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## The impact of economic reforms on R&D by the Indian seed industry

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### Abstract

Declining support for public research and advances in technology and new forms of legal protection have induced more private agricultural research. In developing countries, this has sparked a debate about appropriate policies regarding private research. In this context, we examine empirically the consequences of reforms in India's seed policies which loosened various restrictions on the private sector. The period since the reforms has shown a remarkable increase in R & D effort and an increase in the number of private technology suppliers. We argue these changes were largely due to policy reforms. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords:* Seed; Agricultural research; India; Private sector; Policy reform

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### Introduction

In both developed and developing countries support for public sector agricultural research is declining. Most developed countries have enacted policies to encourage private firms to invest more money in research to make up for public funding. These policies include stronger intellectual property rights, encouraging collaboration

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between public and private research institutions, reducing regulations on new technology, and in some cases selling public research assets to the private sector.

In developing countries also support for public agricultural research is declining and private research is increasing (Pray and Umali-Deininger, 1998), but there is considerably more debate about whether the government should actively encourage private research and technology transfer or not. Stronger patent systems and plant breeders rights have been agreed to by most countries as part of the Uruguay Round of GATT, but in Asia they have met an outcry of popular resistance. While most Latin American countries have privatized their parastatal input supply firms and allowed multinationals to play a major role in the agricultural input industries, many Asian and African countries have had limited privatization. They continue to use large parastatals for supplying fertilizer and seed and severely restrict the participation of foreign firms in the agricultural input industry.

The arguments against encouraging foreign firms and private firms to invest in agricultural industries have been that they will not do research to adapt foreign technology to local conditions and that they will reduce competition in the industry by either buying up local firms or by using their superior marketing know how to drive local firms out of business. On the other hand, those in favor of encouraging private research and technology transfer argue that an open environment for foreign investment and collaborations will stimulate industry competition, technology transfer and industry R & D. This will lead to improved technology for farmers and consumers will be the ultimate beneficiaries.

An opportunity to empirically study these issues is provided by the reforms in the policies towards the Indian seed industry. Till the late 1980s, the Indian seed industry was tightly regulated in terms of (a) entry by large firms, whether domestic or foreign, and (b) private imports of seed, whether for commercial or research purposes. A series of policy changes relaxed these regulations. Since 1991, the policy environment has been drastically different.

Several recent studies have looked at the impact of these policy changes and the privatization of the Indian seed industry. Pal, Singh and Morris (1998) in a detailed study of the maize seed industry found that past government seed supply had made a valuable contribution but that the recent privatization of the industry has improved its efficiency. Tripp showed that local private firms and coops tend to push new rice varieties more rapidly than public seed corporations. Selvarajan, Joshi, and O'Toole (1999) found that foreign firms were an important source of biotechnology tools and information for the Indian seed industry. However, none of these studies are able to provide quantitative evidence of the impact of policy change on private sector R & D for the Indian seed industry as a whole.

Using a unique data set on the structure, research and sales of private seed firms at two points in time, 1987 and 1995, this paper examines the response of the Indian seed industry to the policy reforms of the late 1980s. In particular, we ask whether these reforms led to an increase in R & D. Furthermore, was the outcome an industry structure which was more competitive or one dominated by a few large firms?

## Seed Industry Reforms and Data

Before the late 1980s, the private seed industry in India was regulated by two sets of industrial policies – those that applied to the entire industrial sector and those that were specific to the seed sector. There were changes in both these types of policies.

As for the economy wide policies, they applied to industrial licensing and foreign investment. By these policies, production capacities were regulated by a system of licenses. Secondly, there were severe curbs on the entry of foreign firms. Joint ventures with a majority holding vested in foreign firms were very difficult. In 1991, the industrial licensing system was abolished. In addition, entry of foreign firms was made easier. Approvals for Indian subsidiaries up to 51 percent foreign equity were automatic. Permissions were still required for higher foreign equity but in practice were granted more frequently than in the past.

In the seed sector policy, two changes occurred in the late 1980s. Before 1987, large domestic firms (in terms of assets) as well as foreign firms were prohibited from entering the seed sector. In official parlance, production in the seed industry was reserved for the “small-scale” sector. In 1987, the seed industry was “de-reserved”. Large domestic firms and foreign firms (with equity stake in joint ventures not more than 40 percent) were allowed entry. The other key change was the new seed industry development policy in 1988. Before that, commercial seed imports by private agents were banned. The new policy allowed unrestricted imports of all vegetable seeds (except for a small flat tariff and phytosanitary regulations). The import of seeds of coarse cereals (maize, sorghum and millets), pulses and oilseeds was allowed for two years by companies which have collaborative agreements provided the foreign supplier agreed to supply the parent lines within the two years. Imports of seed for wheat and rice continued to be disallowed.

The empirical basis for our analysis of the impact of these reforms on R & D are two surveys of private seed firms conducted in 1988 and 1996 which collected data for the years 1987 and 1995. In the 1996 survey, questionnaires were sent out to approximately 160 seed companies that had links with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), were members of the Seed Association of India, or were identified by other firms. 49 companies responded to the survey. These included almost all of the major seed firms, accounting for about 75 percent of private commercial seed sales and 38 percent of public and private seed sales in India. Using a similar methodology, the 1988 survey elicited responses from 23 firms that included all the large private firms that were active in the mid-1980s (see Pray et al 1991). 13 firms included in the 1988 survey also participated in the 1996 survey. Of the remainder, three firms (all with negligible R & D) had exited the industry by the time of the second survey while seven firms accounting for less than 1 percent of the total R & D in 1987 did not respond to the second survey.

In both surveys, questions were asked about firm characteristics and activities in the previous year. Information was collected about foreign collaboration, value of sales, date of entry into the business, value of imports, and R & D. The R & D details included the number of experiment stations, number of research staff, expenditure,

allocation between different crops, and the import of research seed. Because of the timing of the surveys, they provide a view of the industry before and after reforms.

### Findings: Policy Reforms and R & D

Between 1987 and 1995, R & D expenditures grew from Rs. 17.3 million to Rs. 155 million which is an increase of more than 800 percent. In real terms (at 1981/2 prices), the increase is from Rs. 13.1 million to Rs. 46.5 million which is a growth of more than 250 percent. Both surveys also asked questions about other inputs of R & D effort such as technical personnel and size of experiment stations. Between the two surveys, the number of researchers with Ph.Ds jumped from 31 to 111 while the number of research scientists with MSc's increased from 45 to 140. These increases were matched by growth in the area under experiment stations which expanded from 400 to over 1200 hectares. Thus, by every measure (rupee investments, technical personnel, size of experiment stations), R & D effort in the private seed industry seems to have tripled within a short span of about 8 years. How much of this was due to seed policy reforms?

As described earlier, seed policy changes were directed at relaxing (a) seed imports and (b) entry into the industry by foreign and large domestic firms. We discuss the effect of each of these in turn.

#### Imports

The impact on seed imports is shown in Table 1. As can be seen, seed imports are important only for vegetables. There have been negligible imports in the case of coarse cereals and pulses. In oilseeds, the primary imports were sunflower seed. Even here, at its peak (in 1991–92), imports accounted for only 7 percent of commercial sales. These findings are corroborated in the 1996 survey. Only 4 firms report commercial import of seeds. In each case, the imports are for vegetable seeds. Thus,

Table 1.  
Seed Imports in Tons<sup>a</sup>

	Cereals (Maize, sorghum, millets)	Pulses	Oilseeds (primarily sunflower)	Vegetable Seed	Total
1988–89	0.64		0.11	11.34	14.14
1989–90	0.13	0.02	0.14	82.52	82.81
1990–91	0.80		5.09	77.59	83.50
1991–92	3.37		373.66	51.33	428.39
1992–93	1.73	0.05	22.50	121.31	148.08
1993–94	0.76		58.32	170.02	235.06
1994–95	2.19	0.01	33.46	414.34	459.91

<sup>a</sup> Source: Ministry of Agriculture, unpublished documents.

Table 2  
Number of Firms that Import Research Seed<sup>a</sup>

Crop	Number of Firms
Sunflower	12
Vegetables	9
Sorghum	9
Maize	8
Cotton	8
Rice	4
SSG	4
Pearl Millet	1
Others	4

<sup>a</sup> Source: Survey

except for vegetables, commercial seed imports have not been an important instrument for technology transfer. This is not surprising since it is only in vegetables that the new policy allowed unrestricted imports (subject to tariffs).

Probably what has been more significant is not the volume of commercial seed imports but the imports of germplasm. In the 1996 sample, 22 firms report imports of seed for research purposes. In order of importance, sunflower, sorghum, maize and cotton are the field crops in which most firms reported that they imported research seed. Table 2 reports the break-down in detail. In terms of accounting for the increase in R & D, imports of research seed rather than commercial seed are likely to have been important.

### Entry

We now turn to the effect of policy on entry into the seed business. Out of the 47 firms for which we have information, 20 firms entered the industry after 1987. Their expenditures on R & D in 1995 totaled Rs 60.4 million or about 44 percent of the increase in R & D expenditures between the two surveys. Out of these 20 firms, 5 firms would not have been allowed entry into the industry under the old policies, i.e., they were either large domestic firms or foreign firms. We can call these five firms the large entrants and the other 15 entrants as small entrants. Table 3 summarizes the average characteristics of these two groups of entrants. The large

Table 3  
Characteristics of Entrants<sup>a</sup>

	Average Sales	Average Number of Employees	Average R&D Budget
Large Entrants	Rs. 174 million	70	Rs. 10 million
Small Entrants	Rs. 17 million	14	Rs. 0.7 million

<sup>a</sup> Source: Calculated from survey data

entrants account for the bulk of R & D of the new entrants. The R & D budgets of the five foreign and large domestic firms that entered the industry since 1987 adds up to nearly Rs 50 million which is 36 percent of the increase in R & D.<sup>1</sup> While the estimate is a lower bound on the contribution of reforms, it does mean that reforms did make a major contribution to the increase in R & D effort.

We now turn to examining whether reforms had a role in (a) inducing the entry of the remaining 15 firms and in (b) the expansion of R & D budgets of the incumbent firms.

Since earlier policies did not prevent the small entrants into the industry, their entry cannot be directly due to "de-reservation" or the reforms allowing foreign investment. Out of these 15 firms, 10 had R & D programmes. These were small employing on average less than three technical personnel and with an average budget of about Rs. 1 million. 5 of these firms imported research seed primarily in vegetables and sorghum. Table 4 shows the crops in which these small entrants had plant breeding programmes. They concentrated on pearl millet, sorghum, and cotton which are hybrids in India and in which Indian public research programmes are strong. In sum, the spurt of entry by small firms does not seem to be directly related to the seed sector reforms but is probably related to opportunities thrown up by the growing market for private hybrids. The evidence suggests that the viability of small research programmes depend on access to research seed whether from publicly funded institutions or from foreign firms.

#### *Expansion of R & D by Incumbent Firms*

In 1995, incumbent firms (i.e., firms that were in the industry before 1987) spent Rs 94.5 million on R & D. This was nearly 61 percent of total spending. The increase in the budgets of incumbent firms amounts to Rs 77 million, which accounts for 54

Table 4  
Plant Breeding Programmes of Small Entrants<sup>a</sup>

Crop	Number of Firms
Pearl Millet	8
Sorghum	6
Cotton	6
Sunflower	5
Rice	3
Maize	2

<sup>a</sup> Source: Survey

<sup>1</sup> It would, of course, not be correct to say that Rs 50 million of R & D expenditure is due to reforms alone. Although reforms allowed the entry of these firms, the amounts that they choose to spend on R & D depend on various factors which are not directly affected by reforms. It is, however, correct to say that in the absence of reforms, R & D expenditures would be lower by at least Rs. 50 million.

percent of the increase in industry R & D budget. We believe that the incumbents were forced to increase their research by the threat that the new entrants with large research investments would capture the Indian seed market. The evidence from the survey does not conclusively prove this argument, but it does eliminate the two main competing explanations – growing seed demand and greater ability of firms to capture the gains from research through hybrids.

Of the 27 incumbent firms, 7 firms had some kind of collaboration with a foreign firm. While in some instances, the collaboration was purely technical, in other cases, the collaboration also included equity holding by the foreign partner. These 7 firms could be called the large incumbents since on average, they recorded sales of more than Rs. 300 million and employed nearly 350 people. Table 5 shows how these characteristics contrast with those of the other incumbents, which we shall call as the small incumbents. The average size of the R & D budget of a large incumbent firm was Rs 11 million and together the large incumbent firms account for nearly 80 percent of the R & D spending of all incumbent firms. Thus, incumbent firms with foreign collaboration tend to have large R & D programmes. This could be due to a combination of two factors. First, the availability of frontier research expertise within the foreign partner may increase the productivity of R & D in India. Second, since these incumbent firms tend to be large, large firms may attract foreign collaborations since their size confers advantages in market access and local research skills.

The expansion of R & D investments by incumbent firms would not have been disallowed by earlier policies and therefore cannot be directly attributed to policy reform. However, by permitting the possibility of entry by large domestic and foreign firms, the new policies would have called for a response by the incumbent firms. How much of the R & D by the large incumbents is then a strategic response to entry? To answer this question, we would have to control for other independent factors, which could have stimulated greater investment in R & D.

Two such factors affect the gains from R & D. Firstly, the possibility of higher sales in future might lead firms to spend more on R & D. Hence the increase in R & D expenditures by incumbent firms might just be a consequence of larger expected sales. If future sales are a projection of current sales, we can control for this factor by comparing the ratio of R & D expenditures to current sales across the two surveys. Column 1 of Table 6 reports these figures. They show that in 1995 the seed industry spends more on research for every rupee of sales. Hence even accounting for higher sales, the research expenditures were greater.

Table 5  
Characteristics of Incumbent Firms<sup>a</sup>

	Average Sales	Average Number of Employees	Average Size of R&D Budget
Large Incumbents	Rs 282 million	313	Rs. 11 million
Small Incumbents	Rs. 41 million	72	Rs. 0.9 million

<sup>a</sup> Source: Calculated from survey data

Table 6  
Ratio of R&D expenditures to current sales<sup>a</sup>

	Ratio of R&D Expenditure to Sales	Adjusted Ratio
1987 Survey mean	3.6	3.6
1996 Survey mean	6.9	5.2
Difference in Mean Ratios	3.3(1.91)	1.6(1.68)

<sup>a</sup> Note: The first column reports ratios unadjusted for rice and rapeseed R&D. The second column reports figures adjusted for rice and rapeseed R&D. The figure in parentheses is the t-statistic for the null hypothesis that there is no difference in R&D to sales ratios between the two periods.

The second factor that may have caused an increase in R & D expenditures has been the development of hybrids for rice and rapeseed. In 1987 commercial hybrids of rice and rapeseed were not thought to be commercially viable, but in the early 1990s scientific breakthroughs showed that they were possible. As is well known, hybrids enhance firms' ability to capture part of benefits from research because seed from hybrids cannot be reused by farmers without significant yield deterioration. This ensures that most farmers will buy seed every year instead of every 4 to 5 years as they would with pureline varieties.

To control for stronger intellectual property rights in rice and rapeseed, we delete the R & D expenditures on rice and rapeseed from the total in 1996 and then compare the ratio of the resulting magnitudes to sales between the two periods. Column 2 of Table 6 reports these figures. We see that even after controlling for sales and the higher appropriability of research, R & D expenditures in 1996 are higher than in 1987. The difference is significant at the 10 percent level if the alternative hypothesis is that the two ratios are different. The difference is significant at the 5 percent level under the more relevant alternative hypothesis that the ratio of R & D expenditures to sales is higher in 1995 than in 1987.

The growth in R & D intensity not explained by growing markets and rice and mustard hybrids can be at least partially explained by competitive pressures from abroad. For example, competitors of the largest Indian seed company — MAHYCO — were no longer Mahendra Hybrids, Nath Seeds, and Proagro, they were Novartis, Monsanto, Pioneer Hi-Bred, and Hindustan Lever. The choice seemed to be either do research to produce competitive hybrids or sell out. Many of the incumbents chose to increase research.

### Competition and Industry Structure

In 1987, at the time when the first changes in seed policies were initiated, the industry consisted of a few large firms and a number of small firms.<sup>2</sup> The large

<sup>2</sup> The large firms were "large" only in relation to the industry. They were not large in relation to the rest of the economy. Indeed, as mentioned earlier, the large firms in the economy were not allowed to operate in the seed sector.



firms accounted for the bulk of R & D expenditures. Nearly 90 percent of all R & D expenditure was by the largest 6 firms. Most of this was concentrated in the top 3 firms whose R & D expenditures were 74 percent of the total.

In 1995, at the time of our second survey, the industry continued to be divided into large and small players with the former accounting for most of the R & D. However, in other respects, the picture changed markedly. The largest six firms now account for 60 percent of R & D, while the share of the top 3 drops to 38 percent. This outcome is directly due to the expansion of the number of firms with significant R & D programmes. Another way of seeing this is that 75 percent of industry R & D is now shared by 10 firms while 3 firms conducted 75 percent of the R & D in 1987.

The seed industry today is, therefore, characterized by a greater number of suppliers of technology. Of the top 10 firms ranked by R & D expenditures, 4 firms were foreign owned or large Indian firms that would not have been able to enter the Indian seed sector without the industrial policy reforms. The other 6 firms are what we identified earlier as the large incumbents. As we argued then, these incumbents have had to increase their R & D expenditures to counter the lowering of entry barriers by policy reforms. Since all of these firms have collaborations with foreign firms, technology transfers appear to complement domestic R & D. Thus, while R & D by incumbent firms might be a strategic response to entry, a permissive policy towards collaborations with foreign firms has also made domestic R & D more productive. These effects seem to be more important for the smaller of these incumbents because the gap in R & D spending between the largest and smallest of the top 6 (ranked by R & D expenditures) or even more dramatically for the top 10 firms was substantially reduced between 1987 and 1995.

The increase in the number of technology suppliers is also reflected in sales concentration ratios. The standard measure of concentration, the four firm concentration ratio, dropped from 69 percent of private sales in 1987 to 51 percent of private sales in 1995.

In sum, the market for private produced hybrid seeds was small and dominated by a few firms in 1987. By 1995, the market was expanded considerably and consisted of a number of technology suppliers. Policy reforms had much to contribute to the expansion as well as the broadening of industry structure.

### **Recent Developments**

Since 1996 concentration and foreign investment in the seed industry have increased. The increase in competition has been primarily due to Monsanto's purchases of seed companies in the U.S. and U.K. Monsanto bought DeKalb and Cargill's international seed business. Each of these companies had seed businesses in India which have been consolidated into Monsanto's agricultural business in India. The increase in foreign investment in the seed industry has primarily been due to large multinational seed companies purchasing shares in Indian seed companies that were previously independent and bought out the shares of their joint venture partners

in seed companies. Aventis bought up the rest of Proagro which they had already partially owned. Pioneer/DuPont has bought out the seed part of their joint venture partner, SPIC. In addition, Monsanto bought 26 percent of MAHYCO and started a 50:50 joint venture with them on hybrid cotton. One US based venture capital company Emergent Technology purchased an important Indian seed company Mahendra Seed Company.

Despite this consolidation the seed industry still appears to be competitive. In major field crops Monsanto competes with Pioneer, Syngenta, Aventis, ITC/Zeneca, Mahendra Seeds, Nath, to a certain extent MAHYCO, and some of the state seed corporations. In hybrid vegetable seeds Syngenta, Aventis, Indo-American, Rallis, Nath, MAHYCO and other companies compete for market share.

The major impacts of these changes appears to be to continue the trends described in the earlier part of this paper – more private R & D investment, particularly by foreign firms. For example, Monsanto has developed a 70-scientists research facility at the Indian Institute of Science, Bangalore (Monsanto 2001). In addition, almost all of the major Indian firms now have foreign partners or collaborators so that they can get access to new technology. These companies will continue to concentrate their research on hybrids: corn, cotton, sunflower, cotton, sorghum, pearl millet, hybrid rice, and hybrid vegetables.

We would expect to see hybrid seed prices rise which in part will reflect higher quality seed and pay off the larger investments in research. This price rise will continue to be mitigated by competition from public and private companies and from farmers who will continue to produce open pollinated varieties and second-generation seeds from hybrids (Singh, Pal, and Morris 1995) if companies try to push seed prices too high.

### **Concluding Remarks**

The late 1980s and the early 90s saw seed policy reforms as well as economy wide reforms that made the seed industry more open to entry from foreign firms and large domestic firms. In this paper, we empirically examined the effect of an “open” seed policy on technology development in the Indian seed industry. We did this by comparing the results of two surveys on the Indian seed industry in 1988 and 1996.

The seed industry in India can be divided into a few relatively large firms and a number of small firms. R & D expenditures are primarily by large firms. Because of reforms, several large firms entered the seed industry. In the absence of reforms, these firms would not have been able to enter and thus the R & D expenditures would have been lower. This is the direct effect of reforms and was worth Rs. 50 million in R & D expenditures or about one-third of all R & D expenditures. However, most of the increase in R & D between the two surveys was because of higher spending by large incumbent firms. As we showed, some of it was undoubtedly a strategic response by these firms to the competition from the large entrants. Hence this was the indirect impact of firms. Taken together, it is likely that more than 50 percent of the observed increase in R & D is due to reforms.

There was another outcome as well – a more competitive seed industry. The entry of research intensive firms and the response that it drew from some of the incumbents led to greater number of technology suppliers in 1995 and less market concentration of the seed industry. Although foreign companies increased their investment in India firms since 1995, it does not appear that a great deal of concentration took place other than the consolidation of DeKalb and Cargill in to Monsanto and Monsanto purchase of part of MAHYCO.

The period of reforms also saw the entry of numerous small firms, some of whom had small R & D programmes as well. The survey information does not allow us to establish a link between their entry and policy reforms. Perhaps, the small firms benefited by free-riding on the market development by large firms. Perhaps, they were able to exploit market niches by using imports of breeder seed. Yet, it seems remarkable that such entry should occur in this period of competition from existing and entering large firms. It suggests that the advantages from the expanding market for hybrid seed (in part due to promotion activities of the large firms) more than compensated for the disadvantages of competing against technology-rich multinational companies.

The implications of this analysis for Indian policy makers are that reducing restrictions on investment by large Indian and foreign firms and reducing restrictions on research inputs such as plant germplasm can lead to more local agricultural research and more competition. Restrictions on seed imports and exports remain in place. It is not clear that these restrictions protect important local businesses or have any benefit to farmers. However, this paper does not provide any evidence on either side of this issue. Finally, the growth of private research suggests changes in public research resources allocation. Tables 2 and 4 suggest that the public research may be able to reduce the amount of resources that they are investing in breeding new varieties of maize and sunflower and concentrate their scarce research resources on research on crops such as wheat, pulses, oilseeds such as groundnut, and rice. The public sector could also reallocate funds to basic research, which could make both public and private applied research more productive.

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