seemingly abundant supply of low-cost scientific and engineering talent would seem to offer exactly the kind of environment in which some degree of R&D outsourcing would make sense.

However, these recent developments need to be placed in appropriate perspective. Using the SDC-Thomson database on strategic alliances, it is possible to track alliance activity between Indian pharmaceutical firms and their foreign counterparts in a fairly comprehensive fashion. Figure 5 provides cumulative counts of these alliances since 1990 and Figure 6 depicts a "flow" measure of these alliances, year by year. Close inspection of the content of these alliances, however, reveals that only a small fraction have involved any meaningful degree of R&D collaboration with Western pharmaceutical or biotechnology firms. Most of these alliances have come in the

most recent years. The number of deals explicitly involving the licensing of technology has been small.

Still, there appears to be a clear trend break in the data that is correlated with the final steps of patent reform. There is something here, and it appears to be growing over time. Alternative data sources on international alliances, such as the MERIT database and Recombinant Capital indicated similar trends to those depicted in the SDC-Thomson data.

Might the outcomes of R&D collaboration emerge in other ways? In principle, Western pharmaceutical firms could be exploiting India's favorable human capital resource endowments by conducting "D" type research in their Indian subsidiaries or through joint ventures in which the patented output is assigned to the Western partner rather than the Indian firm conducting research. However, a careful review of the data do not support these hypotheses. With a few exceptions, multinational firms have neither spent significant sums on R&D in India nor have they generated more than a trivial number of patents assigned to the Indian subsidiary. We also found surprisingly few drug patents developed by inventor teams that include an Indian member and a member in a Western country. This latter finding stands in sharp contrast to observed trends in technical fields related in information technology and related fields. Western IT manufacturers like LSI, Intel, and IBM have set up substantial R&D operations in India which are generating literally hundreds of patents through the efforts of international teams. This trend is depicted in Figure 7, and Figure 8 provides a ranking of foreign firms in terms of the numbers of patents assigned to them which include Indian-based scientists and engineers. In IT, the numbers of patents involved are large enough to substantively affect the trends in India's total U.S. patent count, and the sharp acceleration is clearly visible in the data despite the fact that the patent regimes for IT hardware in India have not changed significantly over the past 15 years and despite the fact that few Indian IT hardware manufacturers have yet acquired much of an international market share or an international reputation. Set against these trends, the numbers of Indian co-invented patents being generated in the pharmaceu-

tical and biotechnology industries appear to be quite small. Still, there is a detectable uptick that is coincident with the most recent stages of patent reform.

## 7 Conclusion

Can a shift to strong intellectual property rights induce higher levels of inventive effort in developing countries? The conventional wisdom in economics has come to regard this proposition with skepticism. Theoretical contributions, most recently that of Grossman and Lai (2005), and a long line of empirical contributions have laid out sound theoretical arguments and empirical evidence suggesting that this is unlikely to be true in general. Qian's (2007) work focuses on pharmaceuticals and suggests especially strong grounds for skepticism there.

The recent experience of the Indian pharmaceutical industry seems to challenge this received wisdom. As documented in ABC (2008), the industry has experienced a profound shift since India ratified the TRIPs Agreement in late 1994. Measures of R&D input and inventive output have grown sharply, in ways that seem to be driven by important developments in India's IPR reform process. The stock market's valuation of R&D investment by firms has grown significantly, at least among the top 50 or so Indian producers. Is the conventional analysis wrong?

Yes and no. Our analysis points to two dimensions along which the conventional analysis may be incomplete. First, if imitation and innovation are strategic substitutes, then a domestic policy change could, in principle, push firms to a greater level of research intensity by foreclosing the imitation option. Second, if R&D collaboration between established producers and potential new entrants is possible, then a domestic policy change could have a similar, related effect, by pushing domestic firms into partnerships that would have not been incentive compatible so long as the imitation option were open. Our empirical analysis provides some evidence for both kinds of

developments in the Indian pharmaceutical industry, and we fully endorse the strong possibility that these two dimensions could become more important over time. Indigenous industry analysts and public statements by industry executives suggest this will be the case.

However, a deeper and more comprehensive examination of the Indian pharmaceutical industry's innovation surge to date points to important causes other than TRIPs and the patent reform process TRIPs ratification triggered. The 1984 Hatch-Waxman Act opened up a market for legal imitations in the world's largest economy. The opening of the Indian economy in the early 1990s reinforced the attractiveness of this external market and similar markets for generics opening up in Western Europe and industrial East Asia, while enhancing the global competitiveness of Indian producers. In a sense, TRIPs provided the stick – the imperative for Indian pharmaceutical firms to seek alternative market opportunities. The generics market (and the related API/bulk drugs market) provided the carrot – a new market opportunity that required some investment to profitably access, but one for which Indian firms arguably had a comparative advantage even in the mid-1990s. India's long transition period to the new regime – a decade of reform – may have also played an important role, providing indigenous firms with continued access to a protected domestic market while they invested in the capability to sell abroad. Over the course of the 1990s and early 2000s, Indian firms were able to upgrade their manufacturing and process R&D capability to the point where they could succeed in a generics market that grew rapidly as a series of blockbuster drugs went off patent. We have presented in this paper substantial evidence linking the largest pieces of the expansion of R&D input and output to process innovations focused on existing drugs rather efforts to develop new drugs or to engage in collaborative R&D with Western pharmaceutical firms. The market's rising valuation of R&D expenditure is largely unrelated to product development.

These considerations suggest important reasons why the Indian drug industry was able to grow and develop even as other indigenous industries in developing countries adopting stronger patent rights were unable to weather



the changes in their markets. To some extent, Indian firms were simply in the right place at the right time. Other developing countries, such as Taiwan, South Korea, and Mexico, were forced to adopt strong patents before the generics market had fully opened up, and they were not given the lengthy transition period India managed to negotiate. Other potential producers, such as Brazil and Argentina, were handicapped by uncompetitive exchange rates and domestic macroeconomic turmoil that undermined their efforts to explore foreign markets.

These considerations also reinforce the difficulties developing countries face in trying to shift from imitation and incremental invention to more substantive product development. These barriers to upgrading may be especially significant in the pharmaceutical industry, but they surely exist to varying degrees across the product space. Is our version of the Indian industrial development story generalizable? Is it true that most developing country industries that have successfully weathered the imposition of strong IPR have done so by identifying an industry submarket in which largely incremental, process-oriented R&D was sufficient to secure a defensible global market position. One wonders if parallels can possibly be drawn between the Indian pharmaceutical industry and the Korean semiconductor industry. Further investigation of this possibility is the focus of ongoing research.

Finally, the indigenous trade press, analysts reports, and the public statements of leading Indian drug CEOs all suggest that the reliance on generics is viewed as a winning strategy in the short run, but not necessarily in the longer run. Rising salaries and an appreciating currency are slowly eroding Indian cost advantages. Producers elsewhere in the developing world are seeking to serve the generics market, increasing competition. Western pharmaceutical companies are increasingly seeking to create their own generics divisions to exploit post-patent market opportunities. Will indigenous drug development or foreign collaboration displace generics as the primary driver of innovative activity in the longer run? We look forward to tracking the ongoing development of this interesting story over the next few years.

## 8 Note on Data Sources

**Patent Data.** U.S. patent data were downloaded from the U.S. PTO website in early July 2008. "Drug" patents were defined as patents in the IPC classes associated with organic chemistry, organic macromolecular compounds, biochemistry (including genetic engineering and fermentation), and medical or veterinary science. Some Indian drug patents were assigned to their U.S. subsidiaries; where possible, care was taken to "re-assign" these to the Indian parent. In some cases, these data were supplemented by the use of the U.S. PTO Cassis CD-ROM (December 2006 version). "Product innovation" patents were defined as those that made explicit references to compounds or compositions in the patent title, and were identified through keyword searches. Patents that listed inventor addresses both inside India and outside its borders were marked as "international coinvention" patents. In some figures, we use counts of patents in this category as an indicator of research collaboration between Indian scientists/engineers and foreign sources of drug development expertise. Data on Indian patents were taken from the EKSAWA database described in Arora et al. (2008) and Chatterjee (2008).

**ANDA Data.** Data on the abbreviated new drug applications (ANDAs) of Indian firms were taken from the on-line FDA Orange Book registry maintained on the FDA website. Patents were matched to ANDAs by undertaking a keyword search of the patent abstract and claims. Patents were linked when explicit reference of the ANDA active ingredient was made in the abstract or claims of the patent.

**Stock Market/Financial Data.** Our primary dataset comes from the Prowess database of the Centre for Monitoring of Indian Economy, which gives a ready-made industry classification of the firms. The Prowess database is similar to Compustat database for U.S. companies providing information that incorporated companies are required to disclose in their annual reports. Our study is conducted on a panel of 315 drugs and pharmaceutical firms (National Industrial Classification 2423) from 1990 to 2005. For these firms, the dataset also provides us annual data from 1990 to 2005, on market

capitalization of the firms at the Bombay Stock Exchange (BSE). This gives us the market value of the common stock of a firm; we also collect data on preferred stock for these firms. To capture the debt component of a firm's market value, we collect data on borrowings and current liabilities; all of this comes from the CMIE dataset. We also collect data on the total assets of firms as a measure of the tangible component in a firm's valuation. Our firm data also includes information on ownership groups, R & D expenditures, exports, sales, profits and age of the firm as measured from their year of incorporation. We validate our firm financial data from annual reports of firms and from the electronic data source, EDIFAR, of the Securities and Exchange Board of India, Government of India. Measures of knowledge assets were constructed using the R & D expenditure reported by firms in their books. We use annual reportage on both the capital and current account of firms and treat the additive combination as the total R & D expenditure of the firms. R&D stocks were created with depreciation rates of 15%.

**Alliance Data.** Data on Indo-Foreign strategic alliances were obtained from the SDC-Thomson Strategic Alliances Database. We restricted our coverage to alliances that involved Indian firms and foreign firms; alliances involving only Indian or only non-Indian firms were deleted. We also deleted alliances that did not focus on pharmaceutical products. Alliances were categorized as being R&D or product development alliances based on the textual description of alliance goals recorded in the SDC database. Trends in these data were cross-checked against those evident in the MERIT database on technology transactions and data on strategic alliances involving Indian pharmaceutical/biotech firms found in the Recombinant Capital database.

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**Table 1 Production of Bulk Drugs and Formulations**

<b>Year</b>	<b>Bulk</b>	<b>Formulations</b>
1974-75	900	4000
1979-80	2260	11500
1984-85	3650	18270
1989-90	6400	34200
1994-95	15180	79350
1999-2000	37770	158600
2003-2004	77790	276920
<i>Source: Ministry of Chemicals and Fertilisers, Government of India Annual Report Various Issues, Chandhuri 2005;</i>		
<i>Figures in Indian Rupees million – at current prices.</i>		

**Table 2 Intellectual Property Laws and Indian Pharmaceuticals**

Year	IPR events in India	Implications
From Pre'72 to Post '72	British Patents and Design Act, 1911 - Patents Act 1970	<ul style="list-style-type: none"> <li>• Pre 1972: A product and process patent regime; Life of drug patents 14 years; One could patent all processes for drug manufacturing.</li> <li>• Post 1972: Product patent regime abolished, patent only a method or a process, Life reduced to 5 – 7 years, for a particular drug only one method or process patentable.</li> </ul>
1994-1995	Signing of the WTO TRIPs treaty by India as a result of the 1986-1994 Uruguay Round of negotiations	<ul style="list-style-type: none"> <li>▪ Dec 31st, 1994: The Patents (Amendment) Ordinance allowing filing and handling of product patent applications for pharmaceutical and agricultural chemical products, as well as the granting of exclusive marketing rights, EMRs on those products. The Ordinance became effective on January 1, 1995.</li> <li>▪ The Patents Amendment Bill 1995 was introduced.</li> </ul>
1996-1997	Transition period	<ul style="list-style-type: none"> <li>• Indian Patent office keeps receiving product patent applications.</li> <li>▪ Meanwhile disputes with US and EU at WTO related to violation of product patents.</li> <li>▪ WTO asks India to complete institutional reform on new IPR laws by April 1999.</li> </ul>
1998 – 2001	India signs and ratifies Paris convention and PCT	<ul style="list-style-type: none"> <li>▪ Indian patent law partially amended in 1999</li> <li>▪ WTO reviews the TRIPs terms and grants an extension to India beyond 2000 but before January 1st 2005 – the new deadline to implement product patents.</li> </ul>
May 2002	Patent Amendment Act Promulgated	<ul style="list-style-type: none"> <li>• Terms of all patents in force on this day including process patents are extended to 20 years from the grant date.</li> </ul>
2002-2003	Period of change, interest groups fight granting of EMRs by IPO, City High Courts put up stay orders.	<ul style="list-style-type: none"> <li>▪ Examples of disputes: Rejection of EMR for GSK's Rosiglitazone and Hoffman La Roche's HIV drug Squinavir, based on patent application having been filed before 1995. Natco Pharma gets a stay order from Chennai High Court on EMR for Novartis's cancer drug Glivec – the Indian generic producers getting a safe cushion against government enforcement.</li> </ul>
Dec 2004 – 1 <sup>st</sup> of Jan' 2005.	Amendments to Patents Act	<ul style="list-style-type: none"> <li>• Product patent regime in place.</li> </ul>
Source: Chaudhuri [2005], Oxford, Analyst Reports, Thomson Scientific, World Wide Web.		



**Table 3 R&D Intensity**

R & D	Year	R & D/Sales (%)
9	1990	0.23
162	1995	1.45
419	2000	1.80
553	2001	2.22
832	2002	2.79
1,059	2003	3.12
1,568	2004	4.19
2,171	2005	8.51

R&D expenditures are given in 10 million INR

**Table 4 Rising Measures of Innovative Output**

Year	US Patent Counts	Indian Patent Counts	ANDAs
1990	6	0	0
1991	0	0	4
1992	2	0	2
1993	2	0	2
1994	2	0	0
1995	7	1	0
1996	4	9	0
1997	18	33	1
1998	34	59	6
1999	31	40	5
2000	38	50	8
2001	42	56	12
2002	44	71	12
2003	50	86	12
2004	62	374	26
2005	35	605	20
2006	45	552	50
2007	63	689	72

Table 5 Period trends in  $\beta$  - in industry subsets and overall sample

	Entire Industry	Only Modern Firms	Analyst Firms	FDA Firms	Other Firms
<b>Pooled OLS</b>					
<i>1990-1994</i>	1.360	0.182	-1.673	-3.830	2.048
	(0.95)	(0.12)	(0.84)	(1.38)	(0.96)
<i>1995-1999</i>	1.990	2.074	2.704	2.681	1.765
	(3.19)**	(2.95)**	(2.62)**	(1.62)	(2.21)*
<i>2000-2005</i>	2.569	3.301	4.567	5.103	1.706
	(6.41)**	(6.94)**	(6.02)**	(5.55)**	(3.58)**
<i>Log of sales</i>	0.010	0.163	0.231	0.158	-0.005
	(0.95)	(9.16)**	(5.68)**	(3.80)**	(0.42)
<i>Industry Q</i>	0.219	0.274	0.239	0.208	0.212
	(4.95)**	(5.50)**	(2.75)**	(2.22)*	(3.93)**
<i>Constant</i>	-0.254	-0.711	-0.932	-0.739	-0.235
	(4.03)**	(8.65)**	(5.12)**	(4.05)**	(3.10)**
<i>P-value of Wald Tests of Equality</i>	0.5047	0.0390	0.0061	0.0041	0.9861
<i>Observations</i>	2686	1330	426	399	2236
<i>Number of Firms</i>	315	143	41	42	268
<i>R Squared</i>	0.11	0.25	0.41	0.37	0.09
<b>Regressions Using Imputed R&amp;D Data</b>					
<i>1990-1994</i>	1.210	0.048	-1.738	-4.822	1.884
	(0.94)	(0.03)	(0.91)	(1.79)	(1.08)
<i>1995-1999</i>	1.764	1.704	1.999	1.351	1.707
	(2.96)**	(2.57)*	(1.95)	(0.88)	(2.26)*
<i>2000-2005</i>	2.249	2.899	3.90	4.634	1.575
	(5.95)**	(6.36)**	(5.33)**	(5.03)**	(3.49)**
<i>Log of sales</i>	0.010	0.165	0.239	0.160	-0.005
	(0.98)	(9.23)**	(5.82)**	(3.80)**	(0.42)
<i>Industry Q</i>	0.218	0.273	0.237	0.215	0.210
	(4.89)**	(5.45)**	(2.69)**	(2.27)*	(3.87)**
<i>Constant</i>	-0.253	-0.715	-0.959	-0.746	-0.233
	(4.01)**	(8.66)**	(5.20)**	(4.05)**	(3.07)**
<i>P-value of Wald Tests of Equality</i>	0.5677	0.0368	0.0087	0.0009	0.9742
<i>Observations</i>	2686	1330	426	399	2236
<i>Number of Firms</i>	315	143	41	42	268
<i>R Squared</i>	0.11	0.25	0.40	0.37	0.09

(T-stats given in parentheses)

**Table 6 Indian Pharmaceutical Product Development, 2005-6**

<b>Output</b>	<b>Outlicensing Products</b>	<b>Preclinical Development</b>	<b>Clinical Trials</b>
Dr. Reddy's	DRF 4158 to NovoNordisk DRF 2725 to NovoNordisk DR 4158 to NovoNordisk DRF 2593 to Rheoscience DRF 1042 to Clin Tech	1	Phase I (1) Phase II (3) Phase III(1)
Glenmark			Phase I (1)
Lupin		1	
Nicholas		1	Phase I (2)
Piramal			Phase II (1)
Panacea		2	
Biotech			
Ranbaxy	RBx 2258 benign prostatic hyperplasia molecule to Scharwz Pharma – later abandoned; RBx 10558 to Pharmaceutical Product Development (CRO)	2	Phase I (1) Phase II (1)
Torrent		1	
Wockhart		2	Phase I (1)

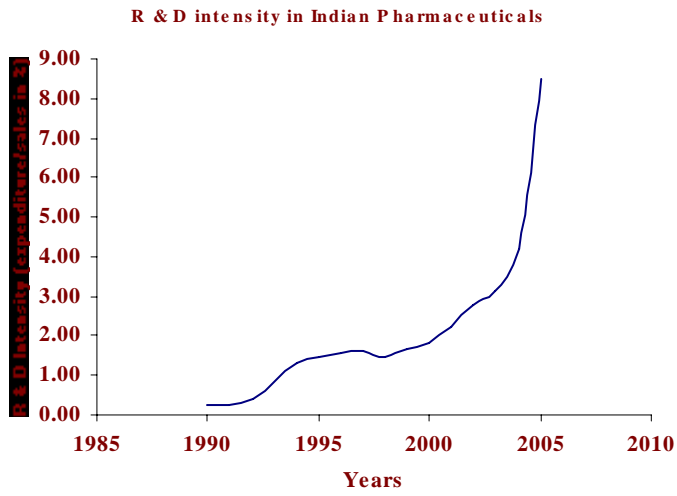
Table lists numbers of products under development, by originating firm, in various stages of the development process. Calculations based on PharmaProjects Data, Company Web Sites, and Athreye et al. (2008)

**Table 7 Market Valuation of Indian Product Innovation**

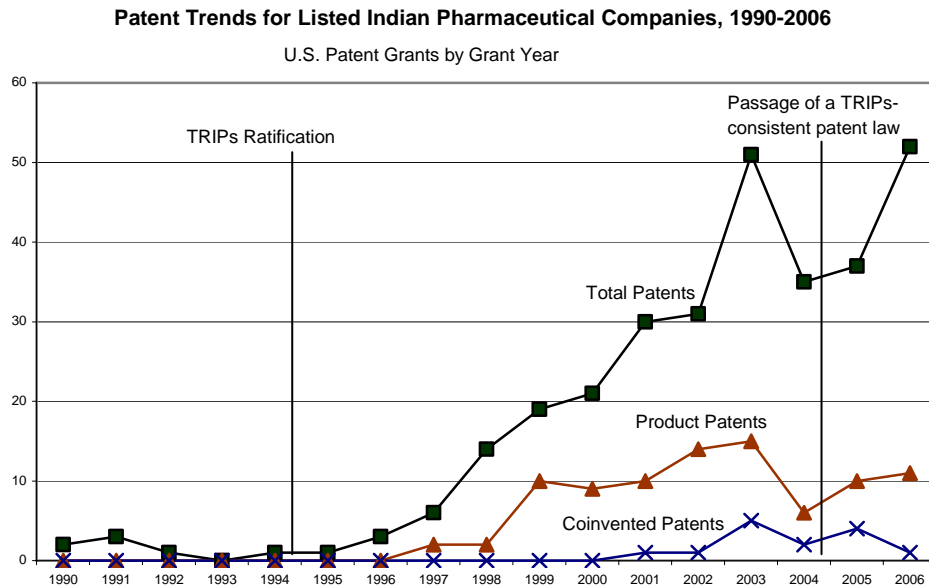
<b>Knowledge Capital Measure</b>	<b>(1)</b>	<b>(2)</b>	<b>(3)</b>	<b>(4)</b>
<b>R&amp;D</b>	<b>1.78</b> <b>(5.38)***</b>		<b>2.14</b> <b>(5.73)***</b>	
<b>U.S. Product Patents</b>		<b>5.12</b> <b>(1.51)</b>	<b>1.43</b> <b>(0.42)</b>	
<b>Indian Patents</b>				<b>-.1531</b> <b>(-0.26)</b>
<b>Sales</b>	.005 (.045)	.011 (1.07)	.010 (.96)	.011 (1.10)
<b>Obs</b>	2,686	2,686	2,686	2,686
<b>R-Squared</b>	.1049	.0980	.1104	.0972

Table presents results of a regression of the market value to assets ratio on the ratio of knowledge capital to tangible assets. Sales, time effects, and firm fixed effects are incorporated in the regression. Patent stocks are cumulated from patent flows, then divided by tangible assets. T-statistics are given in parentheses.

**Figure 1 R&D Intensity in Indian Pharmaceuticals**



**Figure 2 Patent Trends for Listed Indian Pharmaceutical Companies, 1990-2006**



**Figure 3 Cumulative Patent Trends for Listed Indian Pharmaceutical Companies, 1990-2006**

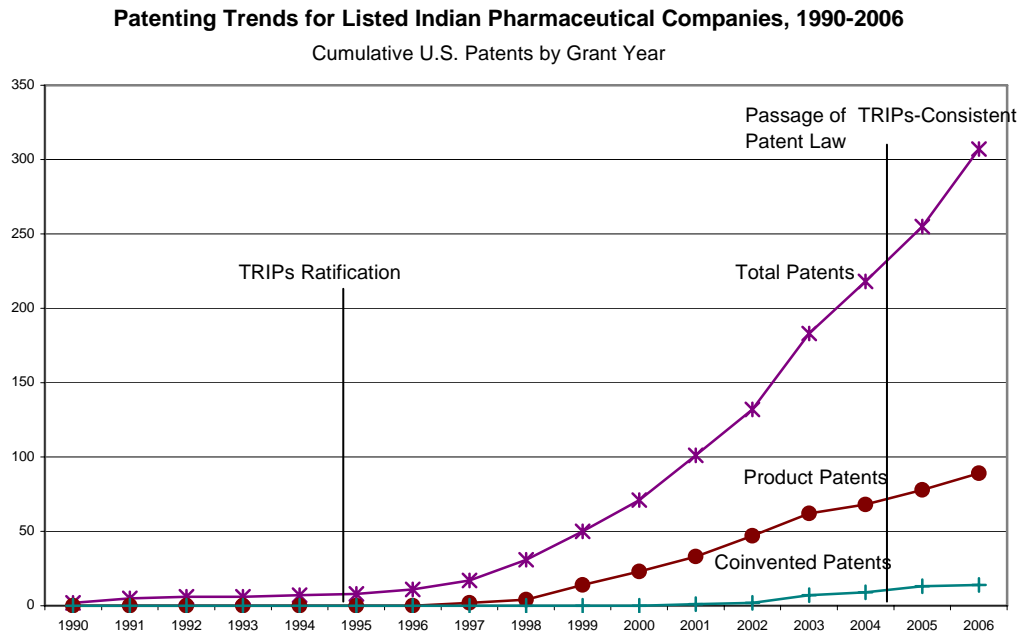
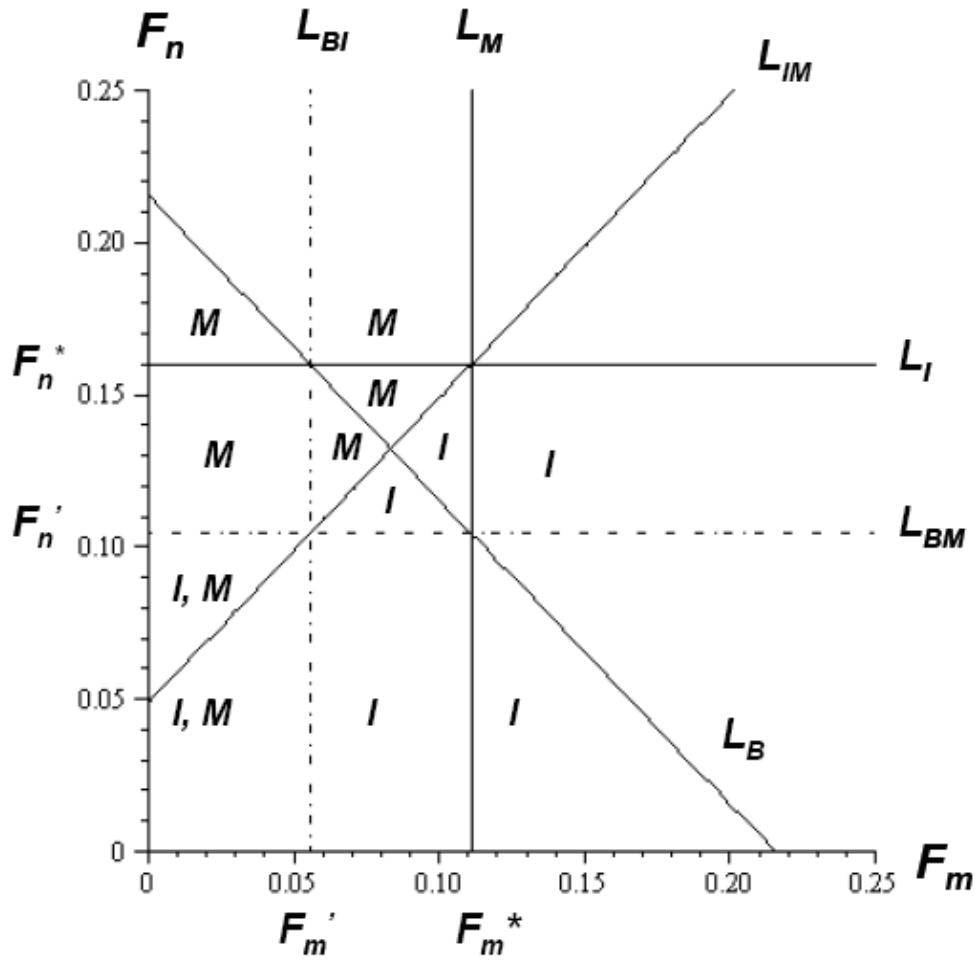
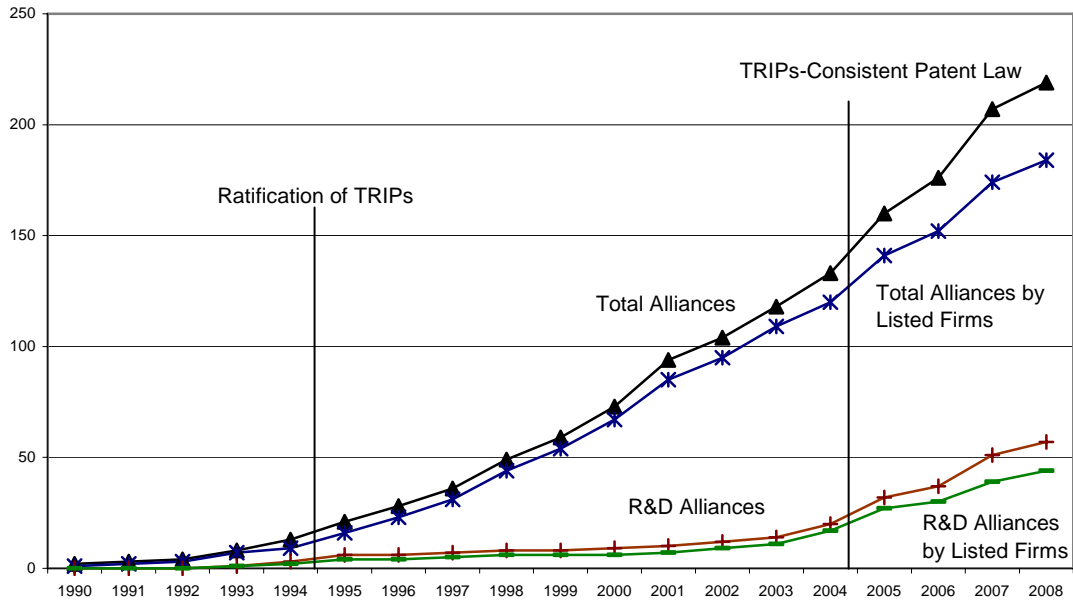


Figure 4 Optimal Investment Choices



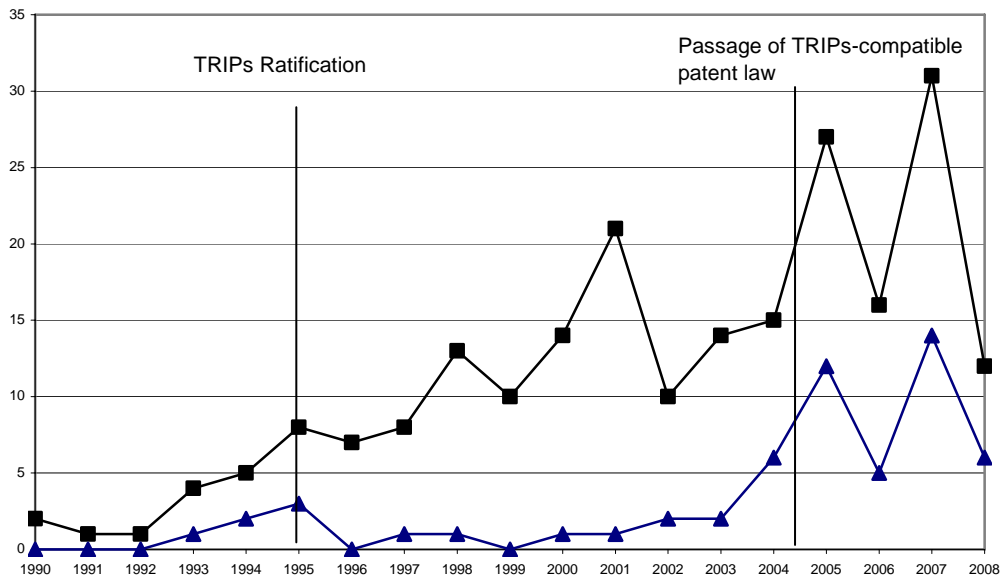
**Figure 5 Cumulative Indo-Foreign Strategic Alliances in Pharmaceuticals**

**Cumulative Alliance Activity by Indian Pharmaceutical Firms, 1990-2008**

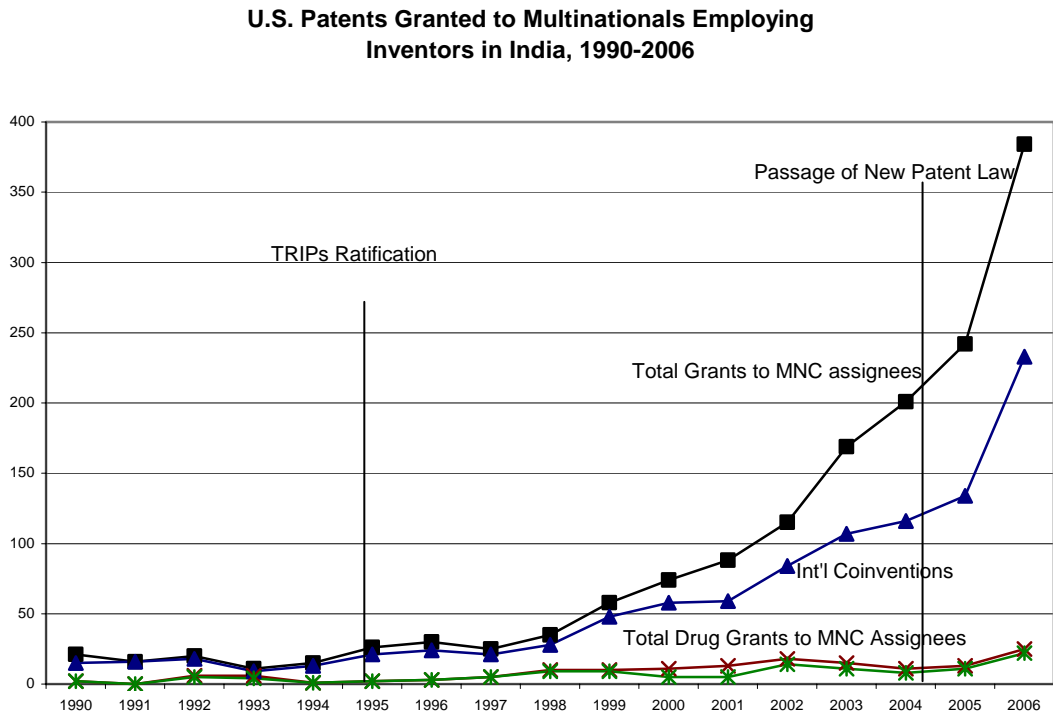


**Figure 6 Indo-Foreign Strategic Alliances in Pharmaceuticals by Year**

**The Strategic Alliances of Indian Pharmaceutical Firms, 1990-2008**



**Figure 7 Multinational Patenting using Indian Inventors**



**Figure 8 Top Foreign Patenting Enterprises in India**

