Rational Investment?
The case study of Gujarat Biotech Parks using patent statistics and publications

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Introduction

Science and Technology Parks (or S&T parks) are an "innovation in public investment" borrowed from the U.S.A. where they first emerged in the University of Stanford in 1951 and evolved to become the famous "silicon valley" phenomenon. During the 1980's they became increasingly popular in Europe as well as developing countries, as a means for the State to support entrepreneurs and innovation creation. S&T parks permit the sharing of scare resources such as quality infrastructure (land, buildings, electricity, water, and communications), provide links to research institutions, give business support, and incubate start-ups, especially from public laboratories. Currently, there are "hundreds possibly even thousands of parks housing technology related activities" in India, according to a report of The Allen Consulting Group (2005). Most of them are supposedly, State sponsored (either by the Central Government or the State Government), though there are parks which have been created by private investors. In any developing country, with resource constraints, it is doubly obviously to ensure the rationality of investment. Most of the existing literature in economics seems to assume that such a condition is always satisfied and go on to focus on two important questions that are pertinent in the post-investment period: how can the performance of an S&T park be evaluated? What are the set of "best practises" that can be replicated? However, it is widely acknowledged that the rates of return from S&T parks in many developing countries are far below the expected mark, which calls for the development of better "indicators" for policy makers to make investment decisions on the location and composition of S&T parks in the first place. With respect to the above problem, the present paper attempts to develop one such tool in the form of indicators based on scientific publications and patents to be used for making investment decisions about S&T parks. It then illustrates them with the case study of investment in S&T parks in the state of Gujarat in India.

The rationality of the spawning of S&T parks in emerging economies is quite clear. Hi-Tech sectors refer to science based industries with well defined niches that require the participation of highly qualified scientists and where the technology embodied in the final product or process is changing rapidly (say between 2 to 6 years) leading to new products, improved quality or a lower cost of production. They include sectors such as pharmaceuticals, crop seeds, microelectronics, new materials, and information and communications technology. These are widely recognized as being crucial thrust areas for employment and revenue generation.

Though no "sufficient conditions" have been identified for the creation of industrial competence in new science based sectors, a set of necessary conditions for any developing country to catch-up in the high-tech sectors seems evident (Jolly and

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Ramani, 1996). First, there has to be an adequate base of skilled scientific labour. This means that the university and public research laboratories have to ensure the supply of a sufficient quantity and quality of scientists, who are up to date in the required scientific fields. Second, there has to be an adequate circulation of resources (information, labour, people and capital) between the research market where public laboratories are most active, the technology markets with both firms and public laboratories and the final product markets formed of manufacturing firms. Third, there must be sufficient incentives for the transformation of research output into product or process innovations. Any costly R&D investment, whose returns are uncertain, will be undertaken only if the expected profit is sufficiently high. Expected profit is determined by a number of technological, firm and market features such as: possibilities for imitation, firm-specific competence, production capacity, market share, market competition, ownership of required and complementary assets, level of entry barriers and macro factors such as government subventions, government regulations, intellectual property rights, functioning of financial markets etc. The sum result of the interaction between these parameters must be so as to result in a high enough expected profit to make R&D investment worthwhile. Fourth, there must be agents in the economy (the government, the public, the firms or the capital markets) who are willing to bear the risk of innovation creation. R&D and targeted innovation efforts are distinguished from other activities such as manufacturing or marketing, in that they are essentially "search" activities whose output is uncertain and which are not amenable to the application of an "efficiency criterion". Therefore, sectors characterized by intense R&D activity will not grow unless there are firms with big pockets or the firms group together to share the risk, or other agents such as venture capitalists, the public, or the government share the risk with innovating firms.

Governments in emerging economies have been able to satisfy the first necessary condition through investment in the creation of qualified personnel through investment in public education and to some extent the last condition through the creation of public venture capital companies, but they are finding it more difficult to satisfy the second and third condition as they require the mobilisation of a variety of agents, changes in the business environment and in market beliefs about the potential for rent appropriation from innovation. In addition, given the paucity of resources to which all emerging economies are subject to, it is even more imperative to maximise the economic returns from existing investment in public research through the creation of institutions and conventions that promote the transfer of knowledge from public laboratories to private firms and aid in its transformation into commercializable technology (Ramani, 2002). S&T parks provide one such convention to promote the satisfaction of the second and third necessary conditions for developing competence in a new science based sector.

How should any country decide where to invest in a science and technology park and who should be permitted to be a member in the Park? There can be many criteria for this choice and many tools according to which such criteria can be measured. In this paper, we do not present the criteria that are necessary or sufficient for a zone to be chosen for investment in a park or for the entry of a firm or a laboratory in such a park. Instead, we explore how data on scientific publications and patents, with all their drawbacks can be used as indicators for investment in Science and Technology Parks. To illustrate our propositions, we draw on a case study of the state of Gujarat in India.

This paper is organized in four sections. The first section, gives an overall description of Science Parks in India with particular focus on the actual investments that have been made in Gujarat. The second section examines how scientific publications and patents can be used as indicators for investment. The third section analyzes the data on scientific publications and patents, with respect to India as a whole as well as the State of Gujarat. The fourth and final section tries to draw inferences for policy and concludes.

Setting the background on India and Gujarat2

Richk, Petkov and Spiro (1999) present the definition of a science and technology (S&T) park that is useful as it clearly identifies its unique features3. According to them, a science park "is a property-based initiative, which has formal and operational links with universities or other higher educational institution, or major centers of research; is designed to encourage the formation and growth of knowledge-based industries or high value-added firms, normally resident on site; and has a steady management team actively engaged in fostering the transfer of technology and business skills to tenant organizations".

S&T parks were introduced in India under the aegis of the STEP program or The "Science and Technology Entrepreneurs Park" program instituted by the government in 1984. Initially there were located in universities and were to aid the development of qualified S&T labour and to integrate them in entrepreneurial industrial development. Today, however, there is a great heterogeneity among the parks; some are just a single building while others are spread over sprawling campuses. Some are very focussed, either on biotechnology or informatics or exports, while others house a variety of tenants. Out of these thousands, only those located in the following cities (or the adjacent suburbs of these cities) have made a mark: New Delhi, Hyderabad, Bangalore, Chennai and Trivandrum. Barring New Delhi, which is the capital of India, all others are located in the cities of the Southern cities, reflecting a southern cluster. Four industrial sectors stand out as having benefited from the S&T parks: soft ware, bio-informatics, Information and communications technology (ICT) and biotechnology (Allen Consulting Group, 2005).

Gujarat emerged as a state of India in 1960 and at that time it was largely an agrarian economy with an insignificant industrial base. Today it is the second most industrialized state (the first being Maharashtra) in India with a per-capita GDP significantly above the national average. This is in part attributed to its cultural heritage. The Gujaratis, as the natives of Gujarat are called, are famed in Indian history, for their entrepreneurial skills. With respect to the whole of India, the state accounts for 11% of industrial production, 8.5% of industrial employment and 9.7% of industrial units. With 4.88% of the country's population, the state contributes to 11% of India's GNP. Being located on the Western coast of India, Gujarat also boasts of the longest coastline (about 1600 kms) in the country, which lends it a rich marine biodiversity.

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[2] The figures on Gujarat cited in this section are drawn from the internet sources given in the references.

[3] According to them this is also the one used by the International Association of Technology Parks.

1.1.1. The pharmaceutical sector of Gujarat

Among the knowledge intensive sectors, Gujarat is best known for its strength in pharmaceuticals though it also has a strong base in chemical, textile, food processing industries. The pharmaceutical firms in Gujarat supply cater to 45% of the total demand in the country. For many years Gujarat has been leading in the pharmaceutical sector. However in recent times, there has been a worry that the industry is on the verge of losing out its premier position to other industrially up-coming states like Karnataka and Andhra Pradesh. The pharma lobby in Gujarat has been quick to point fingers at the unfocussed industrial policies of the successive state governments. The most prominent firms in the pharmaceutical sector are listed below.

1.1.2. The academic-public lab network in Gujarat

Gujarat has 13 universities and 4 agricultural universities (out of which Gujarat Agricultural University is one of the largest in Asia). Among the universities, six offer post-graduate biotech and related courses: M. S. University of Baroda (Vadodara), Sardar Patel University (Vallabh Vidyanagar), Saurastra University (Rajkot), South Gujarat University (Surat), Hemchandracharya North Gujarat University (Patan, North Gujarat) and Gujarat University, Ahmedabad

There are two prominent national laboratories working on biotech related areas.

The CSIR[4]-run Central Salt and Marine Chemicals Research Institute (CSMCRI) in Bhavnagar is the anchor for the biotech research activities in Gujarat[5]. The state is keen to develop expertise in marine biotechnology in a big way with CSMCRI's help. It is discussing with the institute to set up an institute for excellence in marine biotechnology. The Gujarat government has also roped in CSMCRI to initiate environment biotechnology programmes.

The National Dairy Development Board (NDDB), the world's largest dairy development program, based in Anand near Vadodara, is carrying out extensive research and development activities in biotechnology. It aims to develop formulations and technologies useful for improving the productivity of mulch animals.

Interviews with some key faculty at the M. S. University, Baroda as well as with some captains of the pharmaceutical industry revealed that the following problems are being tackled by the public institutions of research (Coronini, Ramani, Venkatesh (2004)).

Low research productivity at the level of the lab: Apart from the M. S. University, other institutions have not made a significant mark in the international research arena. Quality research is largely because of foreign collaborations, where the foreign collaborator provides the funds. To date there has been more hype associated with biotechnology and basic issues such as space and budget allocations have not been

[4] Council of Scientific and Industrial Research.

[5] Its areas of research include salt engineering, marine chemicals desalination of brackish/saline water, marine algae, photo-inorganic chemistry and phyto-salinity

dealt with. There is always a resource crunch and even maintenance budgets are abysmally low.

A teaching curriculum with poles of excellence but without standardization: The biotechnology course syllabus is being constantly revised and kept up to date at the Masters level. In the M. S. University, for instance, starting this year, apart from the regular course, another masters programme has been initiated to meet the needs of industry. However, many institutes have started to offer under-graduate courses in biotechnology, as part of a bandwagon effect, and it is doubtful whether such courses are of any value.

Lack of teachers, lack of good leaders, lack of incentives: Faculty members are in short supply even in reputed institutions like the M. S. University. It has been seen that over the years even filling up of posts where faculty have retired has not happened, leave alone creating new faculty positions. To keep an institution vibrant, it is necessary to ensure that faculty positions are replenished periodically. Quite often academic institutions have poor leadership who do not understand the needs of academia. Archaic rules and regulations also become a constraint in delivering the goods.

Graduates with better practical and communication skills needed: The pharma industry needs pharma graduates and postgraduates with good technical skills (like immunoblotting, protein/genome analysis, western blotting etc), good understanding and reasoning capabilities and good communication skills. Students come armed with theoretical knowledge, but little practical knowledge or awareness of industry and poor communication skills.

1.1.3. Government Initiatives

The State Government had set up the State Biotechnology Mission (GSBTM) in 2003 to facilitate the development of biotechnology in the state. It is under the administrative control of the Department of Science and Technology. This has been created to catalyse the development of the Gujarat Biotech sector through feasibility studies, organization of fairs and exhibitions, organization of seminars and conferences, training etc. The achievements of this mission are not clear at the moment.

In 2004, when we studied the Gujarat biotech landscape, there were a number of promises made on the good things to come[6].

- New R&D centres: to apply industrial biotechnology knowledge into industrial application and commercial products.
- Establishment of an Institute of Bioinformatics in Gujarat.
- Setting up of “The Gujarat Biotechnology Venture Fund (GBVF)”, a 12-year close-ended Venture Capital Fund with an initial proposed fund of Rs. 500 million involving both Government and corporate funding.

[6] Again we are in the process of examining which of these promises came true and to what extent.

- Updated version of the plans for infrastructure development in a document called Blueprint for Infrastructure Development 2020 (BIG 2020).

2. Indicators for investment in S&T Parks

2.1. Compilation of data base

The data on scientific publications was extracted from the database Science Citation Index Expanded™, which is available through the Web of Science®. Two groups of 5 corpuses of information were compiled for the scientific publications. The first five groups were publications stemming from India:

- Exclusively dealing with health and stemming from India as a geographical region[7].
- Exclusively dealing with agriculture and stemming from India as a geographical region[8].
- Exclusively dealing with biotechnology and stemming from India as a geographical region[9].
- Dealing with both biotechnology and health[10].
- Dealing with both biotechnology and Agriculture[11].

From the above corpus of information compiled, we extracted four sub-corpuses of information as related to 5 fields: pure pharmaceuticals, pure agriculture, pure biotechnology, biopharma (pharma and biotech) and agbiotech (agriculture and biotech) as given in figure 1. Then following the same method, we obtained five sets of scientific publications corresponding to the same fields and produced by scientists from Gujarat.

To compile the corpus on patents, two databases available on CD Roms were used, the USPTO (US Patent Office) and EPO (European Patent Office)[12]. The two patent office databases USPTO and EPO yielded two different images of patent depositions from India. In the EPO, India was indentified by the field "PR number" or the priority number of the country with the two letters IN. In order to identify Indian patents in the USPTO, the only indicator was the country of the inventor INCO in which the letters IN implied a patent from India. All patents with at least 1 inventor from India were considered. Then all the common fields of the USPTO and EPO were recorded.

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[7] The research equation used was ((TS=PHARMA* OR TS=DRUG OR TS=DRUGS OR TS=MEDICINE* OR TS=MEDICATION)OR TS=HEALTH) OR (TS=DIAGNOSTIC* AND TS=HEALTH)) AND AD=INDIA.

[8] The research equation used was (TS=AGRO* OR TS=AGRI*) AND AD=INDIA.

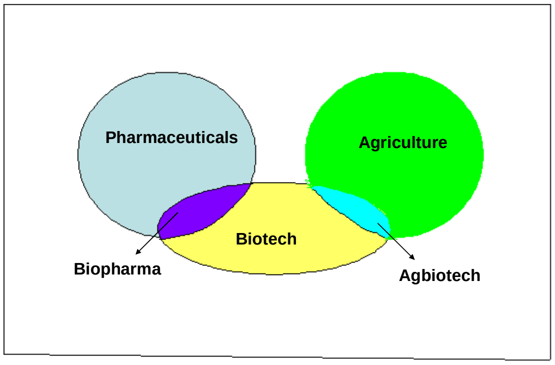
[9] The research equation used was ((TS=BIOTECH* OR TS=BIO-TECH* OR TS=NANOBIOTECH* OR TS=NANO-BIOTECH*) OR (TS=BIOLOG* SAME TS=MOLECU*)) AND AD=INDIA.

[10] Add first and third equations.

[11] Add second and third equations.

[12] (AB = "pharma*" OU AF="pharma*"OU ET="pharma*" OU FT="pharma*" OU AB = "medic*" OU AF="medic*"OU ET="medic*" OU FT="medic*" OU AB = "drug*" OU ET="drug*" OU AB = "bio*" OU AF="bio*"OU ET="bio*" OU FT="bio*" OU AB = "health*" OU AF="sante*"OU ET="health*" OU FT="sante*") AVEC (PR="IN*") ETSAUF NO=*

Figure 1 : The corpus compiled



2.2. Indicators used

DeLooze and Ramani (2002) discuss the uses and misuses of patent statistics as indicators of technological competence. They present a variety of indicators that represent competitive position and comparative advantage of agents (firms, labs, regions, individuals) in a technology. In what follows, we shall be using four of these indicators to analyze investment strategies. We present the four indicators for publications. By replacing patents in the place of publications the same can be derived for patents.

1. Internal Structure of knowledge base

Any agent can invest in creating knowledge in a variety of subjects or technology fields. The internal structure of knowledge base then reveals the ordering of competencies acquired in the different fields, thus giving insight on the priority fields earmarked by the agent.

Relative importance of region or lab j in field k =

$$\left(\frac{\text{number of publications of region/lab j in field k}}{\text{total number of publications of region/lab j in all fields}} \right).100$$

2. Competitive index of region or lab j in field k

Regions compete with each other to create knowledge. The competitive index in a particular field measures the leadership position or the ranking of a region vis-à-vis the country in that particular field.

Competitive index of region or lab j in field k =

$$\left(\frac{\text{number of publications of region/lab j in field k}}{\text{total number of publications of all regions/labs in field k}} \right).100$$

3. Global competitive index of region or lab j

Similarly the Global competitive index is a measure of the over-all differences between agents. It can be regarded as an indicator of the “weight” of the knowledge base. But a best over-all ranking does not necessarily imply a competitive advantage, as an agent which is not ranked well in the overall global competitive index might have a very good position in a particular strategic technology.

Global competitive index of region or lab j =

$$\left(\frac{\text{number of publications of region/lab j in all fields}}{\text{total number of publications of all regions/labs in all fields}}\right).100$$

4. Comparative advantage (CA) of region or lab j in field k

This basically stems from the Ricardian notion that trade is beneficial if the trading countries specialise in their fields of comparative advantage. Areas of comparative advantage refer to fields in which the difference in the efficiency of production of the agent concerned vis-à-vis the other agent or agents is the maximum. This gives an indicator for short-term investment, exhorting regions to invest and develop maximum efficiency in areas of their comparative advantage. On the other hand, many studies have pointed out that blind application of this principle is risky in the long run because of over-concentration of investment on a few sectors or regions that are already the best in an ever-changing environment. Therefore, for long term even development it is also necessary to invest in areas of comparative disadvantage in the long run.

Comparative advantage of region or lab j in field k =

$$\left(\frac{\text{competitive index of region/lab j in field k}}{\text{competitive index of region/lab in all fields}}\right)$$

The comparative advantage index is adapted from the Revealed Technology Advantage Index (RTA index) constructed by Pavitt and Patel, (1988). A country is said to have a CA in a field if its CA index is greater than 1 in that field, otherwise not. The intuition is clear, according to the above formula, the denominator indicates the average competitive position of a region. If in any particular sector, the competitive position of the region is higher than on average then it has a comparative advantage in the area. The CA index specifies the areas of nation-specific advantage, in which a country is encouraged to invest more in the short run.

3. Applications to India and Gujarat

3.1 Publications: India, Gujarat and the rest of the world

Let us first start with an evolution of the scientific publications in the five fields under consideration: pure pharma, pure agriculture, biotechnology, biopharma and agbiotech. The evolution of publications in the world and in India are represented in the following two tables. It is to be noted that for the year 2004 the data is not complete. In what follows, the category “agro” refers to publications that are related to agriculture but without any biotech component and similarly for “pharma”. The "agbiotech" and "biopharma" fields then represent the integration of biotech in the corresponding fields. The "biotech" category gives the number of publications related to biotechnology that are unrelated to pharmaceuticals or agriculture. It could be pure biotechnology or applications to other industrial sectors. The total number of publications in each category was considered as the world production. Then the number of publications from India were identified and these figures were subtracted from the world production to compare production from India vis-à-vis the rest of the world

Table 1
Evolution of publications from India

	Agro	Pharma	Biotech	Agbio	Biopharma
1994	140	415	29	1	2
1995	149	484	28	3	9
1996	154	519	39	4	5
1997	140	550	40	3	4
1998	188	678	46	4	9
1999	201	735	42	8	12
2000	225	755	51	12	16
2001	251	912	39	14	19
2002	254	1102	55	9	19
2003	320	1314	65	8	25
2004	241	1101	46	7	18
Total	**2263**	**8565**	**480**	**73**	**138**
Average rate of growth	**10,29**	**13,90**	**11,31**	**40,17**	**58,62**

The above table clearly indicates that the mass of Indian science production is concentrated in pharmaceuticals. Furthermore, a computation of the average rate of growth[13] reveals that knowledge related to biopharmaceuticals is growing the fastest, followed by agbiotech, indicating that these are the "thrust areas" of growth in scientific knowledge India.

[13] First the average rate of growth per year was computed for the 9 years: 1995-2003. The year 2004 was not considered since data is incomplete. Then an average was computed over these 9 figures for rates of growth.

Table 2
Evolution of publications in the rest of the world

		Agro	Pharma	Biotech	Agbiotech	Biopharma
	1994	3693,00	43613,00	1928,00	73,00	336,00
	1995	3877,00	46613,00	2342,00	60,00	373,00
	1996	4077,00	50591,00	2525,00	86,00	451,00
	1997	4385,00	54132,00	2613,00	101,00	481,00
	1998	4697,00	59429,00	2822,00	106,00	521,00
	1999	4864,00	62262,00	3024,00	114,00	525,00
	2000	5265,00	63587,00	3065,00	145,00	634,00
	2001	5229,00	66616,00	3173,00	151,00	626,00
	2002	5732,00	69081,00	3135,00	134,00	699,00
	2003	6792,00	80942,00	3480,00	168,00	821,00
	2004	4957,00	62616,00	2616,00	116,00	610,00
Total		**53568,00**	**659482,00**	**30723,00**	**1254,00**	**6077,00**
Average rate of growth		**7,12**	**7,19**	**6,96**	**11,21**	**10,70**

Comparing India, with the rest of the world, we can see that they share a number of common features. The common feature is that the mass of publications both worldwide and from India are concentrated in pharmaceuticals. In both regions, the number of publications in pharmaceuticals is almost or greater than four times that in agriculture and more than ten times that in biotechnology. However, the difference in the growth rates of the biotech segments and the pure agriculture and pure pharma segments are much less at the world level. Finally, it is interesting that the rate of growth of science in all biotech realted fields in India, is greater than the rest of the world average, which means that there is a possibility to achieve a leadership position in the same.

As far as Gujarat is concerned, in the SCI database, there are 6553 publications in all fields emanating from Gujarat. Out of this 238 are in pure pharma, 79 in pure agro, 11 articles in biotech (not related to agriculture or pharmaceuticals) and 1 in agbiotech and 1 in biopharma.

Applying the simple indicators given earlier to the above data we can derive the following result.

Result 1:

- *To maximize returns from science production, in the short run, India should invest in agbiotech, pure agriculture and biotechnology (in decreasing order), and to ensure high returns in the long run it should invest in pure pharma.*

- *To maximize returns from science production, in the short run, Gujarat should invest in pure agriculture. To ensure high returns in the long run, Gujarat should invest in pharmaceuticals, biotechnology, agbiotech and biopharma (in decreasing order).*

These results can be easily derived by constructing a portrait of India's investment and Gujarat's investment as follows.

Table 3
India's position in scientific publications vis-à-vis the rest of the world

	Internal structure (world)	Internal structure (India)	Competitive position % of India in world	Comparative advantage
Agro	7,13	19,65	4,22	2,75
Pharma	87,80	74,36	1,30	0,85
Biotech	4,09	4,17	1,56	1,02
Agbiotech	0,17	0,63	5,82	3,80
Biopharma	0,81	1,20	2,27	1,48

From the above table we are able to arrive. It is following the trend by investing the maximum in pharmaceuticals. However the rest of the world is also very hard at work producing knowledge that can be applied to the pharmaceuticals sector. **Thus, we can identify an investment paradox in that even while India exhibits a comparative disadvantage with respect to the rest of the world in pharmaceuticals, this is where its investment is concentrated.** Since the entire world is focussing on pharmaceuticals, the stakes are evidently higher in this field. Therefore, investing in pharmaceuticals makes sense in the long run. However, the discrepancy between science production in agriculture and pharmaceuticals cannot be justified. More investment in agriculture is needed in keeping with India's comparative advantage profile.

Using the information on publications issuing from Gujarat and India, we have the following structure for Gujarat vis-à-vis India.

	Internal structure of India	Internal structure of Gujarat	Competitive position % of Gujarat in India	Comparative advantage of Gujarat with rest of India
Agro	19,65	23,94	3,49	1,22
Pharma	74,36	72,12	2,78	0,97
Biotech	4,17	3,33	2,29	0,80
Agbiotech	0,63	0,30	1,37	0,48
Biopharma	1,20	0,30	0,72	0,25

Again any investment in biotechnology goes against the recommendations of Ricardian theory as in all applications of biotechnology, Gujarat is at a distinct comparative disadvantage vis-à-vis the rest of the world. Again, if we take a long term view, then investment in biotechnology makes sense as a means of bridging the "comparative advantage gap" between Gujarat and the rest of India. In this case, any investment must give priority to agbiotech rather than biopharma.

3.2 Leadership position of regions

In order to identify targets for the location of science parks in biotech, we studied the institutional affiliations of publications in the corpuses of scientific publications related to agriculture, pharmaceuticals, biotechnology. We did not distinguish between agbiotech and biopharma at this level since in any institution publishing on a multidisciplinary field is deemed to have knowledge in both.

An examination revealed that there are 6 clusters of regions active in the creation of knowledge in biotechnology. They are **New Delhi** (with 12 leader labs), **Bangalore** (with 7 leader labs), **Chandigarh** (with 6 leader labs), **Hyderabd** (with 6 leader labs), **Pune** (with 6 leader labs), and **Chennai** (with 5 leader labs); clearly indicating at the all-India level, Gujarat is not among the leaders in biotechnology science production) (Coronini, Ramani and Venkatesh (2004)). However, if investment is to be undertaken in the creation of biotech parks, then an analysis of publications issuing from Gujarat would propose the following.

Result 2: To maximize returns from science production in the fields of pharmaceuticals, agriculture and biotechnology, the "Science Parks" in Gujarat:

- *Ahmedabad and/or Baroda should be first choice to maximize short run returns; Anand and/or Vidyanagar should be second choice to maximize long run returns.*

- *Ahmedabad should be the first choice for any science park to promote pharmaceuticals and biopharma and it should include firms .*

- *Ahmedabad should be the first choice for any science park to promote agbiotech along with agriculture and it should include firms.*

- *Anand should be the first choice for any science park to promote pure agriculture and it should collaborate with Baroda .*

These results are self-evident from the following table.

Table 3
Number of laboratories in regions of Gujarat which have publications in agriculture, pharmaceuticals and biotechnology

	Agriculture	**Pharmaceuticals**	**Biotechnology**	**Total**
Ahmedabad	10*	31**	3 F	44
Anand	7*	3**	0	10
Baroda or Vadodara	3 F	14***	3 F	20
Bhavnagar	0	2	2	4
Rajkot	1	2*	1	4
Vidyanagar	2*	3	1	6

**Agriculture: laboratories with authors who have more than 3 publications in agriculture*

**Pharmaceuticals: laboratories with authors who have more than 5 publications in pharmaceuticals.*

F indicates that a firm is among the science producers in the region.

Table 3 presents the cities which have public laboratories or private firms which are among the science producers in biotechnology or are among the top three regions in agriculture or pharmaceuticals science production. Clearly Ahmedabad and Baroda(now Vadodara) should be the candidate regions for any science park.

In terms of number of labs involved in the publications on agriculture, the maximum number of laboratories involved is from Ahmedabad (10 labs), and then Anand (7 labs). The scientists have a good network of Indian collaborators (28 joint publications) as well as with researchers from foreign institutes (24 joint publications). We find one non-public organization active in science production in Baroda, BAIF.

A lot more is going on in pharmaceuticals as compared to the other fields. There are 70 organizations that have been active in publications; with the two biggest regional clusters being Ahmedabad (with 31 organizations) and Baroda (with 13 organizations. Other cities have less than 5 organizations that are active in biotech science production. **For the first time, we find a number of firms among the producers of science. There are 16 firms that are active in production of science related to pharmaceuticals.** There are 10 hospitals that are also active. There is a good network of collaborations with Indian partners (84 collaborations) and a good network of collaborations with foreign partners (74 collaborations).

In terms of the number of institutes active in creating knowledge in biotechnology, Baroda leads with 4 laboratories, followed by Bhavnagar and Ahmedabad with 2 laboratories each. One firm is also present among the leading authors, namely Sun Pharma Advanced Research Centre.

When we search for “cluster effects” or “synergy or spillover effects” due to the presence of star scientists, we are not able to detect any. Even in pharmaceuticals, where the weight of the publications is concentrated no positive “cluster” effect seems evident. For example publications from Ahmedabad do not dominate inspite of its weight in terms of number of organizations active in the production of science. It is Baroda which has a higher number of star scientists.

A limitation of the above analysis is that with the available information it is not possible to rank the performance of these labs as science producers.

3.3 Patent Analysis

An examination of the patents issuing from Gujarat lent itself to the following evident conclusions.

Result 3: Analysis of patents issuing from Gujarat indicates that:

- *Transformation of science into new technology is greatest in pharmaceuticals; it is absent in agriculture and biotechnology (in terms of patents).*

- *While firms are active in science production there is no university laboratory that is active in new technology creation.*
- *Any ambitious science park should try to include a unit for one or more of the following firms: Torrent Pharmaceuticals, Cadila, Cipla and Sun Pharmaceuticals, as well as public labs.*

There were no patents issuing from Gujarat corresponding to agriculture or biotechnology.

In the field of pharmaceuticals, among the leading patentees from India listed in the USPTO as having more than 2 patents to their credit, we find the firms: Torrent Pharmaceuticals, Sun Pharmaceutical Industries Limited, Cadila Healthcare limited, Cadila pharmaceuticals ltd (Table A1 of Appendix). In the EPO database, among the leading patentees with more than 2 patent applications we again find Sun Pharmaceutical industries limited, Cadila healthcare limited, Cipla ltd, Cadila Pharmaceuticals ltd and Sun Pharmaceutical Industries ltd. (Table A2 of Appendix).

There are many patents from the public lab CSIR (Council for Scientific and Industrial Research) which has branches all over India including Gujarat. Since all patents are taken under the name of the CSIR without mention of which of the CSIR labs in India is responsible for the patent, it is not possible to gauge whether a CSIR lab in Gujarat has a patent.

Thus, as the following table indicates, though we find firms being among the science producers along with universities and public labs, we do not find any university labs features as new technology producers.

Table 4
Leading Pharmaceutical firms in Gujarat

Name of the Company	Publications	Patents	Business Focus	R&D
Torrent Pharmaceuticals, Ahmedabad	Yes	Yes	Neuropsychiatry and cardiovascular drugs	5.8% of revenue in R&D; half of it utilized for discovery
Span Diagnostics, Surat	No	No	Clinical laboratory reagents and diagnostic products with license from USFDA	Technical tie-ups with PATH –USA and Nihon Kohden Corporation, Japan.
Cadila Pharmaceuticals, Ahmedabad	Yes	Yes	Drug formulations, generic medicines, biotech products, veterinary formulations, oncocare, antituberculosis, and cardiovascular products.	Collaborative research with IISc, Bangalore; ICGEB, CBT, NII, Delhi Research facilities at Dholka, Ankaleswar and Bangalore
Cipla, Ahmedabad	No	Yes	Anti-AIDS drugs, animal healthcare, generic medicines	Research in targeted therapy for autoimmune diseases
Zydus Cadila,	Yes	No	Pharmaceuticals,	NMEs for clinical

Ahmedabad			diagnostics, herbal products, skin care products and OTC products.	evaluation, drug delivery systems, therapeutic targets, therapeutic proteins and vaccines by r-DNA
Sun Pharmaceuticals Research Centre, Baroda	Yes	Yes	Speciality medicines for cardiology, psychiatry, neurology, gastroenterology.	4% of turnover committed to R&D
Maps India, Ahmedabad	No	No	Largest producer of industrial enzymes in India	Identifying new microorganisms to isolate enzymes for novel applications.
Gujarat Life Sciences, Baroda	No	No	Agricultural, Environment Biotechnology, Biofertilizers, Biocomposting, Effluent Treatment using Bio-Towers Technology	NA
Indus Biotheraputics, Ahmedabad (a subsidiary of Intas Pharmaceuticals)	No	No	Neukine (rHu G-CSF) and Generic recombinant biopharmaceutical products	Invested $10 million; focus on recombinant products
Claris Life Sciences, Ahmedabad	No	No	Anaesthesia, Nutrition & Blood and Plasma products.	R&D focused on new drug delivery systems
Makson Pharma, Surendranagar	No	No	Contract manufacturing for companies such as Boots Piramal, Nestle and Dabur	N A
Intas Labs, Ahmedabad	No	No	Biologicals, contract research and recombinant products	Invested $10 million in biotech ventures
Alembic Ltd., Baroda	No	No	Pharmaceuticals	Fermentation, Formulation, Process development and drug delivery systems
Sarabhai-Piramal Pharmaceuticals, Baroda	No	No	Pharmaceuticals	Basic, genomic, clinical research

Source : Coronini, Ramani, Venkatesh (2004) Report on: “The Biotech Industry and its Development: What can Gujarat target?”

There is however a fairly good record to technology transfer from public labs to private firms (see table A3 in Appendix). So there seems to an institutional division of labour in this field with:

- Universities being the primary producers of skilled labour that can be absorbed in public laboratories or private firms, and to a lesser extent new knowledge, without producing new technology;
- Public labs conducting contract research for private firms and publishing rather than creating new technology or new firms.
- Firms, especially the leaders, developing in-house R&D capacity so as to keep a foot in the scientific world through publications while creating new technology.

The above implies that any science park in Gujarat must include both public labs and private firms as tenants because the division of labour is so engrained that to be innovation labs, there must be more collaboration between the two.

4. Discussion of Results

4.1. Gujarat's plans for biotech parks

A fact that is even more interesting than the spawning of S&T parks in India is that nobody really seems to know what is going on. Even the Allen Consulting Group (2005) confesses in its preface, "Plans for new parks are the subject of daily media announcements. Separating out what is actually being achieved from the numerous proposals has been a challenge." We found no scientific articles on India or Gujarat on this subject but an internet search yielded four major announcements that had been made in Gujrat between 2003 and 2006.

(i) A biotech park "Gujarat Biotech Park at Vadodara (GBTP)" is being developed by the Gujarat Industrial Development Corporation (GIDC). GBTP is touted to be a hi-tech expandable project involving Rs. 540 million initial investments and spread over 40 hectares land area. Preliminary infrastructure & technical facilities are already in place[14].

(ii) Pharmaceutical Techno Park, a cluster development programme, in cooperation with UNIDO and the Quality Circle Networking for mutual quality upgrading is planned to be set up at Changodar near Ahmedabad[15].

(iii)A private company has also invested in the creation of a Biotech Park[16]. The Ahmedabad based company Ganesh Housing Corporation Ltd., an ISO 9001-2000 has acquired a 32-acre land at Changodar near Ahmedabad on the Sarkhej–Bavla highway considered as the pharma corridor of Gujarat. It has proposed to develop an International Pharma & Biotech Park (IPBP). This corridor already houses pharmaceutical companies like Intas Labs, Claris Life Sciences, Zydus Cadila and Makson Pharma. An investment of about Rs. 150 million is reportedly being pumped into this project and the park is expected to house approximately 50 SME's (small and medium entrepreneurs).

[14] http://www.thehindubusinessline.com/2005/02/11/stories/2005021101931700.htm
[15] http://www.pharmabiz.com/redfr.asp?fn=/specials/PharIndInGuj/PharIndInGuj13.asp
[16] http://www.pharmabiz.com/article/detnews.asp?articleid=19004&sectionid=50

Companies from outside of the State are also being invited to be tenants of the park.

(iv) Plans for a Marine Biotech Park at Bhavnagar have also been revealed[17].

Comparing the investment targets with the results of the preceding analysis, we can infer the following conclusion.

- *Result 4: Investment targets for biotech parks in Gujarat diverge in some cases from those that can be inferred from an analysis of scientific publications and patent statistics.*

As may be recalled Ahmedabad and Baroda or Vadodara are the leaders in the fields of biotech and its applications. Therefore, it is assuring that the two big park investments are in Vadodara and Ahmedabad. However as table 5 summarizes, the comparative advantage of Gujarat lies in agriculture and Anand should be the first choice for any science park to promote pure agriculture. However, this is not present.

There is also a danger of unnecessary competition between parks as two semi-private parks seek to place themselves in the same zone near Ahmedabad.

A marine biotech lab has been announced in Bhavnagar, which already has two labs that have published in biotechnology journals, but it is not clear if this is the best choice for Gujarat to invest.

Finally, there seems to be no search for appropriate public-private partnerships by housing strategic units of public laboratories as tenants with private firms.

Table 5
A comparison of Investment targets and conclusions of analysis

Announced Targets	Inferences from analysis
There are no parks targeting agbiotech	*Gujarat has a comparative advantage in agriculture*
Marine Biotech Park at Bhavnagar	*Though Bhavnagar has 2 biotech labs it is not among the leaders.*
Gujarat Biotech Park at Vadodara	*Good choice; Vadodara or Baroda among leaders in biotech and its applications. What about composition?*
Pharmaceutical Techno Park and Biotech Park at Changodar near Ahmedabad	*Ahmedabad is among the leaders in pharmaceuticals but there are no public labs in Park.*

[17] http://www.thehindubusinessline.com/2004/09/11/stories/2004091101771700.htm

5. Conclusion

With the development of the information technology sectors and the biotechnology sectors, from the late 1980's developing countries like India are spawning a high number of science and technology parks. However, there seems to have been little enquiry as to the rationality of such investment. In the international economics and management literature, we could not find a single article devoted to the study of the evolution of S&T parks in India, marking this subject as an important area for research.

In this article, we propose the use of patent application statistics and information on scientific publications as a tool for deciding where to invest in a science park and who the tenants ought to be.

Using the tools proposed, we are able to recommend for Gujarat that :

- There should be greater investment in science production related to agriculture as compared to pharmaceuticals in keeping with India's and Gujarat's comparative advantage profile.
- There has to a greater generation of "cluster effects" or "spillover effect" in science production, perhaps through creating poles of excellence with star scientists.
- Though Ahmedabad and Baroda are obvious choices for technoparks, they should be no duplication of efforts through focussing on the same sector namely pharmaceuticals.
- Composition of tenants in a park has to be decided according to potential for synergy creation.
- A science or technology park should focus on agriculture and agbiotech and a natural candidate region for this is Anand.

Finally, our results are of course subject to the limitations of using patent application statistics and information on scientific publications. First, patent applications do not capture all of innovative activity and in a developing country like India and in sectors like agriculture, it may quite well miss out on the major innovation achievements. Second, Indian labs might have good access to international journals, so that the knowledge most specific, and perhaps useful to India is published in Indian journals, which are not referenced in international databases. In this case, exploitation of international databases may overlook local scientific production. Third, spatial investments like science and technology parks are also motivated by reasons other than the presence of scientific or technological competence. They might be the result of a private or governmental vision, or local specificities like a coast line.

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Appendix

Table A1
Assignees with more than 2 patent applications in the USPTO in pharmaceuticals (1995-2004)

number.	Assignee
146	COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH
30	DR. REDDY'S RESEARCH FOUNDATION
29	HOECHST AKTIENGESELLSCHAFT
21	RANBAXY LABORATORIES LIMITED
19	DR. REDDY'S LABORATORIES LTD.
15	WOCKHARDT LIMITED
15	DABUR RESEARCH FOUNDATION
14	TORRENT PHARMACEUTICALS LTD.
14	PANACEA BIOTEC LIMITED
8	NATIONAL INSTITUTE OF IMMUNOLOGY
7	BOSTON UNIVERSITY
6	SUN PHARMACEUTICAL INDUSTRIES LIMITED
6	NATREON INC.
5	MILLENNIUM PHARMACEUTICALS, INC.
5	ORCHID CHEMICALS & PHARMACEUTICALS LIMITED
5	DR. REDDY'S RESEARCH FOUNDATION & REDDY?CHEMINOR INC.
5	LIPOSOME COMPANY, INC.
4	KOPRAN RESEARCH LABORATORIES LIMITED
4	RELIANCE LIFE SCIENCES PRIVATE LIMITED
4	CIBA?GEIGY CORPORATION
4	J. B. CHEMICALS & PHARMACEUTICALS LIMITED
3	AVENTIS PHARMA DEUTSCHLAND GMBH
3	UNITED STATES OF AMERICA, HEALTH & HUMAN SERVICES
3	SABINSA CORPORATION
3	BIOCON INDIA LIMITED
3	REDDY CHEMINOR INC.
3	USV LIMITED
3	GENZYME CORPORATION
3	IOWA INDIA INVESTMENTS COMPANY LIMITED
3	CADILA HEALTHCARE LIMITED
2	LUPIN LABORATORIES LIMITED
2	UNIVERSITY OF CINCINNATI
2	KANCOR FLAVOURS AND EXTRACTS LIMITED
2	HEALTH RESEARCH, INCORPORATED
2	AKTIEBOLAGET ASTRA

number.	Assignee
2	BIOPULPING INTERNATIONAL, INC.
2	ORCHID HEALTH CARE
2	UNIVERSITY OF CALIFORNIA, THE REGENTS OF
2	DR. REDDY'S RESEARCH FOUNDATION AND REDDY?CHEMINOR, INC.
2	U & I PHARMACEUTICALS LTD.
2	TSAR HEALTH PRIVATE LTD.
2	CADILA PHARMACEUTICALS, LTD.
2	STRIDES INC.
2	SAHAJANAD BIOTECH PRIVATE LIMITED
2	CORNELL RESEARCH FOUNDATION INC.
2	UNIVERSITY OF FLORIDA BOARD OF REGENTS
2	RUSH?PRESBYTERIAN?ST. LUKE'S MEDICAL CENTER

Table A2
Assignees with more than 2 patent applications in the EPO in pharmaceuticals (1995-2004)

number.	Assignee
53	RANBAXY LABORATORIES LIMITED
14	SUN PHARMACEUTICAL INDUSTRIES LIMITED
9	DR. REDDY'S LABORATORIES LTD.
8	COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH
8	NATCO PHARMA LIMITED
8	DR. REDDY'S RESEARCH FOUNDATION
7	CADILA HEALTHCARE LIMITED
6	SUVEN LIFE SCIENCES LIMITED
6	PANACEA BIOTEC LIMITED
5	ORCHID CHEMICALS & PHARMACEUTICALS LTD
5	SANKARANARAYANAN, ALANGUDI
4	THEMIS LABORATORIES PRIVATE LIMITED
4	DABUR RESEARCH FOUNDATION CORD, JANET, I.
4	STRIDES ARCOLAB LIMITED
4	KHAMAR, BAKULESH, MAFATLAL
4	DR. REDDY'S LABORATORIES LIMITED DR. REDDY'S LABORATORIES, INC.
4	PATEL, DINESH, SHANTILAL KURANI, SHASHIKANT, PRABHUDAS
3	MODI, RAJIV, INDRAVADAN
3	ORCHID CHEMICALS & PHARMACEUTICALS LIMITED

number.	Assignee
3	CIPLA LIMITED WAIN, CHRISTOPHER, PAUL
3	DR. REDDY'S LABORATORIES LIMITED
3	CADILA PHARMACEUTICALS LIMITED
3	SUN PHARMACEUTICAL INDUSTRIES LTD.
3	J.B. CHEMICALS & PHARMACEUTICALS LTD.
3	ASTRAZENECA AB
3	ASTRA AKTIEBOLAG
2	DR. REDDY'S RESEARCH FOUNDATION CORD, JANET, I.
2	WOCKHARDT LIMITED
2	GLENMARK PHARMACEUTICALS LIMITED MASS, CLIFFORD, J.
2	SECRETARY, DEPARTMENT OF ATOMIC ENERGY
2	BLUE CROSS LABORATORIES LIMITED
2	DALMIA CENTRE FOR RESEARCH AND DEVELOPMENT
2	NICHOLAS PIRAMAL INDIA LIMITED
2	UNIVERSITY OF MADRAS
2	INTERNATIONAL CENTRE FOR GENETIC ENGINEERING AND BIOTECHNOLOGY
2	VYAS, SHARAD, KUMAR
2	DR.REDDY'S LABORATORIES LTD.

Table A3
Technology Transfer in Gujarat

➢ A Leprosy immunomodulator has been transferred from the National Institute of Immunology to Cadila Laboratories, Ahmedabad.
➢ A Leishmaniasis detection kit has been transferred from CDRI, Lucknow to Span Diagnostics Ltd. Surat.
➢ Blood grouping monoclonals has been transferred from NII, New Delhi to Cadila Laboratories, Ahmedabad
➢ Mass production of Biopesticides from *Aspergillus niger* has been transferred from IARI, New Delhi to Cadila Laboratories, Ahmedabad
➢ Amaranthus protein gene for nutritionally enriched animal feed has been transferred from NCPGR, New Delhi to Cadila Laboratories, Ahmedabad
➢ The IgM Mac ELISA for the detection of Dengue has been transferred from National Institute of Virology, Pune to Zydus Cadila HealthCare, Ahmedabad
➢ The IgM Mac ELISA for the detection of Japanese Encephalitis has been transferred from National Institute of Virology, Pune to Zydus Cadila HealthCare, Ahmedabad
➢ The IgM Mac ELISA for the detection of West Nile virus has been transferred from National Institute of Virology, Pune to Zydus Cadila HealthCare, Ahmedabad

➢	Urine based system (ELISA) for the detection of Four Reproductive Hormones has been transferred from Institute for Research in Reproduction, Mumbai to Zydus Cadila HealthCare, Ahmedabad
➢	A technology utilizing *Yarrowia lipolytica* expressing Hepatitis B surface and pre S genes (yielding high level of proteins / single step purification) has been transferred from the M. S. University, Baroda to Biological Evans Ltd., Hyderabad
➢	A technology for expressing hCG using *Pichia pastoris* system has been transferred from the Indian Institute of Science, Bangalore to Cadila Pharamaceuticals Ltd., Ahmedabad
➢	Plant Tissue Culture technology has been transferred from TERI, New Delhi to Cadila Pharmaceuticals Ltd., Ahmedabad
➢	Plant Tissue Culture technology has been transferred from NCL, Pune to Cadila Pharmaceuticals Ltd., Ahmedabad

Compiled using Internet sources of information

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- http://www.cadilapharma.com/
- http://www.cipla.com/