Understanding the Seed Industry: Contemporary Trends and Analytical Issues

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1. Introduction

Historical analyses show that paths of technological development in agriculture are not uniquely determined. Usually, there is a set of technological possibilities and the trajectory of technological change can either emphasize labour-saving technologies broadly associated with mechanization or stress land-saving technologies broadly associated with biological innovations.[1] In their work, Hayami and Ruttan (1985) ascribe to resource endowments the role of being the principal determinant of the particular pattern of technological change. In particular, in labour-abundant and land-scarce countries such as ours, biological innovations occupy the central place in technology development.[2] As a result, agricultural growth in India and similarly endowed countries stems primarily from rising productivity of land.

The generation and diffusion of new yield improving technologies is therefore critical in sustaining agricultural growth. As varietal development is embedded in seeds, they are the principal vehicles for delivering new technologies to producers. Indeed, new seeds were the basis for the so-called green revolution of the 1960s and 1970s.[3] Although the green revolution technologies are criticised for their environmental impacts, it is hard to think of any other policy, institutional reform or technology that has had a comparable impact on rural wages and poverty in India.

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[1] The distinction should not be overdrawn. In particular, varieties can be developed so that the crop is more efficiently harvested by mechanical means.

[2] de Janvry, Sadoulet and Fafchamps (1989) have questioned the existence of a direct link between resource endowments and technological bias. They point out that large farmers face different factor costs than small farmers for labour and capital. As a result, technological development can be labour saving even in countries that are labour-abundant. Their arguments seem relevant for situations where there are large disparities in size of farms such as between ranches and holdings of small farmers.

[3] Other inputs such as water and fertilizers were important as well but principally to exploit the full potential of the new seeds.

Yet the seed industry has been a neglected subject of research especially in relation to the wealth of information on technology adoption and its impacts on farmers. In the past decade or so, a small literature has grown around the subject of seed industry and its related issues.[4] The goal of this paper is to broadly summarise the state of knowledge and to point to some of the analytical issues that deserve research.

2. Structure of Seed Industry

The most important characteristic, if it can be called that, of the seed industry is its heterogeneity in many dimensions. The product segments correspond to all the major field crops and vegetables. With respect to product type, a major distinction is between hybrids and open-pollinated varieties. Seeds of varieties can be reproduced for many generations with little deterioration in quality. As a result, beyond the initial purchase, farmers can multiply their own seed. This is not a viable strategy with hybrids because they suffer noticeable declines in yields in subsequent generations. As a result, hybrid seed tend to be repeatedly purchased. The major cereals of rice and wheat are principally open-pollinated varieties.[5] Hybrids dominate in coarse cereals consisting of sorghum, pearl millet and maize. Hybrids are also important in cotton and oilseeds.

In terms of organization, the seed industry consists of a large public sector and a growing private sector. The public sector consists of the National Seed Corporation, the State Farm Corporation of India and 13 State Seed Corporations. These corporations multiply and market varieties bred by the public sector institutions, i.e., the research

[4] This includes Basant (1995), Morris, Singh and Pal (1998), Tripp and Pal (2000a, 2000b), Turner (1994), Pray, Ramaswami and Kelley (2001) and Shiva and Crompton (1998). Pray and Ramaswami (1991) is an early work surveying the state of seed industry in developing countries.

[5] It is much harder to develop hybrids for naturally self-pollinated crops (e.g., rice, wheat) than for cross-pollinated crops (e.g. maize). Rice hybrids have been developed but have not met market success yet.

institutes financed by the Indian Council for Agricultural Research (ICAR) and the State Agricultural Universities.

There are no firm estimates of the number of private seed firms. Estimates vary from 200 to 500. Private seed firms are heterogeneous with respect to size, research capacity and product segments. Plant breeding research is found in the larger firms. Unlike the public sector, where research is separate from seed production and marketing, these functions are integrated in the private firms. The other striking difference is in product types. The private sector focuses largely on hybrid seed. It is therefore unimportant in the product segments of wheat and rice except as a seller of public varieties and hybrids.[6] On the other hand, the private sector is a major player in the hybrid seed markets of vegetables, sorghum, oilseeds (e.g., sunflower), maize, cotton and pearl millet. In terms of ownership, private firms are closely held and not listed in the stock exchanges although some of the large firms have sold equity to foreign seed companies. Foreign firms maintain a presence through equity stakes in Indian firms, technical alliances or through wholly owned subsidiaries.

Seed firms, whether in the private or public sector, outsource the production of seeds to contract growers. These growers are supplied with the foundation seed that is used to produce commercial seed. The seed industry is one of the earliest examples of contract farming in India.

For the cereal crops of rice and wheat, the principal source of seeds is not the seed industry whether private or public but the farmers themselves. Seed saved from the

[6] However, especially for the large firms, the sale of public varieties and hybrids is not their mainline activity.

preceding crop supplies nearly 90% of requirements in these crops.[7] In some cases, a large farmer or groups of farmers specialize in growing seeds and supply to neighbouring areas. In the case of sorghum, maize and sunflower, the proportions of seed supplied by the commercial seed industry ranges between 25% and 43% (see the estimates of Chopra and Thimmaiah quoted in Shiva and Crompton, 1998).

The value of the seed market is estimated to be close to $ 1 billion (www.worldseed2003.com/invitation.htm). The seed industry was probably half this size in the early part of the 1990s (Shiva and Crompton, 1998). It has therefore grown rapidly in the last decade. Estimates of the share of the private sector range from 60% to 70% (Shiva and Crompton, 1998). Because the private sector sells high value hybrids, their share in value is greater than their share in volumes.

3. Seed Policies and Regulation

The government regulates the seed industry and the seed trade in various respects. The Seed Act of 1966, the Seeds Control Order of 1983, and the Seeds Policy of 1988 are the major components of policy specific to the industry. The seed industry has also been subject to policies relating to industrial licensing and direct foreign investment that are applicable to all industry. There have been two recent developments. In September 2001, the Plant Variety Protection and Farmer's Rights Act came into being. In June 2002, the government announced a new seeds policy that significantly alters the framework of regulation.

[7] These figures vary by crop and by state. See Sidhu (1999) for sources of seed for principal crops in Punjab.

The Seed Act of 1966 and the Seeds Control Order of 1983 provide statutory backing to the system of variety release, seed certification and seed testing. Varieties are released after evaluation at multi-location trials for a minimum of three years. Varieties approved are "notified" which is a prerequisite for certification. While all public sector varieties go through this process, it is not mandatory for private varieties.

Certification is a process that certifies that seed is of a specified variety and is of acceptable genetic purity. Usually, seeds are also tested for physical characteristics such as germination capacity, analytical purity and pathogen levels. Certification requires that that the certifying agency has access to the parent lines of the variety. In India, while all public sector varieties are certified, the process is voluntary for private varieties. Often private seed firms do not submit their varieties for certification either because they do not wish to go through the time consuming process of notification or because they have their own quality control processes. However, uncertified seeds are required to be truthfully labeled listing quality attributes on the label.

The seed control order brings seeds within the scope of the Essential Commodities Act that regulates the marketing of essential items. All seed sales outlets have to be licensed and must observe certain marketing practices such as public display of stocks and prices.

Major changes in this system of regulation are proposed in the National Seeds Policy of 2002. Variety registration (i.e., notification) will now be mandatory for all varieties, new and extant. The evaluation will be done over three seasons of field trials. However, certification will continue to be voluntary. The emphasis on registration in the new seeds policy ties in with the demands of the Plant Variety Protection and Farmer's

Rights Act passed in 2001. This Act provides for plant breeder's rights, which requires extant and new plant varieties to be registered on the basis of characteristics relating to novelty, distinctiveness, uniformity and stability.

Besides regulating quality, the government has also controlled imports and exports of seed. The Seed Policy of 1988 allowed limited imports of commercial seed. Curbs were removed from imports of seeds of vegetables, flowers and ornamental plants. Seeds of coarse cereals, pulses and oilseeds could be imported for upto two years provided this finally led to technology transfer in the form of parental lines/breeder seed. The new policy of 2002 allows imports and exports of seeds of all crops. However, all imported seed is also required to go through the process of registration.

Prior to 1991, the seed industry was also subject to the policies on industrial licensing and foreign direct investment that applied generally. The seed sector was reserved for the small-scale sector and the entry of foreign firms was tightly regulated. These controls have fallen by the wayside as a consequence of the economy wide reforms of 1991.[8]

While the system of mandatory registration will irk private seed firms because of its time consuming process as well as the requirement to trust the registry with their proprietary breeding material, the overall emphasis of the new seed policy seems more favourable to the private sector than in the past. The goal seems to be to facilitate private enterprise rather than to control it.

[8] The policy change occurred in two steps. In 1987, the seed industry was de-reserved allowing the entry of large firms and foreign firms with equity stake in joint ventures of not more than 40%. In 1991, reforms allowed the entry of firms with majority foreign equity.

4. Context for Research

In the past, the public sector was the principal vehicle for the development and diffusion of new seeds. Indeed, the seed industry in India had its beginnings in the early 1960s with the establishment of the public sector National Seeds Corporation. The NSC provided foundation seed, training and technical assistance to state governments and private companies. This was followed in 1969 by the Terai Seed Development Corporation that became the model for state seed corporations established in the 1970s and 1980s.[9] The primary purpose of these and related public sector organizations (such as the state seed certification agencies) was to produce, certify and distribute high quality seeds that were the product of public research. But they also stimulated private sector activity in direct (through distribution of foundation seed) and indirect ways (through the creation of expertise in seed technology, processing and distribution) (Candler, 1995).[10] As the import of commercial seeds was prohibited and since foreign direct investment was not permitted, private sector activity depended on home grown firms. Consequently, it grew in incremental steps focusing first on vegetables and later moving on to sorghum and pearl millet.

The obstacles to private industry were not just their lack of capabilities whether in research or access to capital and technology. There was also lack of confidence, on the part of the government, about leaving these activities to the forces of market. Probably, the most important of all is the fact that with certain kinds of varietal development, the

[9] The Rockfeller Foundation and the World Bank were closely associated with India's seed programme in those initial years through grants, credits and technical assistance. In terms of effectiveness, they probably constitute the best examples of foreign aid.

[10] B.R. Barwale, the founder of MAHYCO, India's largest private seed firm, began his career producing and marketing vegetable seeds developed by ICAR and later graduated to producing hybrid maize with seed supplied by the Rockfeller Foundation that was developed in a joint research programme between ICAR and the Rockfeller Foundation (Padmanabhan, 1998).

innovator cannot appropriate a significant enough share of the gains leaving little incentives for private effort. This is certainly true for seeds of open-pollinated varieties (which includes rice and wheat) that can be reproduced by farmers for their own use or sale to other farmers. On the other hand, this scenario is ideal for public intervention. Not only does public plant breeding fill this gap, the ease of reproduction aids rapid diffusion and adoption. As a result, even in cross-pollinated crops, public sector research emphasized variety development rather than hybrids.

Although hybrids, wherever technologically feasible, offer a route for private sector development, they were not always regarded with much promise in the initial years. It was thought that the technology does not offer much to small farmers as hybrid seed would be high priced and would have to be repeatedly purchased. As a result, government policy focused principally on public sector seed provision and neglected private industry.

In recent years, however, the private seed industry has grown to be a sizeable presence in many crops. In the last decade, regulatory reforms have eased the restrictions on the entry of large and foreign owned private firms into this industry. It is also expected that the strengthening of intellectual property rights and the new technologies of genetic selection offered by biotechnology would make this sector even more attractive for private investment. These developments have affected the structure of the seed industry worldwide. In the United States, private spending for food and agricultural research tripled in real terms between 1960 and 1982. As a result, the private sector invests considerably more in food and agricultural R&D than the government. Furthermore, private research has expanded its range of activities. While earlier most

private research in the U.S. was for farm machinery, new food products and processing methods, the private sector has since developed research capabilities in plant breeding that was once a traditional area of public sector research (Fuglie et.al, 1996).

In India too, private sector spending on seed R&D is rapidly growing. According to one estimate, R&D effort (measured by rupee investments, technical personnel, size of experiment stations) in the private sector tripled within a short span of about 8 years from 1988 to 1996. This period was associated with changes in government policy towards the seed industry as well as the industry wide economic reforms. The same study concludes that about 50% of the observed increase in R&D was attributable to the liberalization in government policies that allowed entry into the seed industry by large domestic firms as well as foreign firms (Pray, Ramaswami and Kelley, 2001).

The growing importance of the private seed industry has prompted new policy concerns. Broadly speaking, there are three inter-related issues. First, is the issue of efficiency. Since the entry of private players is possibly only because of greater appropriability (of the gains from higher productivity), does the exercise of resulting monopoly power reduce social gains and in particular, the benefits to farmers and consumers? The earlier literature that estimated the gains to agricultural research typically assumed competitive markets and therefore does not address the new situation.[11] This question is important because some of the regulatory reform, like the New Seed Policy of 1988, was explicitly motivated by the objective of facilitating rapid technology transfer from the private sector (and in particular, the multinational seed firms) to

[11] This research showed that payoffs to agricultural research generally are high and that therefore more resources should be invested in research and development and in alleviating the factors that constrain adoption of new technologies at the farm-level.

farmers. The Seed Policy of 2002 is even more direct in its goal of fostering the growth of a private seed industry. The last decade has seen the entry of major international seed firms into the Indian market. However, it has also been accompanied by consolidation of the industry through mergers and acquisitions. The entry of large firms, backed presumably by formidable marketing and technological prowess, has also raised fears about the viability of smaller seed firms.

Second is the issue of equity. Would the products of private technology suppliers be so high priced that small farmers would not be able to afford it ? Note that such issues are not exclusive to private research; they were debated vigorously in the context of the Green Revolution technologies as well although the concerns there were not with the price of seed but with the cost of complementary inputs.

Third, do these developments call for a redefinition of the priorities of the public sector whether in terms of research, seed production, certification and environment regulation? On the one hand, there is now considerable expertise outside the public sector that is capable of applied plant breeding, seed production, seed certification and testing. On the other hand, the public sector constitutes a countervailing power in the marketplace. Furthermore, it is still the major supplier of seeds of open-pollinated varieties.

5. Monopoly Power and Benefits from Research

Intellectual property rights provide an incentive for private investments in research. However, private suppliers of technology would appropriate some of the returns from research (away from producers and consumers). Further, the overall social

gains might also be lower (than in the case of public research) if the award of property rights leads the market structure to be noncompetitive.

Consider first the competitive markets case. In figure 1 below, $D(p)$ is the demand curve for a product. $S_0(p)$ is the pre-innovation supply curve for the same product. Innovation shifts the supply curve to $S_1(p)$. The increase in economic surplus is the area enclosed by ABCD of which the area EBD is received by consumers and the area AEDC is received by farmers.

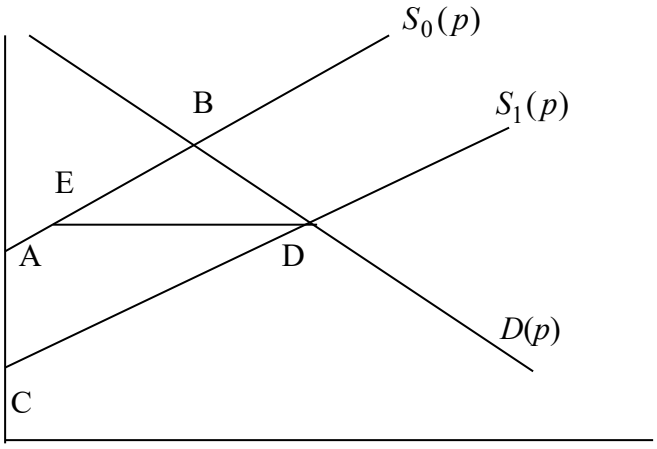

Figure 1: Benefits from Research in Competitive Case

The above analysis assumes that the innovation is costlessly received by farmers. The assumption is inappropriate when new seed is provided by private technology suppliers. These suppliers are likely to charge more for better seed. If the price of new seed is higher, the new supply curve will be to the right of $S_0(p)$but to the left of $S_1(p)$. Hence the increase in economic surplus will be less than ABCD. In addition, the market structure is unlikely to remain competitive. A framework for the analysis of social benefits of research in noncompetitive markets is provided by Moschini and Lapan (1997). Here I consider a simplified representation of their model.

Suppose the pre-innovation production function is $y = f(x)$, where y is output and x is the quantity of pre-innovation seed input. Output depends on other inputs as well but these are suppressed here as they do not play a substantive role in the analysis. Also let $y = g(x)$ be the post-innovation production function where $g(.)$ is the new functional relationship and x is the quantity of post-innovation seed input. Assume also that the two production functions are related in the following manner: $g(x) = f(\alpha x)$, where $\alpha > 1$. In words, this assumption says that 1 unit of new seed is equivalent (in terms of production) to α units of the old seed. Thus, αx represents the amount of improved input in the "efficiency units" of the old input.

Let w_0 be the price of old seed and w_1 be the price of new seed. Measured in terms of the efficiency units, the price of new seed is w_1 / α. Thus, farmers will adopt the new seed if $w_1 / \alpha \leq w_0$. To determine the equilibrium price of the new seed, assume that the supplier of new seed has a monopoly over its sales (because of intellectual property rights). Also let w_1^m be the price that maximises the monopoly profits of the supplier. But whether this will be the price charged in equilibrium will depend on the constraints to the monopolist's behaviour.

The first case is when $w_1^m / \alpha \geq w_0$. This is the case of a nondrastic innovation (Moschini and Lapan). In this instance, if the monopolist charges w_1^m, the innovation will not be adopted. The monopolist will therefore charge the price $w_1 = \alpha w_0$. Suppose the old and new seed are produced are both produced at a constant marginal cost, c. Then if the initial market structure is competitive, $w_0 = c$ and so $w_1 = \alpha c$. Thus, the seed price increases by the same amount as the increase in efficiency. As a result, the social

gains consist solely of the profits earned by the monopolist and there is no change in surplus either for farmers or consumers.

The second case is when the innovation is nondrastic but suppose the old seed was supplied by a monopolist at a price $w_0 > c$. If the new market structure is characterised by Bertrand competition, then the price of new seed is still constrained by $w_1 \leq \alpha c$ because the original monopolist will be willing to reduce price to c. Hence the price of new seed is $w_1 = \alpha c$. In efficiency units, the new price is $(w_1 / \alpha) = c$ which is less than w_0, the price of old seed. In this instance, consumers gain, farmers gain or lose depending on the price elasticity of demand while monopoly profits fall.

In a drastic innovation, $w_1^m < \alpha c$ and so there are no constraints to the monopolist's pricing decision. As the efficiency price falls, consumers gain while the benefits to farmers depend on the price elasticity of demand. In addition, there are the changes in industry profits. This depends on the initial market structure. If the initial market structure is competitive, then industry profits are higher in the new situation. If an existing monopoly is replaced by a new monopoly then the resulting change in profits is theoretically indeterminate.

This framework has been used by Falck-Zepeda, Traxler and Nelson (2000) to estimate the distribution of benefits due to Bt cotton adoption in the United States. If we were to focus only on the gains to farmers and consumers, then the insight offered by Moschini and Lapan is that the answer depends on whether the innovation decreases the efficiency price of seed. If this does not happen, then the gains of research accrue only to the seed supplier. The impact on the efficiency price of seed depends on whether the innovation is drastic and on initial market structure.

5. Appropriating the Gains from Research

In India, private technology suppliers have had a form of intellectual property rights protection in the form of hybrids. How has this helped private firms to appropriate the gains from improved seed? Evidence from the United States suggests that for crops grown with hybrid seed like sorghum and maize, seed companies capture between 35 to 48% of the gains (Fuglie, et.al , 1996). For India, Pray et.al (1991) calculated that seed companies captured 18.5% of the yield increases of hybrid sorghum and 6% of the gains from pearl millet hybrids. These estimates were based on yield data from 1986 and 1987. Studies that can update these numbers to more recent experience would be valuable although the way private investment favours hybrids suggests that this route continues to facilitate appropriation by seed suppliers. This fact is also relevant for stimulating private investments in plant breeding. In India, private R&D expenditures by seed companies as a proportion of their sales are estimated to have risen from 3.6% to 6.9% between 1987 and 1996 (Pray, Ramaswami and Kelley, 2001). About half of the increase in the R&D ratio was due to the development of hybrids of rice and rapeseed that become commercially viable during this period.

The only partial appropriation of gains by private seed firms suggests that new hybrids reduced the efficiency price of seed. This is consistent with the evidence of Ramaswami, Pray and Kelley (2002) who showed that private hybrids in coarse cereals have become important enough to contribute to increases in average district yields in Andhra Pradesh, Karnataka and Maharashtra. The social gains of these private hybrids must be reckoned to be particularly high because (a) of their success in the pre-dominantly poorly endowed regions of the semi-arid tropics and because of (b) the

greater importance of coarse cereals in the cereal budgets of poor households relative to the richer households.

Recently with the enactment of the Plant Variety Protection and Farmer's Rights Act, protection has been extended to the rights of breeders of open-pollinated varieties. Following the experience of hybrids, could we then expect that this would enable breeders of open-pollinated varieties to appropriate some of the gains of the improved seed? And would it provide substantial incentives for investment in breeding for open-pollinated varieties?

In the United States, which has had the longest experience with plant breeders rights, seed companies appropriate about 12 to 24% of yield gains from improved nonhybrid varieties (Fuglie, et. al, 1996). The extent of appropriability is significantly lower here compared to hybrid seed. Further, plant breeders rights did not stimulate investments uniformly in all crops. While investments in soybean breeding increased substantially, impacts on small grains (wheat, rice, barley, oats, rye and triticale) were insignificant (Fuglie, et. al, 1996). This reflects the seed industry's perceptions about future grain sales, technological opportunities and research costs which are not uniform across crops. Hence, even in the U.S., public breeding continues to be an important source of finished varieties for some major field crops. In an evaluation of plant breeding rights in the U.S., Butler and Marion (1985) concluded that the "…(plant breeders rights) has resulted in modest private and public benefits at modest private and public costs".

Could it be otherwise in India? If anything, the Indian regulation affords a lesser degree of protection to breeders rights than the American legislation. The breeders rights

are limited by the farmer's right to save, use, exchange and sell seed.[12] Of these it is the right to exchange and sell seed that limits appropriability. If farmers had only the right to save and use seed, without the right to sell, the seed becomes like a durable good that could be priced appropriately. Such pricing cannot be sustained when competition (to the seed company) arises from farmers themselves.[13]

Enforcement of intellectual property rights is an issue that is sometimes ignored in evaluating policies. Yet, from the point of view of a seed firm, its ability to enforce its rights of intellectual property is paramount. Theft of parental lines, theft of foundation seeds (by contract growers) and the sale of counterfeit seed are some of the threats to the intellectual property of a seed company (Shiva and Crompton, 1998). If there was stronger enforcement of existing laws for trade secrets (to protect parental lines), contracts (to protect foundation seeds) and trade-marks (for action against counterfeit seeds), they could have a significant impact on hybrids as well. Inability to protect parental lines means that Indian varieties are usually double-cross hybrids that have 10-15% lower yields than single-cross hybrids.

6. Market Structure and Regulation

In the global seed industry, the seed business is usually a part of a larger agricultural business consisting most often of agro-chemicals. In the last decade or so, there was a further wave of consolidation involving pharmaceutical and agricultural

[12] Farmers are not, however, entitled to sell branded seed of a protected variety under the brand name.
[13] The Plant Variety Protection and Farmers Rights Act has been criticised especially by NGOs because they believe that it provides the legal framework for trans-national firms to monopolise the Indian seed industry. A fairly typical assertion is the following. "A much greater threat to farmer comes (from)…..the likely loss of Indian markets in future…This is evident from the Plant Variety Protection and Farmer's Rights (PVPFR) bill … facilitating industries to obtain seed monopolies." (Utkarsh and Satheesh, 2002).

businesses. However, in recent years, this trend has weakened and even reversed as these "life sciences" firms have spun off their agricultural business primarily because investors perceived the earnings from agriculture to be more volatile on account of the controversies over GMO food. Monsanto (which has acquired DeKalb Plant Genetics, the international seed business of Cargill and Plant Breeding International and many other smaller firms), Aventis Crop Science (now taken over by Bayer), Syngenta (the agriculture arm of the merger between Novartis and AstraZeneca), Dow Agro Sciences (which acquired Cargill Hybrids) and DuPont (which acquired PioneerHiBred) are some of major input supplying agricultural businesses today.

The consolidation in the global seed industry is attributed to the rising cost of research, the patenting of life forms and the scramble to control access to elite germplasm. The impact of these changes in India has so far been limited to changes in ownership rather than a dramatic reduction in seed companies. But they have raised fears of corporate control of agriculture. In the United States, corporate control is seen to be most prominent in the livestock sectors where producers are contractually tied to agri-businesses in the supply of inputs as well as in marketing.

It is not clear whether smallholder agriculture offers greater or lesser opportunities for corporate control. As issues of market structure have traditionally been analyzed by looking at the market shares of the leading seed firms, there has not been much research on the market structure at the micro level. How do firms compete at the retail level? What choices do farmers exercise?

According to Shiva and Crompton (1998), the marketing strategies of seed firms aim at persuading farmers to switch to hybrids from open-pollinated varieties. Some of

these strategies are organization of field days and demonstration plots, using field assistants to visit farmers, farmer advocacy by the selection of model farmers, customer contact programmes, free distribution of farmer's handbook and free distribution of small packets of seeds. Yet, the same study points out, the hybrid seed market is fickle and farmers' preferences for particular brands of seed change rapidly reflecting the specific marketing success of individual company. This suggests that seed firms in India have not yet built successful brands that could be leveraged into some degree of monopoly power.

At the same time, it has also been observed that public hybrids sold under private brand names are sometimes sold at premiums reflecting the farmers' perceptions of quality. Tripp and Pal (2000) studied the information flow between seed firms and farmers in the pearl millet market of eastern Rajasthan. They found that even in areas where the use of private hybrids is extensive, while farmers can recall the brand or the company that produced their seed they cannot often distinguish between a company's hybrids. This is possibly because companies invest resources in advertising company brands rather than in communicating information about the varieties. As established seed companies have reputations to protect, branding is a convenient short-cut for communicating product quality.

Branding is also an entry barrier to small and new firms that cannot afford advertising or do not have past reputations to build on. Ideally, seed certification should provide the route for small firms to convey signals about their product quality. However, Tripp and Pal find that such information is not used by farmers. The farmers in the survey could not explain the difference between certified and truthfully labeled seed.

Thus, in the absence of farmer education, quality regulation fails to protect farmers and neither does it reduce barriers to entry that are created by branding.[14]

7. Conclusions

Like many countries, India has invested considerable resources in public sector agricultural research. Within this framework, the focus has been in generating, testing and diffusing relevant technologies. The public sector driven picture of agricultural research has, however, been changing. Because of new technologies and stronger intellectual property rights, innovators can now appropriate a significant enough share of the gains from research. This has transformed the seed industry as the private sector has grown to be a sizeable presence in many crops. As the payoff to research and higher agricultural productivity is high in poor countries, the investment of private capital in agricultural research contributes to economic development.

The appropriability of research gains is made possible by monopoly power in the hands of seed suppliers. This paper has pointed out some of the research challenges that are posed by non-competitive market structures. However, there are other issues as well. The growth of private seed industry has occurred in the context of global capital flows, the agreements on intellectual property rights and patents at the WTO and continuing applications of biotechnology to crops and livestock. NGOs and in particular, environmentalists have strong misgivings about the impact of these developments on bio-diversity and low input agriculture is cited by them as the only sustainable form of agricultural development. For economists, it is often not clear what is objected to: market

[14] See Tripp and Louwaars (1998) for analysis of seed regulation that is appropriate to the state of development of the national seed system.

forces, trans-national companies, monopolies, patents or bio-technology itself. Therefore, as a research strategy, this paper has focused on challenges posed by non-competitive market structures. However, it should be clear this is only a small part of the work that is necessary to advance our understanding of the place of seed industry in today's world.

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