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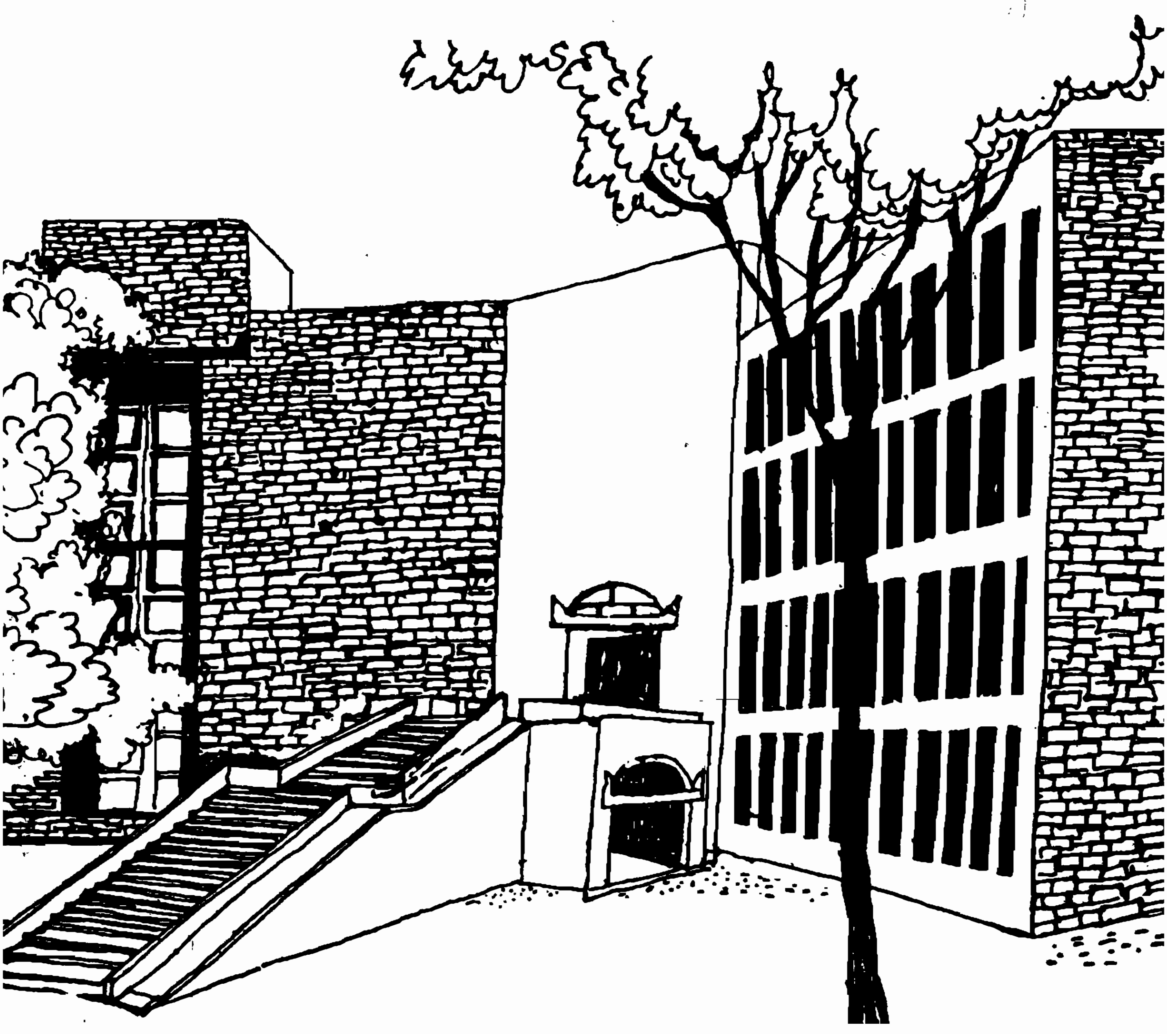

AGRICULTURAL RESEARCH AND TECHNOLOGY TRANSFER BY THE PRIVATE SECTOR IN INDIA

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Agricultural Research and Technology Transfer by the Private Sector in India

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This paper is part of a larger study on *The Private Sector and International Agricultural Technology Transfer in Developing Countries: Case Studies of China, India, Indonesia, Malaysia, Pakistan, the Philippines and Thailand,* co-ordinated by Carl E. Pray and Keith Fuglie.

ABSTRACT

The demand for new agricultural technology is growing in India. Since 1985 public sector investment in agricultural research in India continues to grow, but the growth rate is slowing down. With liberalisation, the private sector is expected to fill the void created by slow withdrawal of the public sector. In addition, private firms can do certain activities such as commercializing and marketing new varieties more efficiently than the public sector. Thus, private sector research presents an opportunity for more growth for Asian agriculture. Along with liberalisation, the new WTO regime and the major restructuring of agriculture related firms in the world have significantly changed the environment in which the Indian firms operate. It is not known how the private sector has responded to these new challenges and opportunities. This paper reviews evidence on the structure and development of the Indian agricultural sector to provide insights on the changing demand and supply conditions for agricultural input and agro-processing industries in the country. It documents the quantum and nature agricultural research and technology transfer that is going on in India to show that such activity is on the rise. Apart from other factors, the size and growth in the Indian agricultural input and food market and the liberalization of restrictions on Indian and foreign firms that wish to invest in the food and input industries seem to have facilitated this increase. However, private sector research in agriculture is still quite inadequate and policy initiatives including those ensuring further liberalization, continued support for public research , stronger IPRs and competition policy are required to encourage it.

Agricultural Research and Technology Transfer by the Private Sector in India

Carl E. Pray and Rakesh Basant

I. Introduction: Issues in Private Agricultural Research

The demand for new agricultural technology is growing in India. Population continues to grow rapidly and per capita income growth has grown even more rapidly pushing up the demand for food. In India the land frontier is closed, irrigation is growing more expensive, and urban growth is pulling people out of agriculture, which leaves research as the remaining major source of growth. Wealthier consumers want higher quality food and less environmental pollution, which also increases the demands on research.

Since 1985 public sector investment in agricultural research in India continues to grow, but the growth rate is slowing down. In many of the Indian Council of Agricultural Research (ICAR) institutes there is an acute shortage of operating funds which has reduced scientists' productivity. In some of the State Agricultural Universities (SAUs) the funding crunch is even more acute. For example, the state government of Maharashtra is gradually reducing funding to the state universities every year. In addition, the international agricultural research centers that contributed to India's growth in the past have had their budgets reduced considerably (Desai, 1997; Pal, Singh & Jha, 1997)[1].The result of the shortages of funds in some states and ICAR institutes and the weakness of public institutions for distributing public technology is that new public technology spreads to farmers very slowly. Consequently, farmers are planting older varieties. For example, wheat varieties in India have an average age of nine years compared with U.K. farmers where the average age is three years. (Witcombe, Virk, and Farrington 1998).

The private sector holds the promise of alleviating some of these problems. Private firms are funding more agricultural research in Asia and the rest of the world. In addition, private firms can do certain activities such as commercializing and marketing new varieties more efficiently than the public sector. Thus, private sector research presents an opportunity for more growth for Asian agriculture. It could be encouraged through policy changes and public research that was more responsive to private firms needs.

Recently, major international trends have reshaped world agricultural input industries and food industries to make more technology available to developing countries through the private sector. Barriers to international trade and foreign direct investment are falling. Breakthroughs in biological sciences and favorable business conditions have led to a major consolidation of biotech, seed, pesticide, veterinary and human pharmaceutical firms into a few major "life science" companies. These same firms are starting to link up with the food industry through alliances,

1 According to some estimates the agriculture related R&D and education expenditures (in real terms) funded by ICAR and state governments grew at the rate of about 5.7 per cent during 1974-83. This rate of growth declined to 4.9 per cent during 1984-93. (See, Pal, Singh and Jha 1997). Presumably if agriculture education related expenditure is excluded, the decline would have been sharper

mergers and acquisitions. These companies are making the latest biotechnology available to developing countries that have large markets and an attractive business climate.

The increasing prominence of these life science companies is, however, raising some concerns. Will the technology they provide really be appropriate for India's thousands for small farmers? Will they somehow force Indian farmers to use seeds with "terminator" genes, which prevent farmers from keeping their own seed? Will they force farmers to use certain herbicides which fit genetically engineered crops? Will they be able to force up the price of seed, pesticides, or machines because of their market power? Will they patent products that farmers have been using for decades and restrict their use to farmers who pay high prices? Will Indian scientist be unable to access new genes and constructs developed in OECD countries that would be useful to Indian farmers?

To fulfill the growing demand for food, fiber and beverages, India needs the private sector to play a larger role. The international private sector appears to be ready to play a larger role and Indian firms are increasing their investment in agricultural research. Both local and international firms could fund more research. They can also do some types of research and technology transfer activities more efficiently than the public sector. The questions that this paper attempts to answer are - What role is private research playing at present? What policy instruments are available to policy makers to influence the amount and direction of private research? What role should the private sector play? And finally, what policies would be appropriate for India?

This paper provides answers to some of these questions. The next section of the paper reviews the structure and development of the Indian agricultural sector. Such a review provides insights on the changing demand and supply conditions for agricultural input and agro-processing industries in the country. Section three describes the agricultural research and technology transfer that is going on in India. Section four focuses on the causes of growth in research and technology transfer. The final section explores policy options for the Indian government and makes some concluding observations.

II. Agricultural Development in India

It is well known that the major impetus to Indian agriculture was given during the late 1960s and early 1970s with the advent of the so-called green revolution technology. Agricultural production in India has grown rapidly since then. In what follows, we briefly discuss recent trends in Indian agricultural growth. This is useful in ascertaining the changing demand/supply patterns of agriculture related products. Table 1 highlights some major features of agricultural development in India in recent years.

The index of agricultural production rose from about 86 in 1970-71 to 176 in 1996-97. Since the last major drought in 1987-88, production in agriculture has grown at a decent rate in recent years. Despite marginal setbacks in 1991-92 and 1995-96, the overall experience of agricultural growth in the 1990s has been good. Given the limits to area expansion, the increased production has essentially been the result of rising land productivity. These higher yields in turn have been achieved by the use of modern agricultural inputs including irrigation, chemical fertilizers, improved and high yielding seeds and pesticides.

About 80 million hectares of cropped area is under irrigation today. While the area under irrigation has increased consistently over the years, only about 38 per cent of the gross cropped area has access to irrigation (Government of India (GOI), 1998, pp 92-93). The dependence of Indian agriculture on the rainfall continues to be significant. The use of high yielding varieties (HYVs) grew rapidly during the 1970s and 1980s; the rates of growth of HYV use seem to have declined in the 1990s. Along with the use of HYV seeds, the production and distribution of certified/quality seeds has also increased (Table 1). The consumption of chemical fertilizers has also increased rapidly. The index of fertilizer consumption rose from about 40 in 1970-71 to 259 in 1996-97. In terms of per hectare usage, the consumption has risen from about 13 kg in 1970-71 to 77 kg in 1996-97 (GOI, 1998, pp 97-98).

About 56 thousand tonnes of pesticides (technical grade material) was consumed in 1996-97. This is a marked increase from 24 thousand tonnes in 1970-71 (GOI, 1998, pp 97-98). As Table 1 shows, 1990s experienced some deceleration in the use of pesticides; the index declined from 167 in 1990-91 to 125 in 1996-97. These indices are based on official statistics. Estimates provided by industry sources suggest an increase in the consumption of agro-chemicals even during the 1990s (Unni 1997, Table 6, p 559). The pesticide market in India is dominated by insecticides (76 per cent); the share of herbicides (13 per cent) and fungicides (11 per cent) in the agro-chemical market is rather small (Unni 1997, p 560).

Tractor production in India has been rising since the early 1970s. Recent years have seen a sudden spurt in tractor production. More than 191,300 tractors were manufactured in India in 1995-96; the reported production in 1990-91 was only about 138,500. No reliable estimates of production of diesel engines and electric motors for irrigation purposes are available. According to industry sources approximately 5-600,000 diesel engines are produced for agricultural purposes in India and the demand for such engines has been rising at the rate of 5 per cent during the 1980s and early 1990s (Basant, 1997).

Two other dimensions of agricultural growth in India in recent years need to be highlighted: changes in cropping pattern and trends in capital formation in India. Changes in cropping pattern can also contribute to increase in agricultural yields per hectare if the area shifts from low yielding to high yielding crops. Such changes also have implications for the demand patterns of agri-inputs as the use intensity of these inputs varies significantly across crops. The rate and nature of capital formation in agriculture also impinges on the rate of agricultural growth.

The share of foodgrains in gross cropped area has declined from about 75 per cent in 1971-72 to about 67 per cent in 1994-95. Within the foodgrains category the percentage of area under coarse cereals (maize, sorghum and millets) has declined from about 28 per cent in 1971-72 to 17 per cent in 1994-95. The share of area under pulses has also marginally declined during this period. While rice has retained its share of about 23 per cent during this period, the share of wheat has increased from about 11 per cent in 1971-72 to 14 per cent in 1994-95. Oilseeds have been the major gainers among non-foodgrains; their share in cropped area increased from 9 per cent in 1971-72 to about 15 per cent in mid-1990s. Cotton, which had suffered a bit in the 1980s, has improved its share in the 1990s (Sawant 1997, Table 2, p 235 and GOI 1998, p 94). Crop pattern shifts in favor of superior cereals and non-food grain crops like oilseeds can *ceteris paribus* increase the demand for agri-inputs as these crops consume relatively more inputs per unit of land. For example, bulk of pesticide consumption is concentrated in cotton.

Despite the decent performance of Indian agriculture discussed above, which augurs well for the agriculture related industry, a few disconcerting aspects of recent growth in Indian agriculture need to be emphasized (see Desai 1997 for details):

- The annual rate of growth of agricultural production (both foodgrains and non-foodgrains) was lower in the 1990s as compared to the late 1980s; and

- The annual rate of growth of input use (HYVs, fertilizer, irrigation, power) was also lower in the 1990s vis-a-vis late 1980s.

It has been argued that this "down turn" is partly due to the relatively slow growth of real plan expenditure on agriculture since early 1990s (Desai, 1997). Available estimates suggest that after peaking in 1978-79 (Rs 52 billion at 1980-81 prices), gross capital formation in agriculture, showed a relative decline in subsequent periods. Things have looked up again in the 1990s with investment going upto Rs 70 billion in 1996-97 (1980-81 prices). The stagnancy of the 1980s, which continued into early 1990s, was essentially due to the decline in the *public sector* gross capital formation. The *private sector* investment did not rise fast enough to compensate for the relative decline in state sponsored investment. The 1990s have seen a reversal of this trend with private sector investment rising rapidly (See, GOI 1998, Table 1.5, p 8 for some estimates). In 1996-67, as much as 84 per cent of the total investment came from the private sector (See Table 1).

One can view these trends in two ways. It can be argued that public sector investment is gradually being substituted by private sector investment and one need not be perturbed by the decline in the role of state in agriculture related investment. The other view could be that given the complementarities between public and private investment (especially in irrigation), private sector investment would have risen even faster if the public sector investments had continued to grow at a rapid pace. In fact, the decline in the rate of growth of fertilizer use, irrigation and HYV use could have been arrested, given the complementarities of use in these inputs and the importance of the state support in expanding the use of HYVs (extension), irrigation (investment) and fertilizer (subsidy). Limited availability of concessional agricultural credit could also have contributed to this process.[2]

Overall, the picture that emerges is that agricultural growth in the 1990s years has been decent enough to support the growth of agri-business. However, there are some indications that the

2 See Desai (1997) for the role of credit in the recent experience of agricultural growth in India.

growth performance (and, therefore, the market for agri-inputs etc.) could have been better if public investment in agriculture had not declined in recent years.

III. Private R&D and Technology Transfer in Indian economy.

Recent information on R&D and other technological activities of the private sector is analyzed in three parts. The first analyses data on type and quantum of research being conducted by private firms in this sector. The second discusses data on technology imports and technology licensing. The third part reviews evidence on the impact of private research on agricultural production and productivity and the final part examines some technologies that may be important in the near future.

Private Sector Research: Levels, Trends and Goals

Most of the agricultural research conducted in India is very applied. The types of research being conducted by private firms, the amount of expenditure, and some of the impacts of this research are shown in Table 2. Estimates of levels and growth of private R&D expenditures by different industries based primarily on Department of Science and Technology (DST) data to obtain comparability over time is presented in Table 3. These estimates are supplemented by some firm level estimates for different agricultural sub-sectors from the Centre for Monitoring Indian Economy (CMIE). These estimates are reported in Tables 4 and 5. In what follows we discuss the nature and extent of R&D by private firms in various sub-sectors[3].

The private sector spends between $39 and $43 million on food and agricultural research in India. The second column of Table 2 shows our estimates of R&D expenditure based on our interviews, questionnaires, and individual firm data from DST. In industries where sufficient interview data was not available, industry level data for 1994-95 from DST was used. We did not include any expenditure from government owned firms in constructing this table. The largest research expenditure was by the food industry at about $13 million, followed by pesticides with $7 to 11 million, the seed industry and agricultural machinery are both $5 to $6 million. The poultry industry, fertilizer industry, and the feed industry made smaller investments in R&D.

Private research in India has grown rapidly since 1985. Between 1985 and 1995 (the last year for which official figures are available) private sector at least doubled its research expenditure. This

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3 The data compiled by these sources is not strictly comparable. For example, the estimates of R&D expenditures compiled by the DST are based on the data made available by firms having DST recognised R&D units in different industry groups. Not all recognised firms provide this information every year and not all firms doing R&D are recognised by DST. Consequently, these data usually underestimate the R&D in the sector. The CMIE estimates are based on data compiled from company annual reports. All companies listed in the Mumbai Stock Exchange are covered. Here again, not all firms annual reports are available to CMIE every year. At times firms do not report R&D expenditures in their annual reports. By and large, for the organised sector CMIE estimates are more robust.

is faster than public agricultural R&D that grew 69 percent in this period. Table 3 shows growth in food and agricultural research by private firms and government owned corporations that are registered Science and Technology Firms by the Department of Science and Technology (DST) plus data from the seed industry from a survey by Pray and Kelley (1998). The DST data under estimates growth - particularly in industries where there are many new entrants – because it takes a number of years for new firms to get approval. In addition some firms do not bother to get approval because there is little benefit from this designation – some tax reductions – and substantial costs in paperwork. In the Pray and Kelley (1998) survey of the Indian seed industry firms that were not approved by DST conducted 24 percent of the research of the firms surveyed. Similarly, the DST estimates of private sector R&D for firms producing chemical fertilizers and tractors (Tables 2 and 3) are much lower than the estimates derived from CMIE data (Tables 4 & 5); $ 2.2 million versus $ 9.7 million in the case of fertilizers and $ 5.6 million versus $ 25.4 million for tractor firms (US $ 1 = Rs 31.4). This is largely due to the fact that CMIE data includes all R&D by these firms including other chemicals for fertilizer and trucks and other machines for tractor firms.

The most rapid growth took place in food processing followed by the seed industry, veterinary pharmaceuticals and the sugar industry. Pesticides research almost doubled during this period. Actually, pesticide research probably grew even more rapidly, but a number of the firms which have increased their research recently such as Monsanto and DuPont are not registered as research companies with DST. Tractor research also went up substantially – 75 percent higher in 1995, but declined in 1996-97. The other industry which shows a decline according to DST data was fertilizers. The decline suggested by a comparison of Tables 3 and 4 is particularly sharp but given the alternate estimates from CMIE, this decline may not be real. For pesticides, however, the CMIE and our survey estimates are about the same (because they also do not have many U.S. pesticide firms).

Seed Sector

A large number of seed firms exist in India. However, only a few have large-scale operations. About half of seed sales are by public sector corporations. Since the mid 1980s, large Indian firms and multinationals have also entered the Indian seed industry. According to one recent study (Pray and Kelley 1997), in 1995 firms with some foreign ownership account for about a third of the private half of the seed market and large Indian firms accounted for 23 per cent.

Most seed firms conduct breeding research to develop new hybrids based on inbred lines that have been developed in the public sector, international agricultural research centers, or parent companies. A few of the larger programs conduct research to develop their own inbred lines.

At least three seed companies have major biotechnology labs in India which are conducting basic biological research. One lab spent about $700,000 last year, has 11 PhDs out of a total of 34 scientists, and has collaborative research with some of the top university biotech labs in the U.S. Two of these labs are working on hybrid rice issues – understanding hybridization or identifying markers which can be used to screen for grain quality. They are also transforming cotton and vegetables with Bt. and other genes. A number of companies are testing transgenic varieties either from their own programs or from foreign programs. The Department of Biotechnology, which has to approve any field trials of genetically modified organisms, reports that there have been 28 field trials of transgenic crops since 1996 of which about 95 per cent were by private firms. These trials have been on cotton, mustard, tomato, eggplant and cabbage. Soybean trials have been approved but are not yet in the field, and potatoes and tobacco are in the pipeline.

Animal Feed

There are very few corporate players in the animal feed industry; the bulk of the animal feed production takes place either in the small scale sector or the cooperative sector. Besides, many farmers prepare their own animal feed. The share of the corporate sector in the animal feed industry is close to 33 per cent and has been rising in recent years. About 40 relatively large players exist in this market, the rest are small players. The total estimated market size was about Rs 23 billion in 1995-96. We have R&D data for only three major players. (Table 4)

Godrej Agrovet and Hindustan Lever have emerged as two significant corporate players in this market. Hindustan Lever has increased its market share in recent years by acquiring some firms and expanding capacities. While the R&D to sales ratio for Hindustan Lever declined somewhat during the 1990s, the R&D intensity has increased for the other listed companies (Table 4). Unlike the other two firms, Hindustan Lever is a large diversified firm, *the R&D estimates include expenditures on activities other than animal feed.* The research arms of animal feed firms essentially test new ingredients. They try to find ways to reduce anti-nutritional factors. In addition they test new additives that are provided by other firms.

Flowers

This sector has attracted a lot of investment in recent years. MNCs have been involved in the setting up of export oriented units. There is no estimate of the total sales of flowers. About 15 major firms sell about Rs 150 million worth of flowers. Estimates of R&D expenditures, many of which are bio-tech companies, are difficult to get. Available evidence suggests that the private sector R&D expenditures have risen in this segment (Table 4). The focus of R&D in this area has been testing foreign varieties and developing management techniques to grow them efficiently.

Agro-Chemicals/Crop Protection

Several large players operate in this segment and the extent of rivalry has been high in recent years. MNC participation in this area has also been significant in this sector. Many international mergers and acquisitions have impinged on the market structure of this segment. Hoechst and Schering became Agrevo in 1994. Ciba-Geigy and Sandoz agricultural chemicals merged to become Novartis in 1996. Between 70-80 firms in the corporate sector are engaged in the production of agri-chemicals. The top ten firms have approximately 63 per cent share of about Rs 31 billion market. While the CMIE data (Table 4) seems to suggest that there are hardly any firms producing pesticides in the small scale sector. Other estimates provide contradictory evidence. According to Unni (1997), the industry has about 60 basic manufacturers and over 400 formulators. The current annual production capacity is approximately 1,24,000 tons. The installed formulations capacity in the organised (large) sector is about 70,000 metric tons, the small scale sector having similar capacities.

Research by the crop protection industry was also almost entirely applied. The two main research activities of these industries are conducting efficacy tests on chemicals that are new to India and developing new methods of producing commercial chemicals. The first type of research is conducted primarily by the subsidiaries of foreign firms because they are the source of almost all new pesticides in India. They test the chemicals that have been commercialized elsewhere to find out how effective they are against Indian pests and diseases under Indian climatic conditions, application methods, and market conditions. These tests are required by the companies themselves to ensure that the product meets their specifications and also to meet the registration requirements of the government. In addition, the chemicals have to be tested for their impact on the environment, on workers' health, and on animals. Both foreign and local firms spend some research resources trying to develop the most effective package of practices for the use of these chemicals. Some of these packages probably qualify as IPM.

The main research activity of local firms has been developing new methods of producing the active ingredient of pesticides that were discovered elsewhere. This allows the local firm to produce chemicals which originally were produced by a method that was kept secret by the inventor or protected by process patents. Both local and foreign firms test different formulations for their products and test different combinations of their products and other chemicals that might complement them.

A few local firms are starting to develop research programs to develop new active ingredients for pesticides using standard chemical synthesis methods. A larger number of local firms and at least one foreign firm are looking at natural products that can be used as pesticides. Local firms seem to be concentrating on neem tree extracts, plant growth regulators, and a few other things that have been traditionally used in Indian agriculture. One foreign firm has a program to actively collect plants that might have biological activity. They then screen these plants and send off a handful of the most promising ones to Europe each year. In 20 years this program still has not led to a new commercial product.

Tractors

About 12 firms are currently manufacturing tractors in India. The major players listed in Table 4 produce about 93 per cent of all tractors and have a share of 92 per cent in the estimated tractor sales revenue of Rs 47 billion. In recent years, Mahindra and Mahindra, TAFE and Punjab Tractors have gained in market share while Eicher, Escorts and HMT have lost out. However, all major players, except HMT, increased their R&D intensity in the 1990s. The decline in the R&D expenditures at HMT tractors is understandable as it is currently on sale. The tractor industry has undergone major restructuring in recent years. While the demand for tractors has grown consistently over the years, its rate of growth declined in 1996-97 as compared to 1995-96. It is expected to decline further in the future.

Small tractors (below 20 horsepower) were exempted from the excise taxes until 1994. Even inputs used to produce these tractors were excluded from duties. The 1994-95 budget made the final product (small tractor) excise free and the companies had to pay duties on raw materials. Subsequent changes in the value added tax meant that tax advantages of making small tractors declined further. To add to the problems of small tractor manufacturers, in 1995-96 the government extended subsidies on tractors to the high horsepower (HP) versions also. This was an extremely important step as tractor demand is significantly influenced by availability of subsidies and soft loans. Larger tractors are not only more efficient in the field, but these are also more useful for transport purposes. Over the years, non availability of adequate transport infrastructure has resulted in the use of tractors to transport men and produce. Given these policy and market changes, it was expected that firms will try to upgrade the HP range of their tractor production.

Tractor firms are doing a substantial amount of research in India. A major thrust in recent years has been to develop higher horsepower tractors that are also affordable to Indian farmers. For Indian firms this means developing tractors with higher horsepower (hp). For example, Eicher which is known for its low HP tractors (less than 25 HP range), has recently started selling a 38 hp model and hope to produce 42 and 62 HP tractors in future. A large part of R&D by almost all tractor firms in India is spent to gear up for the production of larger tractors (more than 50 HP). Besides, in anticipation of a boom in demand, the market players had enlarged their capacities. This along with the entry of new players resulted in under-utilization of capacities. Exports are seen as a source of improving rates of capacity utilization. But such a strategy also requires capability to produce large tractors as the external markets do not prefer small machines. The export markets (especially US and Europe) also have certain design and quality specifications which are different from the Indian market specifications. Firms are also doing R&D to conform to these standards to enlarge their export markets.

Most of the leading players in the market have made efforts to obtain technology for large tractors through multi-national participation. In addition, three of the new entrants (New Holland, Sami-Greaves and John Deere-L&T) are entering with more advanced foreign tractor models. For foreign firms this means modifying large tractors models developed for the U.S., Europe and South America to be less expensive and to be efficient and safe on the road (one of the main uses of Indian tractors is hauling crops to market).

Diesel Engines

There are about 31 manufacturers of diesel engines in the corporate sector, not all of them, however, made engines for the agricultural sector. Slow speed low HP (<10 HP) diesel engines are reserved for small scale firms. As a result, the bulk of the agricultural demand is satisfied by about 800 small units spread all over the country. The small scale sector produced about 500,000 small (upto 20 HP) diesel engines every year mainly for irrigation purposes but also for sugarcane crushers and generating power. The corporate sector contributes another 90,000 engines for irrigation purposes. No estimates of R&D are available for this segment.

The diesel engines produced by small firms are based on outdated Petter and Lister models. Concessional credit and subsidy by the government has been restricted to slow speed low HP diesel engines. As such financial support drives demand to a significant extent, policy has contributed to technological obsolescence. Small Scale Industry reservation and financial support for slow speed low HP engines has meant that producers have not spent in R&D to upgrade the old models (See Basant 1997 for details).

The diesel engine story is, therefore, somewhat similar to the tractor story where government support for small tractors helped their persistence in the Indian market. However, unlike the tractor industry, not many new entrants have started producing new engines with multi-national technologies. Field Marshall in Rajkot is one exception, which is trying to introduce HATZ diesel engines through German collaboration.

Marine Products

A significant number of large scale sector firms (more than 125) are engaged in the production of marine products. But their share of the estimated sales of Rs 123 billion is only about 10 per cent. Most of these major players are engaged in the exports of marine products. The relatively high R&D expenditure of ITC Ltd in this segment (Table 4) is misleading because ITC is a large conglomerate firm and separate estimates for R&D in the marine products sector are not available. Similar data are not available for other firms as well. Our discussions with some large firms in this sector revealed that whatever limited R&D is done is to meet the quality standards of the export (especially the US and EU) markets. Recent bans on Indian exports from EU have intensified these efforts. Most Indian firms export unprocessed marine products. Some firms are making efforts to move up the value chain and are undertaking research for this purpose. Only a few firms are trying to enter the ready-to-cook market and are conducting research to develop these products.

Fertilisers

Tables 5a and 5b suggests that the market for all types of chemical fertilizers has grown in recent years. It is a relatively concentrated industry; except in the case of phosphate fertilizers. The top ten companies account for more than 73 per cent of sales. About Rs 310 million were spent on R&D in the industry. In the case of most firms, the R&D intensity either increased or remained roughly the same during the 1990s. The increases, however, have been marginal. The DST estimates (Table 3) suggest that as compared to the private firms, the government-owned fertilizer firms do much more research. This conclusion does not seem robust given the CMIE data presented in Table 5b. It needs to be emphasized, however, that the coverage of public, private, joint and co-operative sector firms in Table 5b is not representative of these sectors. Moreover, the private sector firms may be more diversified than other firms and the reported R&D

expenditures may include research on products other than fertilizers. Besides, the CMIE data is missing the largest component of public sector research; projects funded by the State in various public sector labs and research organisations including field trials.

The research that gets done is primarily engineering work to reduce costs of fertilizer production and some agronomic tests on how best to apply fertilizer to different crops. Some firms are also actively working on developing bio-fertilisers. Hardly any research is conducted by the private sector in India on the methods of fertilizer application, long term effects of fertilizers on productivity etc.. Such research remains in the public domain. (Pal et. al., 1997).

Poultry

India has several poultry-breeding firms – more than anywhere outside of the U.S. and Europe. These firms use purelines from U.S. or European firms and breed them in Indian conditions. This means that they have to be able to survive extreme heat and some cold (because few barns have climate controls) and less hygienic conditions. They also have to be competitive in the Indian market structure in which the commercial hatcheries are separate firms from the suppliers of grand parent stock. Therefore, the parents have to lay large number of eggs.

Poultry industry is largely in the small scale sector in India. No estimate of the total market size is available. Including Venkateswara, the largest group, there are approximately 10 major corporate players in the poultry market. The total sales of chickens for these firms was of the order of Rs 1.6 billion in 1995-96. R&D data is available only for three firms (Table 4). As Venkateshwara Research, Venkateshwara Breeding Farm and Western Hatcheries actually belong to the Venkateshwara group, effectively we have data for only one company. We were informed that other than the Venkateshwara group, only a few other firms undertake any significant R&D in the poultry sector.

While the market share of Venkateshwara group in processed chicken (including Venkateshwara Breeding) has declined a bit in the 1990s, their R&D expenditures have gone up significantly. In fact, the data made available to us by the firm shows an even higher level and increase in R&D expenditures for the group; from about Rs 52 million in 1993-94 to about Rs 129 million in 1997-98. Their research covers a variety of aspects (see discussion below).

Food Processing

The data on the structure of food processing industry is difficult to compile as it includes a large variety of products. Therefore only flour milling is included here. Food processing industries do a limited amount of agricultural research to improve their inputs. For example, beer companies try to improve the quality of the grain they use for malting and tobacco firms try to reduce the cost of the tobacco they buy while retaining a certain quality standard. Most of the research of the food industry is, however, concentrated on developing new products and manufacturing processes.

There are about 30 relatively large firms engaged in the manufacturing of flour milling products. Their share in the market is, however, very small; only about 10 per cent of the Rs 58 billion market is served by them. Very few of them report R&D expenditures. Besides, the R&D activity in this segment is meager. (Table 4)

The entry of corporate players in flour milling (especially wheat flour) is a recent phenomenon. By and large, the packed and branded wheat flour has not been able to withstand the competition from the small scale producers. Consequently, the R&D activity initiated in the early 1990s has not picked up. Some respondents indicated that increasing the shelf life was the major focus of this research. Apparently, some research is also being done to retain the softness of the kneaded wheat flour for relatively long periods.

Technology Transfer

Even in agriculture where new technology is often embodied in plants and animals which are very sensitive to changes in climatic, soil and pest conditions, some technology can be transferred with very little adaptive research in India. Some of this technology comes in as finished or almost finished inputs and the quantities can be indicated by input imports. For other technology the knowhow is purchased and the production of the product is done in India. Finally, some technology is brought in as a part of direct foreign investment by foreign firms.

Imports of agricultural inputs are very limited into India. For example, seed imports are negligible except in vegetables. Table 6 shows that sunflower is the only field crop with appreciable imports of commercial seed in recent years and that was only for one year 1991-92. Even that was only about 7% of total commercial use. The volume of imports of vegetable seed, for which restrictions on trade were eliminated except a small tariff, increased much more than field crops but were still small. Imports of many other inputs are such as tractors and diesel engines are not permitted. Fertilizer imports are not insignificant; between 20 to 30 per cent of the total consumption has been bought from outside in recent years (Table 6). Nearly 90 per cent of the country's requirement of pesticides is met indigenously. Out of the 132 active ingredients registered in India, over 60 are manufactured in the country (Unni, 1997). Pesticide imports may have increased in recent years.

Imports of technology through multinational firms can be indicated by proposals approved by the Indian government. Table 7 provides details of the proposals approved by the Foreign Investment Promotion Board (FIPB) during the period 1991-97 for the agriculture related product groups. Of the 8,795 approved proposals for which we have data 1582 (about 18 per cent) were in the agriculture related sectors. These approved proposals anticipated equity flows of approximately $31 billion, about 12 per cent of which were to flow into agriculture related sectors4.

The proposed participation of the MNCs in agri-business industry was mainly in the form of

4 Data are not available to check how many of these proposals actually materialised.

equity flows and setting up export oriented units. Licensing of technology was the third most important MNC linkage (Table 7). Financial and technical participation of MNCs in these industry groups is likely to enhance technology flows as well.

Food processing of various kinds (instant semi-processed foods, meat preparations and other food products), vegetables and fruits and flowers are the main sectors attracting MNC participation. Interestingly, input industries (fertilizers, pesticides, agricultural machinery) have not attracted many projects. However, the input industry is not as diversified as the other product groups and the number of players in the former is also small in relative terms. Consequently, the entry of even few MNCs may have significantly increased the competitive pressures in the input segments. The same may have been the impact of MNC entry on some of the food processing segments as well.

Impact of Private Sector Research

In the debates about intellectual property rights and about biotechnology, critics of the private sector continually make the argument that private firms will drive up prices of inputs and not provide farmers any benefit from research. In contrast, most economists argue that although the price of improved inputs such as hybrid maize may go up, farmers' total costs of production go down because they need less of other inputs per unit of output. The reduction in needed inputs can be measured as partial factor productivity such as output per hectare or total factor productivity. If output per hectare goes up it means that less land is needed to produce the same amount of output. Thus, a farmer is saving on his costs of land by using the new technology. If total factor productivity increases it means that all of his costs go down by using the new technology.

Measuring the impact of private research is beyond the scope of this study. However, three types of evidence are available that private research has increased productivity and thus reduced farmers' costs of production. Firstly, evidence is available from the companies interviewed about the impact of their R&D effort on partial productivity measures. Second, three recent studies have measured the impact of private research on output per hectare and total factor productivity. Third, recent studies of industrial research and technology purchase in India have shown positive impact of R&D and technology purchase on total factor productivity of industry. This suggests that research on new processes by the food industry and input industries increases productivity which will eventually benefit farmers and consumers.

The industries interviewed provided several examples of productivity increases due to their research. Venkateshwara Hatcheries (VH) increased the productivity of their layers and broilers considerably through breeding. The top part of Table 8 shows that the number of days required to get broilers to a marketable size bird was reduced by 20 per cent, the amount of feed required went down by 26 per cent and mortality also dropped. The lower part of Table 8 shows that the number of eggs their layers produced went up by 17 per cent while the feed requirement declined by 7 per cent and mortality declined. This data comes from VH poultry operations. No data was available from other commercial farms. It seems likely that the productivity increases on other commercial farms would be less.

Another success of the VH group has been producing vaccines that are less expensive than some commercial vaccines, and more reliable than the government vaccines. They have also developed vaccines that provide protection against diseases for which no other vaccine exists. In fact, they have developed one vaccine that no other country has developed. This vaccine is for a form of hepatitis that has become a serious problem in India over the last five years. The commercial sale of this vaccine in the last few years has greatly reduced deaths from this disease and increased industry productivity.

Agro-chemical companies argued that their research was leading to the introduction of pesticides and formulations that are more effective at controlling pests, safer for the farmer, and less of a problem for the environment.

As mentioned above several recent studies have attempted to measure the impact of technology developed and introduced by the private sector. A study of maize (Singh and Morris 1997) uses farm level data from six states in 1994-95 to show that the adoption of hybrid maize leads to yield increases of about one ton per hectare over improved open pollinated varieties. In total, this led to an increase in maize production of 1.1 million tons. To obtain these increases farmers had to increase fertilizer, irrigation and pesticide use in addition to adopting hybrids. Therefore, increased output is not entirely productivity growth. Since most of the hybrids in 1995 were from private firms, most of this gain is due to private research.

A recent study by Ramaswami, Pray, and Kelley (1999) looks at the factors that influence the partial productivity index, yield per unit of land[5]. The dependent variables were cotton, maize, sunflower, sorghum, and pearl millet yields. The independent variables included a measure of the spread of high yielding varieties, the spread of private varieties, the proportion of crop area that is irrigated, fertilizer use in the entire district, the number of regulated markets in the district, the length of roads in the district, a measure of profitability of the crop, a trend variable, and variables measuring rainfall. The basic model is augmented by interaction variables of high yielding varieties with private varieties, irrigation and fertilizer use. Since private varieties have been significant in these crops only recently, our analysis is confined to the period from 1985 onwards.

Private hybrid's impact on yields are positive and statistically significant in 5 of the 9 crops and provinces and close to significant in a 6th case. Table 9 summarizes the results of the regressions. These estimates provide first econometric evidence that private plant breeding has an impact on crop yields in developing countries. This is particularly impressive because the region examined is in the semi-arid tropics where private research is not expected to have much impact.

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[5] This partial productivity index was used rather than the index of total factor productivity (TFP) because input data is available only for the entire crop sector not for individual crops. Thus, it is not possible crop-wise determinants of total factor productivity.

The only study that has looked at how the benefits of private hybrids were divided was conducted by Pray et al. (1991). It examined the increases in seed prices and increases in farmers' yields of hybrid sorghum and pearl millet in Maharashtra and Gujarat. For hybrid sorghum, at most 18.5 per cent of the benefits were captured by the seed companies through higher prices while 81.5 per cent went to farmers as the value of increased production minus the increased cost of seed. For hybrid pearl millet, only about 6 percent of benefits were captured by seed firms. More than 90 percent of the benefits from private pearl millet research went to farmers. Using this same data Ribeiro (1989) estimated the social rate of return to private plant breeding research in India to be 38 % or more.

A study of total factor productivity of crop production by district in 13 major states of India from the 1950s to the 1980s also provides evidence of the impact of private research and technology transfer (Evenson, Pray, and Rosegrant 1999). It found that private sector research and technology transfer, advances in agricultural research outside India, and public research all made major positive contributions to TFP growth in the crop sector. The social rate of return from investments in private research was very high – exceeding one hundred percent – which suggests most of the benefits from private research go to farmers and consumers rather than the input companies and that from the point of view of society there is a substantial underinvestment in private research.

Recent studies of the experience of Indian industry found that technology imports reduced local R&D by a small amounts, but increased the productivity of Indian firms (Fikkert, 1995; Basant and Fikkert, 1996). The lost productivity from the small decline in research was more than offset by increased productivity from the imported technology. Indian firms did not have to use their own resources to reinvent technology that had been developed elsewhere and could concentrate their research instead on new products and processes that could not be purchased from abroad.

Impact of Technology in the Pipeline

Perhaps the most important technology in the pipeline is hybrid rice which both the public and private sector are racing to commercialize. Sixteen private seed firms reported that they are doing hybrid rice breeding in India and several of these breeding programs are quite substantial. Two firms – MAHYCO and SPIC - have biotech research programs on hybrid rice. This is the second year that hybrid rice has been grown by farmers. Most of the 250,000 ha under hybrids (ICAR 1998) in 1997-98 is under private hybrids with Proagro, Pioneer, and MAHYCO leading the way. These private hybrids are based on public lines from ICAR, IRRI, and China; but they are private hybrids. Yields are often one ton per hectare more than the best conventional varieties and yields of hybrid seed are now high enough to make the one ton increase commercially viable. The main problem is the grain quality of the hybrids which is low. Thus, most private firms and many of the public research institutes are concentrating on improving grain quality.

Another important technology that several private firms and a number of public institutes are working on is single cross hybrids of maize. Companies reported that single cross hybrids produce 10 to 30 % higher yields than double cross hybrids in trials in India. Seed of double cross hybrids is still not being marketed in significant quantities because of its high cost of seed production and the ease with which it can be copied by contract farmers and competitors. But this technology will be supplied as intellectual property rights are strengthened.

Among the first biotechnology products that is likely to be approved are Bt cotton which allows farmers to reduce the number of insecticide applications from 15 or more to 3 and achieve higher yields than cotton with 15 sprays. Another likely early approval is hybrid rapeseed that yields 10 to 20 percent more than improved local varieties. The other crops that are close to approval are pest resistant tomatoes, cabbage, and eggplant.

A new generation of pesticides is being introduced which is effective against some of the pests that have grown resistant to older pesticides and are much safer for people and the environment. Several new wheat herbicides have been approved for control of *Emperata* grass which is resistant to the herbicides currently in the market in India. Companies estimate that use of these herbicides, which are much more environmentally friendly, will increase yields by 20 percent.

These new products will be more expensive. A CIMMYT survey found that the ratio of the price of hybrid maize seed to the price of commercial grain in selected developing countries in 1990 ranged from 1.3 in China to 25 in Cameroon with India at 4.2. Single cross hybrid seed in the U.S. and Europe cost 30+ times the cost of grain (Byerlee and Lopez-Pereira 1994). Thus, it is probable that as Indian farmers adopt better double cross hybrids and single cross hybrids, prices will go up. However, so far they have been held down by intensive competition among private seed companies, public seed firms, and farmers themselves who save seed (even the F2 generations of hybrids – Singh and Morris 1997). There is no evidence that this will change soon. Even if the firms in which Monsanto has some ownership, MAHYCO, Cargill, and E.I.D-Parry, were to merge they would have less than 14 per cent of the commercial seed market which is a small part of the total seed planted which primarily comes from farmers themselves (Ramaswami, Pray and Kelley, 1999).

No one yet knows what the price of pest resistant hybrid cotton with Bt. in it will be. However, the experience of China gives some indication. In China the price of Bt cotton seed (variety not hybrid) increased from Yuan 5 per kg to Yuan 42 per kg[6]. However, because of the higher quality of the seed the quantity sown could be reduced to one quarter of the amount of traditional seed. Thus, the seed cost per unit of land doubled rather than going up five times. In return, farmers were able to save 10 to 20 pesticide applications which saves money for chemicals plus the cost of labor to apply the chemicals. Bt cotton is very popular in Hebei province where it was released.

6 The exchange rate in 1998 was approximately 8 Yuan = US $ 1.00. There are 6 mu per acre.

IV. Reasons for Increase of R&D

Lliberalization in India and changes in multinational firms' policies have been two major causes of the increase in research and technology transfer to India. Analysis of seed industry data indicates that both local companies and foreign companies have increased their research in response to liberalization. Foreign firms such as Monsanto and DuPont are investing in new agricultural research stations and John Deere is entering the Indian market for the first time with its latest line of tractors. The FIPB data (Table 7) on MNC proposals for entry into different industry groups also suggests such a trend.

According to neoclassical economic theory, firms seek to maximize expected profits. The expected profits to a firm from investing in research are a function of the expected benefits and costs of research and development of a commercial product discounted by an interest rate. The expected benefits will be based on the expected size of the market, the share of the market that they can capture, and the expected price of the new product. Firms will calculate the expected market size based on current market size and growth rates for this industry. They will estimate their expected share of the market by looking at their current market share in the industry, the strength of intellectual property rights in the country and technical means of protecting their product from copying.. The expected price will be based on current prices of similar products plus their ability to keep the other firms from copying the product and competing against them. Economists call this ability to capture economic gains from research, *appropriability*.
The expected costs of research depend on the availability of needed technology elsewhere in the world. The environmental specificity of foreign technology will determine whether there are opportunities for adaptive research or direct material transfer. The availability of technology from public institutes which can be adapted or modified through local research. The salaries and benefits of scientists, engineers, and technicians will be an important component of research costs. In addition laboratories, experiment stations and the supplies to run them are important expenses of research.

This section examines changes in the benefits and costs of research which caused growth of private R&D in categories: (i) market size and growth, (ii) appropriability, (iii) research costs and (iv) government policies which influence all three of the other factors.

Market Size and Growth

Increased agricultural research was partially a function of increased demand for agricultural products and modern agricultural inputs. The size of Indian markets for agricultural inputs has grown substantially since 1980 as shown in Table 1. The private sector supplies most of the equipment for minor irrigation, half the certified/quality seed, half of the fertilizer, most of the pesticides, and most tractors. This table and our earlier discussion indicate that production of almost all inputs at least doubled during the 1980s. In the 1990s rapid growth continued in tractors, power tillers and minor irrigation. It appears to have slowed down in seeds and pesticides. In fact growth continued in those industries also. In the seed industry more expensive private hybrids replaced subsidized public hybrids and public varieties. This increased the value of the seed market but does not show up in the quantity measures in Table 1. In the pesticide industry newer more expensive pesticides, which require 40 to 50 grams of technical material per ha, replaced older, cheaper pesticides which required 2000 grams per ha. The result was more sales measured in value terms.

India is one of the largest national markets for agricultural inputs in the world. It currently ranks first in the number of tractors produced and sold. It is also one of the largest fertilizer and pesticide producers and consumers. Part of the increase in research in the last decade is due to foreign input firms deciding that the Indian market was simply too big to ignore even if many of the policies were not conducive to high profits.

Like the input industries the Indian food industry is one of the largest in the world and it is growing rapidly. India will become the world's most populated country early in the 21st Century. The demand for processed foods, poultry products, dairy and meat has also grown rapidly increasing demand for improved livestock technology. Output by the food industry doubled between 1980-81 and 1995-96. Production of poultry products more than doubled in the 1980s and increased another 25 percent from 1990-91 to 1995-96. Milk production increased by 70 percent in the 1980s and 22 percent from 1990-91 to 1995-96 (Tata Services Ltd. 1997). Production of livestock feed has also grown rapidly (from 1.2 million mts in 1980-81 to 2.9 million mts in 1995-96 (Compound 1998)). These increases were driven largely by increased demand created by gains in per capita income.

In addition to increased market size the market share of large private Indian firms and foreign firms increased during this period. Very large Indian firms and firms with foreign ownership of more than 40 percent were excluded from the seed and biotechnology industries until 1986. Half of the active ingredients of pesticides had to be formulated by small firms and all of the agricultural implements industry was reserved for the small-scale firms until the 1990s. This elimination of these policies, allowed large firms into the seed market and permitted the manufacturers of the active ingredients of pesticides to increase their market. It is also expected to induce tractor manufacturers into the implement industry.

The market shares of government owned corporations have declined in the seed industry and in tractors as government sales grew slower than private sales. In addition some of the public sector companies in this sector, like HMT tractors have been included in the state's disinvestment program. Both factors gave private firms a large market.

Changes in the input markets in the U.S. and Europe have made the markets of countries of Asia in general and India in particular look very attractive relative to their traditional markets. From World War II to the late 1970s were boom years for agricultural input firms in the U.S., Europe and to a lessor extent Latin America. The 1980s were a period of stagnant or declining growth. Starting in the mid 1980s most U.S. companies reacted by reducing costs. By the early 1990s they had squeezed costs as much as they could. At this point many of them started to look to developing countries, Eastern Europe and the Former Soviet Union for further growth. John Deere, DuPont, and Monsanto all made decisions in the early 1990s to expand into developing countries including India. In addition, due in part to developments in biotechnology, agricultural chemical and pharmaceutical companies were shedding their traditional chemical business and buying biotech and seed firms to transform themselves into "Life Science" companies. Table 10 shows the impact of the mergers and acquisitions in the U.S. and Europe on the Indian seed industry. These companies invest large sums of money in basic research to develop new drugs, seeds, and agricultural chemicals which they then try to sell worldwide to pay for their research..

Appropriability

Appropriability – the ability of a firm that owns new technology to capture some of the benefits that users of the technology obtain – can be due to several causes. First, laws like patent acts can give owners temporary monopolies, which enable them to raise prices and profit from selling the technology. Second, the structure of the industry may allow firms to capture some of the benefits. Monopoly or oligopoly power in a market can give inventors high enough prices to make profits from technology. Third, the technology itself may allow firms to keep others from copying a technology thus giving inventors market power. Fourth, firms can simply keep inventing and stay ahead of their competition. This also would allow them to charge more.

Since 1985 there have only been a few changes in appropriability in India. The laws and enforcement of intellectual property rights have not changed since 1972 when new chemicals, pharmaceuticals and food and agricultural products were excluded from product patent protection. However, as mentioned above, the markets have become more competitive.

India has signed the Uruguay Round of GATT and committed herself to a *sui generis* plant breeder's rights(PBR) law and strong process patents on biotechnology products by January 1, 2000; and to product patents for new chemicals, pharmaceuticals and food and agricultural products by 2005. PBR legislation and amendments to the patent act have been proposed and debated by several different Indian governments but not passed. In addition India will have to protect trade secrets and extend liability to third parties that induced breach of a trade secret, and India will have to protect test data which is submitted for obtaining marketing approval of a new product. India's signature to the GATT agreement may have raised the hopes of research based firms for stronger intellectual property rights, but firms are not getting their hopes up very high yet.

In the seed sector appropriability has been increased through technical means. Hybrid seed is becoming viable in more and more crops. After 1985 developments in hybrid rice seed production led to the commercial adoption of hybrid rice in 1997. In addition several systems for producing hybrid rapeseed looks possible. These developments led to the development of a number of new research programs on rice and rapeseed which increased total seed research (Pray and Kelley 1998).

Regulatory changes have allowed one group of firms – foreign firms – to increase their share of ownership in all sectors. This enables the foreign owner to appropriate a larger share of the profits from new technology back to the firm's headquarters where much of the research is conducted. This will increase the interest of foreign firms in investing in India.

The increased entry of foreign firms and in some cases large Indian firms into agricultural input and agricultural processing industries has increased the competitive pressure on all firms in these industries. Firms have to innovate more rapidly to keep their market share. They will need to try and appropriate the gains from their research by staying ahead of the competition.

The Cost of Innovation

Firms must weigh the expected benefits, which are based on market size and appropriability, against the cost of innovation and the possibility that the innovation will fail. The cost of innovation and the probability of success are a function of the state of basic science, the quantity and price of scientific inputs such as scientists and labs, and the agroclimatic differences between the place which a new product was designed for and India.

Advances in basic science can lead to new possible products from applied research. One major breakthrough during this period has been in biotechnology. Profits from plant biotechnology products are no longer a dream. They are a reality in the U.S., Canada and Argentina. This has drawn a number of seed firms and agricultural chemical firms to invest in biotechnology research in India. In 1985 a survey of seed firms found that Hindustan Lever and a few other firms had started to do work on plant biotechnology (Pray, 1986). Now Hindustan Lever, Tata Tea, and at least three seed firms have substantial plant biotech labs in India. A large number of other firms are doing tissue culture and some research on tissue culture.

The output of more applied public research can also stimulate private research. During this period public research institutes in India and international centers provide considerable stimulus to private plant breeding research. Participants of a recent study of the Indian seed industry (Pray, Ramaswamy and Kelley 1998) reported that ICRISAT was a very important source of germplasm by 65 per cent and 80 per cent of the sorghum and millet breeding firms, respectively. ICAR/SAUs are very important for 66 per cent of the cotton breeders. Sunflower was the only crop in which international centers and ICAR/SAUS were not reported to be important. Joint venture partners are the most important source of sunflower breeding material. Singh, Pal and Morris (1995) have documented the importance of ICAR and CIMMYT germplasm as the basis of private maize research.

The downsizing of ICRISAT and weak funding of ICAR meant that many well trained and experienced scientists were available to private firms to lead and staff their administrative and research positions. The negative side of weak funding is that less public science and technology is available from these institutions in the long run. Some impact of declining funds can already be seen at ICRISAT, which has stopped having the sorghum and pearl millet field days. At these field days ICRISAT scientists displayed and distributed samples of their latest hybrids, varieties and inbred lines.

Another way to reduce the cost of research is to learn from ideas and innovations elsewhere in the world. Over the period since 1985 several types of innovations became more accessible to private firms in India. The reforms of the seed industry in the late 1980s made inbred lines and earlier generation germplasm more easily accessible. The reforms made it easier to import varieties for research purposes and to import finished varieties for a few years to try them on a commercial basis. Allowing foreign owned firms in India meant that they brought in germplasm and new ideas that spilled over to local firms. Some of our survey respondents expressed the fear that new IPRs might result in less sharing of germplasm and other research materials.

Regulatory reforms which reduced the time it took to get new chemicals approved from 7 or 8 years to 3 or 4 influenced pesticide companies to bring in many more products, which stimulates local research on these products. Research by the agricultural chemical industry in India depends primarily on how many new chemicals are being introduced. Each new chemical needs a minimum amount of research to ensure that it works well here and that it is registered.

Policy

Most of the key government actions which could have stimulated private research are described in the earlier sections and in the sub-sections on markets, appropriability and cost of research. But the key set of policy changes were the liberalization of the policies and regulations on the input industries. Table 11 lists some of the key policies before and after liberalization. They allow foreign firms more control over their Indian operations – as majority owners or wholly owned subsidiaries. Inputs in the production of the finished agricultural inputs such as the active ingredients of pesticides, grandparent stock of poultry and germplasm for the seed industry were easier to import. Requirements for licenses to build new plants or expand old ones were eliminated. In addition, although most of the safety, environmental and efficacy regulations have not changed, their implementation has become more efficient. For example, it used to take 7 to 8 years on average to register a new pesticide while it now takes 3 to 4 years.

Summary

The two major forces behind the recent increase in private research are the size and growth in the Indian agricultural input and food market and the liberalization of restrictions on Indian and foreign firms that wish to invest in the food and input industries. Liberalization has also resulted in an increase in the competitive pressures faced by the players in the market. Another factor that was important but not as important as the first two factors was developments within the international food and agricultural input industries – declining growth rates in demand in OECD countries and mergers and acquisitions in the food and input industries. A fourth set of factors that was important for some industries, seed and biotech, was breakthrough in plants biotechnology and more applied research by Indian government and international non-profit institutions.

V. Policy Options

The government has a number of policy options that could improve the supply and the prices of technology from the private sector. Firstly, if the government truly is concerned about prices of inputs for farmers, as it claims to be, the government could eliminate the bans on the importation of most agricultural inputs. The best way to keep prices down is through competition. Protecting local industry behind import bans or quotas is counter productive. None of the agricultural input industries are infant industries anymore. If India is afraid that its local industries such as the pesticide industry or diesel pumps would face unfair competition or dumping from subsidized Chinese (or other foreign) firms, then India should deal with it using anti-dumping legislation not blanket import bans. Under WTO, India is committed to removing bans and quotas or at least turning the quotas into tariffs, but it is not clear when this will happen. If India wants to produce world class seed, machinery or pesticide firms; then it should support local industry with public sector research, loans, and intellectual property rights in their home market not by continuing current trade barriers. Trade barriers will, however, need to be dismantled carefully so that the final product manufacturers are not constrained by inverted tariff structures. The fertilizer companies in India, for example, have to work with feed stock which is much more expensive than what is available internationally. Therefore, liberalisation of fertilizer trade alone may not be the appropriate policy. Further, deregulation, trade liberalization and a more stringent IPR regime will have to be accompanied by a sensible competition policy so that monopolistic and unfair trade practices do not adversely affect the consumers.

Second, patents and plant breeders rights need to be strengthened. Legislation to bring these laws in line with the World Trade Organization is still hung up in Parliament. Thus, it seems likely that India will wait until the last moment – 2005 - to put stronger patents in place. In the meantime Brazilian, Mexican, Turkish, and Chinese inventors and plant breeders have had stronger IPR protection since the mid 1990s.

We asked firms to speculate about the impact of potential policy changes on the availability of technology. In our 1997 survey of seed firms we asked "Would stronger intellectual property rights, changes in the regulatory regime, and trade in agricultural inputs really lead to more technology for farmers?" There was considerable variation in firms' answers. Of the seed firms surveyed by Pray, Ramaswamy and Kelley (1998) 19 of 33 respondents reported that plant breeders rights (PBR) legislation would encourage them to do more research while 12 said it would have no impact on their research and 2 thought they would reduce their research. In interviews with the major seed firms it was clear that they would not start major breeding programs on self-pollinated crops even with PBRs. It would be impossible to keep farmers and small traders from multiplying and selling protected seed of protected varieties. They did suggest that more research would be done on cross-pollinated crops because you could protect key inbred lines. The major impact of this might be the release of single cross hybrids of maize. Companies reported that single cross hybrids produce 10 to 30 % higher yields than double cross hybrids in trials in India. No one has released them, however, because they are worried that they would be immediately copied by their competitors.[7]

The pesticide industry claims that a lot of technology is not available to farmers because of weak intellectual property rights, the barriers on imports of formulated products and regulatory hurdles. For example, sulfonylurea herbicides are just being introduced here. DuPont's sulfonylurea soybean herbicide "Classic" was first sold in the U.S. in 1986. It was marketed in Brazil in 1987 but will not be marketed in India until 1999 at the earliest. Cyanamid's new class of herbicides call IMIs (imidazolinones) were first sold in the U.S. in the late 1980s. The first one is just being released this year as part of the Ministry of Agriculture's emergency wheat herbicide program. Several firms reported that they were not bringing in their latest insecticides. There were a few, however, who argued that high competitive pressures and the need to introduce new products quickly to get first mover advantages in such a scenario, may result MNCs to bring in new products quickly.

The major questions that remain unanswered are: (i.) with stronger IPRs and lower barriers to entry – i.e. allowing the importation of formulated products- would the MNCs come in with new products? and (ii.) is the absence of these pesticides really reducing yields?. Regarding the first question, some pesticides will not be introduced because their superiority over the previous pesticides is not enough for farmers to be willing to pay higher prices for the new pesticides. The increase in yield may be small or the main advantage may be the environmental impact or health benefits which farmers are not willing to pay for. Regarding the second question, only a few major pests do not seem to have solutions – the imperata grass problem in wheat and insect pests for cotton are two important ones. In the case of wheat the government has set up a special program which reduced the time it takes for registration of a new product from 3 or 4 years to one year. By this means they were able to import more advanced herbicides. Insect pests for cotton are a problem but it is not clear that any new chemicals would be a lot more effective than the current ones. What India mainly seems to be missing out on is products that are safer for humans and more environmentally friendly (see Bt cotton below). Stronger IPRs will probably not help much, but allowing formulated products to be imported might help. Until farmers or the government are willing to pay for them or they can be brought in more cheaply, they will not be available.

In the poultry breeding, feed, fertilizer, and machinery industry stronger IPRs will not have much, if any, impact. However, allowing imports of these inputs would probably reduce the price farmers have to pay for some of these products. For example, Chinese diesel engines and power tillers are very inexpensive. We were not able to assess how much prices might be lowered of these commodities. The diesel engine manufacturers in India feel that the Chinese government provides a lot of hidden subsidies to their producers; else exports of engines at the current prices would not have been possible. It is very difficult to check the veracity of these claims.

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7 With double cross hybrids contract seed growers are given seeds from single cross hybrids which they can not reproduce. With a single cross hybrids they are given seeds of two inbred lines which they can reproduce. Thus, it is easy for them to sell some of the inbreds to a competitor or reproduce the new hybrid themselves

A third policy change that would increase technology to farmers from the seed industry is less regulation on transgenic plants. At the earliest genetically engineered crops will be in commercial use in the year 2000 but pressure by environmental groups and bureaucratic inertia could easily push that year back. This year (1998) China is growing 200,000 acres of cotton that has had the Bacillis thuringiensis (Bt) gene for resistance to boll worm inserted. Monsanto (Achievements: Plant Biotechnology 1997 [illegible].com/) projects that Mexico is growing 200,000 acres of Bt cotton, Argentina 10 million ha of herbicide resistant soybeans, Canada 2 million acres of herbicide resistant canola, and the U.S. 25 million acres of herbicide resistant soybeans, 2.6 million acres of Bt. cotton, 10 million acres of Bt.corn, and other crops.

As mentioned, among the first things that are likely to be approved are Bt cotton which allows farmers to reduce the number of insecticide applications from 15 or more to 3 and achieve higher yields than cotton with 15 sprays. Another likely early approval is hybrid rapeseed that yields 10 to 20 percent more than improved local varieties. The other crops that are close to approval are tomatoes, cabbage, and eggplant.

Fourth, the government has passed some tax packages that could assist private firms. The new government passed a law allowing R&D firms to write off 120 per cent of their total R&D expenditure as costs on their corporate income tax. These and other R&D related policies, however, have not been stable. Besides, the implementation of many such schemes requires that the firm register its R&D centre with the DST. The procedures to do this are tedious and time consuming. If this changes from a year to year policy into a consistent long term policy, it might give some firms incentive to do more research.

Fifth, public research has successfully supported private research in the seed industry in the past. However, the reduction in funding of ICRISAT and other international centers and the poverty of some of the Indian public agricultural research systems is starting to hurt private research. The public research system is attempting to become more responsive to the needs of private firms, but leading firms are still dissatisfied with public research performance. They report that part the problem is that the public sector is perennially short of funds and part of the problem is a scientific culture that rewards basic research more than research that actually solves agricultural problems. The "corporatisation" of public sector labs is being attempted. Hopefully, this will alleviate some of these problems.

Finally, a number of foreign companies singled out infrastructure.– particularly roads and communications - as a major constraint to further investment in India.

VI. Conclusions

Private research is growing rapidly – more rapidly than public research – but the total R&D expenditures in the private sector is still only about 16 per cent of the total funding of Indian research. According our estimates based on our surveys and DST data, about US $ 347.9 million (Rs 31.4=US $ 1) were spent in 1994-95 on R&D for the *development of agriculture, forestry* *and fishing*, only about 14 per cent of which was contributed by the private sector. Empirical studies noted above suggest that private research is contributing to agricultural productivity growth and that farmers capture more of the benefits of research than input firms. There is no immediate threat of Indian or foreign firms gaining monopoly power over any of the agricultural input industries in India. There is simply too much competition not only from other private firms but also public firms and in the case of the seed industry - farmers themselves. Even if there were a threat the way to deal with it would be competition policy not technology policy.

The factors behind this growth in private food and agricultural research fall into four groups. The first factor is the size and growth in the Indian agricultural input and food markets. The second factor is the liberalization of restrictions on Indian and foreign firms that wish to invest in the food and input industries and the associated increase in levels of competition. A third factor was developments within the international food and agricultural input industries – declining growth rates in demand in OECD countries and mergers and acquisitions in the food and input industries. A fourth set of factors that was important for some (e.g., seed) industries, was the breakthroughs in plant biotechnology and the applied research by Indian government and international non-profit institutions such as ICRISAT.

Based on the history of recent growth and the responses of the surveyed companies we believe that private food and agricultural research can be strengthened and farmers' access to new technology improved by further liberalization, continued support for public research and stronger IPRs.

- Liberalization would include continuing to liberalizing rules on foreign investments in the input industries, replacing the bans on imports of inputs with tariffs which will be gradually lowered, and continued rationalization of tariff structures and of the regulations on the release of new pesticides and biotech products so that farmers and consumers are protected against health and environmental dangers while the input companies are not burdened with unnecessary requirements.
- Continued support of Indian and international public research that will support the growth of competitive modern food and inputs industries. It will give Indian firms opportunities to grow and compete with multinational firms.

- Stronger IPR legislation and enforcement will enable farmers to get access to the most advanced technology and to give local and foreign firms incentives to conduct research on the problems of Indian farmers.

Most of these policies are not new. India is committed to continue liberalization and stronger IPRs by becoming a member of WTO and has made a commitment to increasing government research in the next plan. The real question is how long will India continue to resist these commitments.

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Table 1: Trends in Agricultural Growth, India, 1970-1997

	1970-71	1980-81	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
Agricultural Production (Index 1981 82=100)	85.9	102.1	148.4	145.5	151.5	157.3	165.2	160.7	175.7
Area Under Principal Crops	96.3	99.7	105.2	102.6	103.1	103.8	104.2	103.8	106.8
Yield of Principal Crops (Index 1981-82=100)	92.6	102.9	133.1	131.1	137.0	140.7	145.5	139.9	149.0
Irrigated Area (Index 1981-82=100)	74.3	96.8	121.5	127.8	129.9	132.8	137.4	140.9	NA
Area Under HYV (Index 1981-82=100)	35.7	100.0	150.1	150.1	151.7	155.4	164.5	167.3	NA
Fertilizer Consumption (NPK, Index 1980-81=100) *(1)*	39.5 (13.1)	100.0 (31.9)	227.4 (67.5)	230.7 (69.8)	220.4 (65.5)	224.2 (66.7)	245.9 (72.6)	251.6	259.4
Pesticides Consumption (Index 1980-81=100)	54.0	100.0	166.7	160.2	157.3	141.6	136.4	136.2	124.7
Tractor Production (Index 1981-82=100)	21.1	71.7	131.2	159.7	159.4	146.4	172.9	202.8	NA
Gross Capital Formation in agriculture. (Index 1981-82 = 100) *(2)*	61.2 (71.4)	103.0 (61.3)	102.0 (74.9)	105.0 (78.8)	119.3 (80.3)	111.7 (77.1)	138.9 (79.0)	154.6 (81.8)	155.4 (83.8)
Production of Breeder Seeds (thousand Mt)		0.5	3.4	3.5	3.6	3.7	4.0	4.3	4.5
Production of Foundation Seeds (thousand mt)			34.0	38.0	39.0	41.0	47.0	48.0	57.0
Distribution of Certified/ Quality seeds (thousand mt)		250.0	571.0	575.0	603.0	622.0	659.0	699.0	700.0

Source: Government of India (1998)

Notes. 1. Figures in parentheses indicate consumption of fertilizer per hectare of gross-cropped area (kg/hectare).

2. Figures in parentheses indicate the share of the private sector in the gross capital formation in agriculture.

3. NA - Not Available.

Table 2: Private Research Objectives, Expenditure and Impact by Industry 1996-97

Industry	Research Objectives	Amount of Research	Impact of Research
Seed - Field Crops	Increase yields, pest resistance & quality of maize, sunflower, PM, sorghum, cotton, rice, rape/mustard	$5 million + (survey)	Higher yields of maize, sunflower, PM, sorghum, cotton
Seed – Vegetables	Increase yields, pest resistance & quality of tomato, cabbage, okra, hot pepper,	$1 million (survey)	Higher yields of tomatoes
Pesticides	Increase yields and quality of crop, reduce farmers' costs of production, improve human and environmental safety. New processes for Active Ingredients. Combinations of pesticides. IPM.	$7-11 million (survey)	Reduced costs through herbicides, improve environment through safer products. Indian production of foreign technical materials.
Fertilizers	Better agronomic practices for farmers, lower costs of fertilizer production.	$2.2 million (DST)	
Agricultural Machinery	Increase power of tractors keeping cost low. Adjust gears, brakes for hauling on road	$5.6 million (DST)	
Poultry breeding	Breeds adapted to Indian conditions	$3.2 million (survey)	Increased FCR and eggs per bird
Dairy research	Buffalo & cow breeding & management	$1.7 million (DST)	
Vaccines, vet. Pharmaceuticals	Produce vaccines for new diseases and testing foreign products	$2.72 million (DST)	Vaccine for new type of Hepatitis, approval of vet. Pharmaceuticals
Feed	New ingredients, reduce anti-nutritional factors, and identify useful additives	$300,000 (survey)	
Food Processing +Sugar+Oilseed		$13.0 million (DST)	

Sources: Survey by authors and Department of Science and Technology. *Research and Development Statistics 1994-95* New Delhi 1997.

Table 3: Research Expenditures by Private Firms and SOEs

	Research Expenditure (millions of 1995$s)[1]		% SOE[2] in 1994-95	Increase (percent)
	1984-85	1994-5		
Seeds	1.33	4.93	0	271
Agricultural Machinery	3.70	6.48	13	75
Fertilizers	6.80	6.65	67	-2
Pesticides[3]	9.00	17.02	15	89
Veterinary pharmaceuticals[4]	0.90	2.72	5	203
Sugar industry	0.90	2.49	1	177
Food processing	1.27	10.33	1	712
Vegetable oil processing	0.07	0.14	0	99
Total	23.97	50.75	16	112
Public Research	206.22	347.90	---	69

Notes: 1. Exchange rate Rs31.4=$1.00.

2. SOE: State Owned Enterprises.

3. Pesticides are calculated as 30 per cent of chemicals (other than fertilizer) research which is based on the assessments of each chemicals firms research by Dr. B.P.Srivastava, former head of research at Pesticides India and Union Carbide India.

4. Veterinary pharmaceuticals are calculated as 5 per cent of pharmaceutical research.

Source: Seed expenditures Ramaswami, Pray and Kelley (1999); rest from Department of Science and Technology.

Table 4: Market Shares and R&D Expenditures of Major Firms: Various Product Groups

Product	Name of the Company	Market Share		R&D Expenditure in 1996/97 (Rs Million)			R&D/Sales	
		1991/92	1996/97	Capital	Current	Total	1991/92	1996/97
Animal Feed	Godrej Agrovet Ltd		8.21	0.5	3.4	3.9	neg[2]	0.18
	Hindustan Lever Ltd	1.04	10.29	120.9	227.6	348.5	0.66	0.45
	Western Hatcheries	0.04	2.34	0.0	1.6	1.6	0.08[4]	0.10
Flour Milling	NEPC Agro Foods		2.32	0.0	0.1	0.1	0.31[1]	neg
	DCW Home Products		0.37	0.0	0.0	0.0	0.22[4]	0.00[3]
Flowers	Century Textiles & Industries Ltd		12.97	0.1	25.9	26.0	0.14[1]	0.15
	Lakshmi Machine Works Ltd		6.25	31.1	32.0	33.1	0.23	0.61
Pesticides	Bayer (India)	8.39	8.27	0.1	14.6	14.7	0.52[4]	0.33[6]
	Excel Industries Ltd	7.97	5.15	1.2	37.4	38.6	0.96	1.06[6]
	Hindustan Insecticides	4.57	3.83	0.3	7.6	7.9	0.00	0.60
	Hoechst Schering AgroEvo India Ltd		6.63	0.0	9.1	9.1	0.55[3]	0.40[6]
	Modipon Ltd	3.27	3.51	1.0	3.8	4.8	1.11[5]	0.15
	PI Industries	3.54	3.41	3.3	1.4	4.7	0.52	0.32
	Rallis India	9.65	11.29	12.8	94.8	107.6	0.77[1]	0.92[6]
	Searle (India)	2.57	3.61	25.7	15.4	41.1	0.66[1]	2.33
	United Phosphorus	0.05	9.15	1.3	12.3	13.6	0.52[1]	0.35[4]

Table 4 contd

Product	Name of the Company	Market Share		R&D Expenditure in 1996/97 (Rs Million)			R&D/Sales	
		1991/92	1996/97	Capital	Current	Total	1991/92	1996/97
Marine Products	ITC Ltd	0.77	0.67	34.5	40.4	74.9	0.08[2]	0.24[6]
Poultry	Venkateshwara Hatcheries	82.01	52.00	0.0	10.7	10.7	1.94[2]	0.99[3]
	Venkateshwara Research & Breeding Farm	-	5.50	6.3	33.6	39.9	36.68[4]	39.35
	Western Hatcheries	17.99	24.7	0.0	1.6	1.6	0.08[4]	0.10
Tractors	Bajaj Tempo	-	0.01	11.0	93.8	104.8	2.34[1]	1.78
	Eicher Ltd	8.00	7.55	133.4	42.4	175.8	0.19	3.09[6]
	Escorts Ltd	31.02	19.41	16.0	83.8	99.8	0.00	0.60
	HMT Ltd	9.04	8.25	0.3	90.9	91.2	1.86	0.99
	Mahindra & Mahindra Ltd	17.30	24.54	0.0	279.2	279.2	0.19	0.83[6]
	Punjab Tractors	7.43	13.38	2.6	23.6	26.2	0.38[2]	0.33[6]
	Tractors & Farm Equipment	14.52	18.55	0.4	19.7	20.1	0.20[1]	0.23

Source: CMIE (1998); CMIE electronic data base.
Notes : neg = Negligible (< 0.01).
1. For the year 1992-93; 2. For the year 1993-94; 3. For the year 1994-95; 4. For the year 1995-96; 5. F or the year 1990-91; 6. For the year 1997-98.

Table 5a: Market Size and Market Shares - Fertilizer Industry

Name of the Product	Market Size (Value) (Rs Billion)		Growth in Market Size (%)	Market Share of the Top 10 Companies	
	1991/92	1996/97	1991 to 1997	1991/92	1996/97
Urea	40.9	84.5	106.6	67.6	72.8
Phosphate Fertilizers	4.8	8.5	79.5	52.2	62.2
Ammonium Nitrate[1]	.2	1.6	688.3	100.0	100.0
Other Nitrogenous Fertilizers	25.1	5.4	113.7	98.1	99.7
Di-Ammonium Phosphate (DAP)	21.3	26.8	25.7	82.2	85.0
Mixed & Complex Fertilizers other than DAP	11.7	27.5	135.0	95.7	98.4

Source: CMIE (1998)
Note: 1. For all the 7 companies in the product group.

Table 5b: R&D Expenditures of Major Firms - Fertilizer Industry

Name of the Company	R&D Expn. in 1996/97 (Rs millions)	R&D/Sales (Percent)	
		1991/92	1996/97
Deepak Fertilisers & Petrochemicals Corpn Ltd[a]	15.7	0.02[2]	0.54
Deepak Nitrite Ltd[a]	6.5	0.31	0.52
Dharamsi Morarji Chemical Co. Ltd[a]	13.8	0.33	0.64
EID-Parry (India) Ltd[a]	42.1	NA	0.49[6]
Fertilizers & Chemicals. Travancore Ltd[b]	5.4	0.08[1]	0.05
Godavari Fertilizers & Chemicals Ltd[c]	0.0	0.06[1]	0.00
Gujarat Narmada Valley Fertilizers Co. Ltd[c]	5.4	0.02[2]	0.04
Gujarat State Fertilizers & Chemicals Ltd[c]	54.9	0.51[1]	0.31
Hind Lever Chemicals Ltd[a]	0.0	0.28[1]	0.00
Indian Farmers Fertilizer Co-Op. Ltd[d]	0.0	neg[3]	0.00
Jay Shree Tea & Inds Ltd[a]	1.3	0.07[4]	0.06
Madras Fertilizers Ltd[b]	1.3	0.00	0.02
Mangalore Chemicals & Fertilizers Ltd[a]	0.5	0.00	0.02
Oswal Chemicals & Fertilizers Ltd[a]	0.0	0.11[6]	0.00[4]
Rama Phosphates Ltd[a]	1.2	0.00	0.05
Rashtriya Chemicals & Fertilizers Ltd[b]	10.3	0.06[2]	0.08
Southern Petrochemical Ind. Corp. Ltd[a]	78.5	0.39[1]	0.39[6]
Tata Chemicals Ltd[a]	51.8	0.07[3]	0.35
Tuticorin Alkali Chemicals & Fertilizers Ltd[a]	2.6	0.24[3]	0.23
Vam Organic Chemicals Ltd[a]	14.4	0.55[1]	0.58
All firms	305.7	0.15	0.19

Source: CMIE electronic data base.

Notes: 1. For the year 1992-93; 2. For the year 1993-94; 3. For the year 1994-95; 4. For the year 1995-96; 5. F or the year 1990-91; 6. For the year 1997-98.
a) Private sector firms; b) Public sector firms; c) Joint sector firms; d) Cooperative sector firms.

Table 6: Import of Agricultural Inputs

	Seed Imports in Tons					Fertilizers Imports	
Year	Cereals (Maize, sorghum, millets)	Pulses	Oilseeds (primarily sunflower)	Vegetable Seed	Total	Lakh Tonnes	% of total Consumption
1988-89	0.64	---	0.11	11.34	14.14	16.08	14.6
1989-90	0.13	0.02	0.14	82.52	82.81	35.14	30.6
1990-91	0.80	---	5.09	77.59	83.50	27.58	22.0
1991-92	3.37	---	373.66	51.33	428.39	27.69	21.8
1992-93	1.73	0.05	22.50	121.31	148.08	29.76	24.5
1993-94	0.76	---	58.32	170.02	235.06	31.67	25.6
1994-95	2.19	0.01	33.46	414.34	459.91	29.65	21.9
1995-96	---	---	---	---	---	39.55	28.5

Source: Ministry of Agriculture, Government of India (1998)

Table 7: Proposals Approved by Foreign Investment Board, 1991-97

Product Category	Export-oriented Units	Holdings	Licensing	Technology	Financial	Equity Flows (Million Rupees)
Animal & Animal Products	20	0	9	2	38	445
Agri. Products (except Flowers)	40	0	40	0	73	838
Flowers	157	0	11	1	111	43,236
Agricultural Products (Total)	197	0	51	1	184	44,074
Fats, Oil, etc.	18	0	9	0	29	1,622
Food Products	8	2	27	2	61	21,057
Meat Preparations	41	0	14	1	74	661
Dairy Products	1	0	1	0	12	5,269
Cocoa	1	0	5	0	14	1.685
Instant Semi-processed Foods	47	1	11	0	71	8,316
Vegetable Fruits	108	0	9	0	124	1,327
Beverages	5	1	17	0	48	49,765
Other Foods	20	3	11	0	42	10,541
Food Industry (Total)	249	7	104	3	475	100,243
Food Processing Machinery	0	0	16	0	19	362
Fertilizers	1	0	6	0	7	2,477
Pesticides	0	0	6	0	8	239
Agricultural Machinery	0	0	15	0	11	2,292
Agricultural Inputs (Total)	1	0	27	0	26	5,008
Total (Agri. Industries)	507 (32.05)	7 (4.4)	247 (15.6)	6 (0.4)	815 (51.5)	150,969
Total (All Industries)	1225	42	2762	43	4723	1,226,696
Agriculture Related/Total Investment (%)	41.4	16.7	8.9	14.0	17.3	12.3

Source: SIA Data Base, Ministry of Industry, Government of India.

Table 8: Increases in Efficiency Due to Poultry Research

	1981	1996
Broilers		
Days to 1.5 kg.	47	38
Body Weight		
Feed Conversion	2.5	1.85
Mortality % .	3.0	2.0
Layers		
Eggs Production	270	315
to 72 weeks		
Feed Efficiency	145	134
Mortality % (72 weeks)	8.0	6.0

Source: Venkateshwara Hatcheries Limited

Table 9: Summary of Impact of Private and Public Hybrids on Yields

Crop & State	PVT	HYV	Estimation Technique
Sorghum, Andhra Pradesh	.0027[1] (1.92)	-.09 (1.54)	Random Effects
Sorghum, Karnataka	.0083[2] (2.34)	.44[2] (2.99)	Random Effects
Sorghum, Maharashtra	0.008 (1.54)	.23[1] (1.88)	Fixed Effects
Pearl Millet, Andhra Pradesh	0.0007 (.27)	-.084 (1.1)	Fixed Effects
Pearl Millet, Karnataka	-.0002 (.11)	.39[2] (3.2)	Random Effects
Pearl Millet, Maharashtra	.01[1] (1.91)	.02 (.32)	Fixed Effects
Maize, Andhra Pradesh	.023[2] (2.27)	-.11 (.7)	Fixed Effects
Maize, Karnataka	.005 (.48)	.77[1] (1.7)	Random Effects
Maize, Maharashtra	.04[2] (3.33)	.13 (.96)	Fixed Effects

Source: Ramawamy, Pray, and Kelley 1999.
Notes: t-values in parentheses.
1. Denotes estimates significant at the 10% level.
2. Denotes estimates significant at the 5% level.

Table 10: Impact of Mergers and Acquisitions on U.S. and Indian Seed Industries

Parent Co. (main business)	U.S. Seed Companies	Indian Seed Companies
Monsanto (agricultural chemicals, pharmaceuticals, food additives)	Holden's DeKalb Asgrow (soybeans and corn) Stoneville Delta & Pineland. Cargill International Seed Business	MAHYCO (50-50 cotton Monsanto; 26% of MAHYCO) E.I.D.Parry (corn, sorghum and sunflower with DeKalb), Cargill
Du Pont (chemicals, oil, fiber, & food)	Pioneer	Southern Petrochemicals (Pioneer)
AgrEvo (agricultural chemicals)	AgrEvo PGS	Proagro (PGS) Sunseeds
Novartis (agricultural chemicals & pharmaceuticals)	Northrup King	Novartis (was Sandoz)
Zeneca (agricultural chemicals & human health)	Advanta	ITC/Zeneca
Empresas La Moderna (Mexican owned conglomerate)	Seminis Peto Asgrow (vegetables) George Ball	MAHYCO (Asgrow), Nath Slius, Indo-American Seeds

Table 11: Key Policies Before and After Reforms

Industry	Before	After
Seed	• MRTP&FERA Cos. Not allowed • Veg.seed restricted • Other seed imports banned	• All firms allowed • Veg.seeds Open General License • Limited imports of commercial seed of coarse grains and oilseeds. Imports of wheat and rice only by government
Agricultural Machinery	• No imports • Equipment reserved for small scale industry • Licenses required for production and expansion	• No imports • Anyone can produce equipment • Licenses not required for production and expansion
Pesticides	• Active Ingredient(AI) could be imported for limited time with 150-180% tariff. then had to be manufactured in India • No imports of formulated products except emergency • 50% of AI must be formulated by small scale sector • Licenses required for production and expansion • New product registration took 5 to 10 years	• AI imports with 35% tariff • No imports of formulated products except emergency • No reservation of AI for small scale sector • No licensing requirement for expansion • New product registration takes 3-4 years
Poultry	• Grandparent imports restricted • Parent imports banned	• Grandparent imports OGL • Parents imports banned