The Structure of US Agricultural and Food Research, with an Emphasis on Seed-Biotechnology Research

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The complex US system of research for agriculture and food is composed of a variety of funders—USDA, other federal entities, states, and the private sector. Three major classes of research performers include two from the public sector: USDA intramural research, and research done at the State Agricultural Experiment Stations and other institutions. In recent years, research investment by the third performer, the private sector, has grown more rapidly than public sector research investment, which it now surpasses by a considerable amount.

Public sector research investments are spread across a broader array of research topics, including socially important areas such as the environment and food safety, but private sector research dominates farm machinery and food manufacturing research. Much of the private sector research in food manufacturing consists of new product development. The public sector invests more in animal research—much of the private sector research in this area is in animal health product development, as Figure 1 shows.

Complementarity of Public and Private Research

Crop research shows significant R&D investment by both the public and private sectors. A recent influential report by the President's Council of Advisors on Science and Technology (PCAST, 2012) suggested that the public sector should consider potential "overlap" with private sector research when determining allocation of research resources. Differences in the nature of the research conducted, however, suggest complementarity of public and private research. Frey (1996) conducted a near-census of plant breeders in both public and

* The views expressed are those of the author and should not be attributed to the Economic Research Service or USDA.

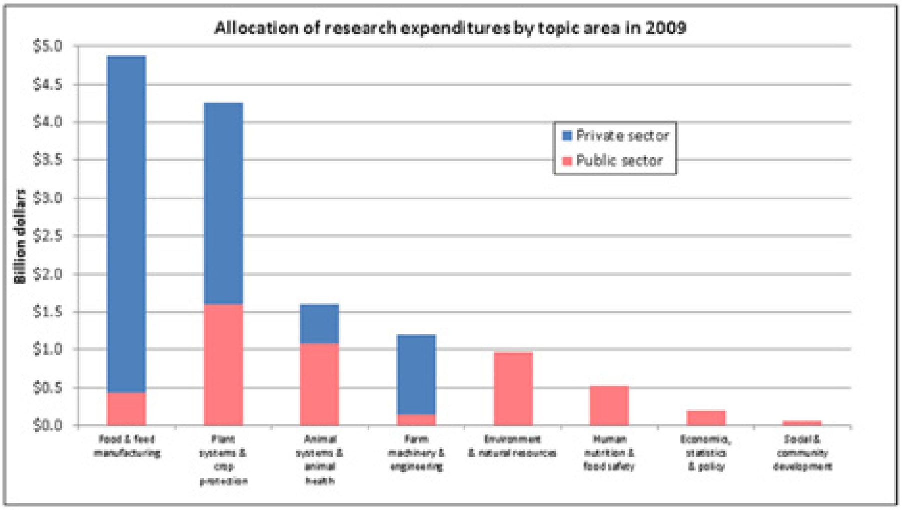

Figure 1. Public agricultural research investments:
Public and private sectors invest significant amounts in crop-related research.
Source: USDA Economic Research Service, based on Current
Research Information System and Fuglie et al. (2011).

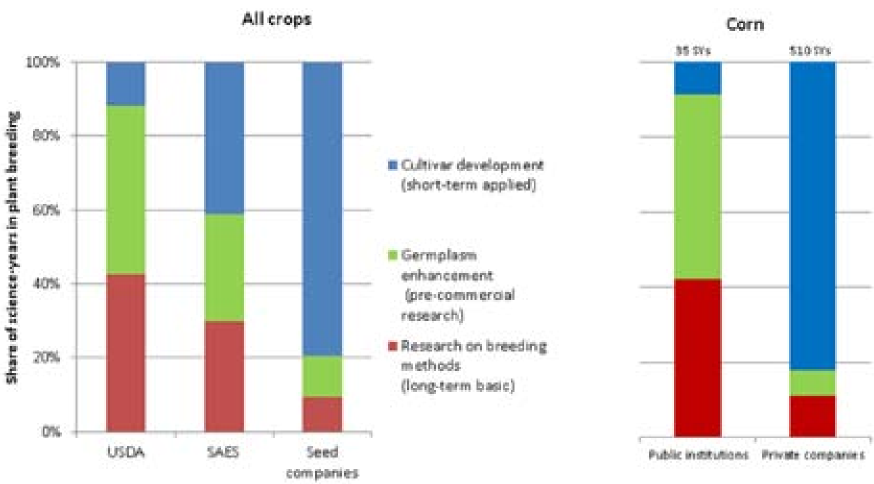

Figure 2. Differences in public and private sector plant-breeding activity allocation (National Plant Breeding Study, 1994).
Source: Calculated from Frey (1996).

private sectors in 1994. He found that of nearly 1,500 breeders in the private sector, 80% were concentrated on downstream "cultivar development." The more upstream categories of "germplasm enhancement" and "basic plant breeding research" were primarily in the public sector, where two-thirds of the roughly 700 scientist-years were occupied in these activities. This breakdown could also be observed for a major crop like corn, where over 80% of the roughly 510 private sector scientist-years in corn research were occupied with cultivar development, while less than 10% of the only 35 public sector scientist-years in corn went to cultivar development. Figure 2 shows this relationship.

Fuglie and Walker (2001) used the Frey data and controlled for market size and other factors. They found that higher levels of public upstream research were associated with higher levels of private cultivar development. Only higher levels of public cultivar development suggested the potential for public research to "crowd out" private cultivar development. The early history of corn research in the US, the resource allocation in Frey's data, and more recent history all show the public sector has, indeed, rebalanced its corn research portfolio in response to increases in private investment.

Comparable data are not available for a more recent period, but the evidence for all public and all private research suggests, in general, complementarity (Fuglie & Toole, 2014). Wang et al. (2013) found evidence of complementarity for public and private crop research (i.e., all crop research, not simply seed-biotechnology research).

Another facet of the perception of the dominance of private seed-biotechnology research is the fact that this category has been the major growth area among all the private sector agricultural input categories. In 1975, seed research constituted a little over 5% of all US private sector agricultural input investment; by 2010, seed-biotechnology research

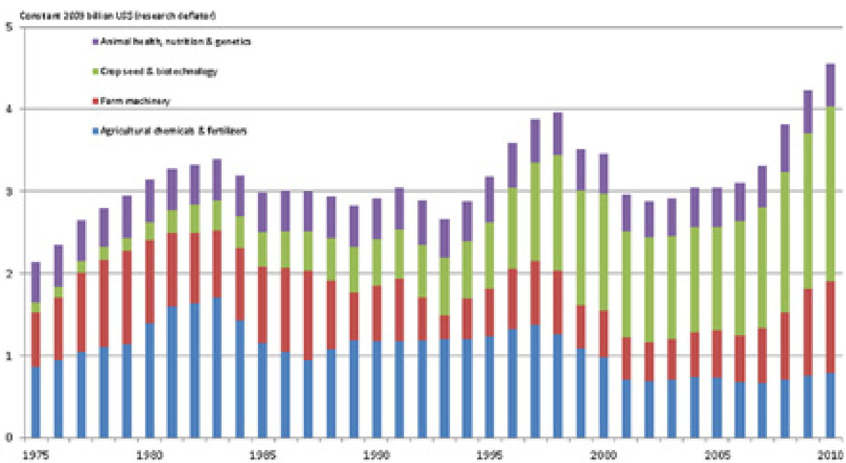

Figure 3. Seed-biotechnology research has been the growth component of all US private sector agricultural research.
Source: Fuglie et al. (2011).

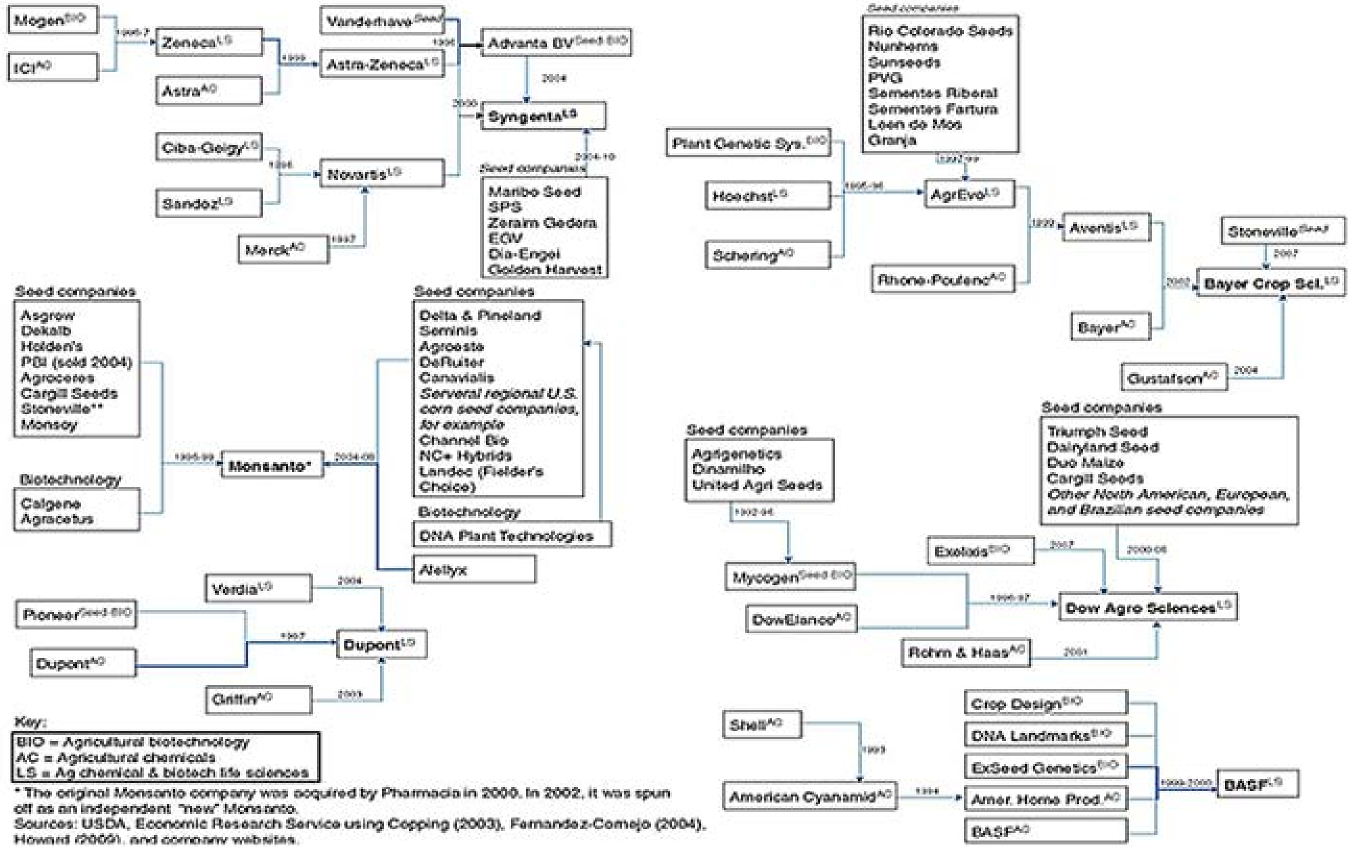

Figure 4. Formation of the "Big 6" seed-biotechnology-chemical companies. Source: Fuglie et al. (2011).

accounted for over 47% of the agricultural input total, as we see in Figure 3. By way of comparison, I used data from Fuglie et al. (2011) for the private sector and the Current Research Information System (CRIS) maintained by the National Institute for Food and Agriculture (NIFA) for the public sector to calculate some rough comparisons for 2009. In that year, the private sector spent two-thirds as much again as the public sector for *all* crop research. Private sector expenditures on seed-biotech research were over three and a half times as much as public sector expenditures on the CRIS category "genetic resources, genetics, genomics, and plant biological efficiency and abiotic stresses." It is very difficult to allocate private sector seed-biotech to particular crops, but an industry estimate that about 45% of all private seed-biotech research is devoted to corn suggests that in 2009 in the US, private seed-biotech corn research alone was seven times as great as *all* public corn research—that is, public corn research in all categories, not only those focused on genetics or genomics.

Growing Concentration in the Private Seed-Biotechnology Industry

Growth in the US and global seed-biotech industries has been marked by increasing concentration, which has also been characteristic of other private sector agricultural input industries whose research expenditures have not grown as rapidly. Globally, in 1994 the top four seed-biotechnology firms held 21% of market sales, and the top eight firms, 29%. By 2010, the share of the top four firms was nearly 54%, and the share of the top eight, 63%.

Table 1 presents more detailed data. Much of the growth in sales by leading firms was driven by mergers and acquisitions. The average annual growth in sales by all seed-biotech firms from 1994 through 2010 was about 10%; for the top four firms, the annual growth rate was 15%. Acquisitions accounted for about two-thirds of the sales growth for the top four firms. From the early 2000s, consolidation has resulted in a group of companies sometimes known as the Big 6 in the seed-biotech and agricultural chemical industries—Monsanto, DuPont Pioneer, Syngenta, Bayer Crop Science, Dow, and BASF. Figure 4 tracks that consolidation. And as we see in the statistics in Table 2, these Big 6 companies dominate various measures of research output or product com-

TABLE 1. Rising Market Concentration in the Global Crop Seed-Biotechnology Industry

Year	Four-firm concentration ratio	Eight-firm concentration ratio
	Share of global market (percent)	
1994	21.1	29.0
2000	32.5	43.1
2009	53.9	63.4

Source: USDA, Economic Research Service, based on Fuglie et al. (2011).

mercialization, including patents, field trials, GM crop approvals, seed market shares, and trait-acre market shares.

A "trait-acre" is a measure of the area sown to GM crops in which stacked GM traits are counted as multiple acres, depending on the number of traits stacked in a single seed (Fuglie et al., 2012). In fact, in the US 90% of the trait-acres can be attributed to the top firm, Monsanto. Seed share estimates for years more recent than 2007 are less certain, but it appears that in recent years the top two firms in corn, soybeans, and cotton in the US have had from 60% to over 70% of the total market share (Monsanto and DuPont Pioneer for corn and soybeans, Bayer Crop Science and Monsanto for cotton).

These changes in market structure in the crop seed and biotechnology industries have been driven by acquisition of complementary technology and marketing assets, and economies of scale in crop biotechnology R&D (Fuglie et al., 2012). Greater market power resulting from concentration may be one factor contributing to higher seed prices for farmers to pay. For purposes of this discussion, though, I will focus primarily on the potential effects of market power on innovation. On the one hand, Kalaitzandonakes et al. (2010) calculate that the value of price premiums and markups for GM corn and

TABLE 2: Measures of Research Output or New Product Commercialization Reflecting High Concentration Ratios in the Seed-Biotechnology Industry

Measure of research output or new product commercialization	**Share held by "Big 6" companies (including subsidiaries and acquisitions)**
US patents issued for all crop cultivars, 1982–2007	76
US patents issued for agricultural biotechnology, 1976–2000	64
Field trials of GM plants in US, 1985 to mid-2008	62
GM crop approvals for planting or environmental release globally, 1985-2007	87
Market share for US corn seed, 2007	70
Market share for US soybean seed, 2007	55
Market share for US cotton seed, 2007	92
Market share of trait-acres* for GM corn, soybeans, cotton, and canola worldwide in 2007	>95
Market share of trait-acres* for GM corn, soybeans, and cotton in the US in 2009	>95 (90% held by top firm)

*A "trait-acre" is the area sown to GM crops, where stacked GM traits are counted as multiple acres, depending on the number of traits stacked in a single seed.

Source: USDA Economic Research Service, using Fuglie et al. (2011) and Moschini (2010).

soybean seed in the US did not exceed R&D expenditures until 2007 and contend that this supports a claim of "dynamic efficiency." On the other hand, Schimmelpfennig et al. (2004), using field trial data, argue that increases in industry concentration have had a negative effect on research intensity in agricultural biotechnology. Shi et al. (2013) claim that concentration may favor "too much" emphasis on trait development and "too little" on core germplasm improvement.

These and other claims are complex and difficult to evaluate, but worthy of discussion. In the next presentation, Rick Welsh will address some of the issues concerning intellectual property and regulation in greater depth. Here, I'll conclude with a few notes on some observable trends that could be related to the rate of innovation in agricultural biotechnology, as well as another phenomenon—movement of some large firms towards provision of data services to aid with farm management, particularly in the context of precision agriculture.

Small and medium agricultural biotechnology firms only account for about 5% of the total research by the private seed-biotechnology industry. Nonetheless, they have been the source of some of the major innovations in the field, both for research tools and for traits. Since the early 2000s, the number of small to medium agricultural biotechnology start-ups has slowed down. Given exits from this sector, the total number of firms has begun to decline slightly from about 2002. About 75 percent of exiting firms have left through acquisition by another firm, and Figure 5 presents several graphs of those trends. Petitions to USDA for deregulation of GM crops are another indicator of activity

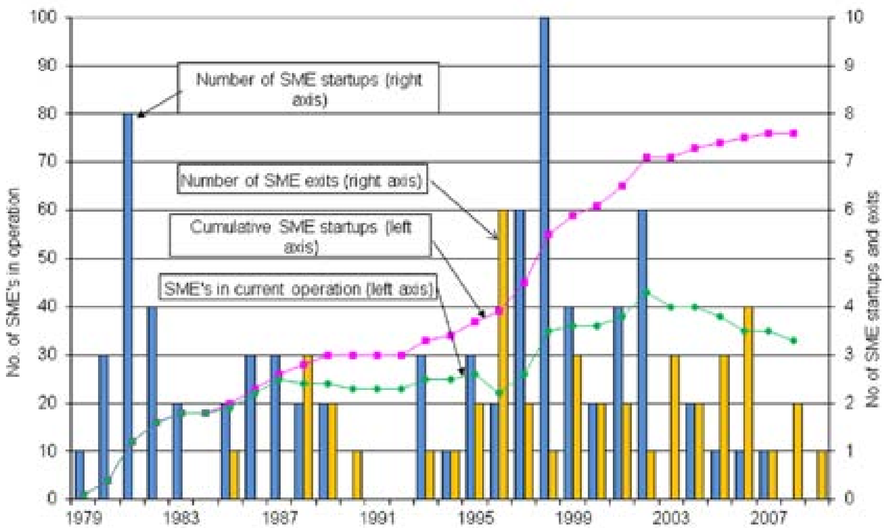

Figure 5. Recent decline in small and medium-sized enterprises (SMEs) in agricultural biotechnology.
Source: Fuglie et al. (2011).

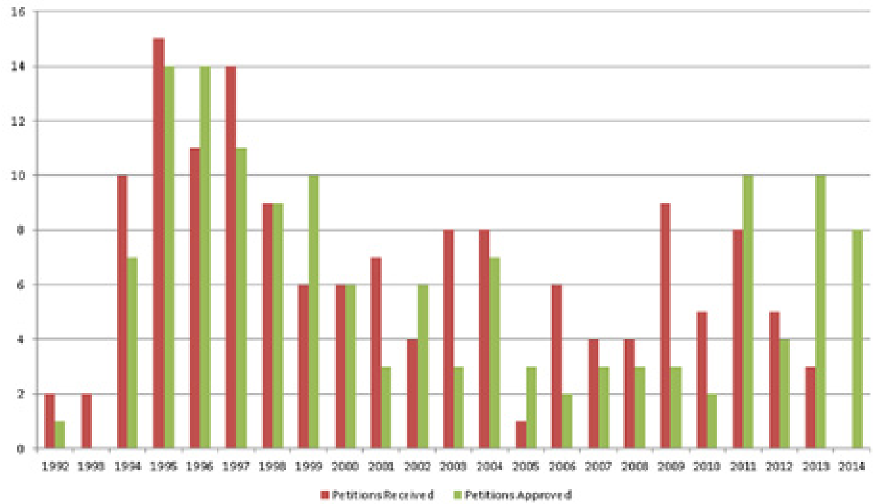

Figure 6. Trends in petitions to USDA for deregulation of GM crops, 1992–2014. Source: ISB, Virginia Tech.

in agricultural biotechnology. Annual petitions received were highest in the late 1990s; since then they have been fewer and more variable. In fact, the Information Systems for Biotechnology (ISB) database records no deregulation petitions received in 2014, although eight petitions were granted because of the lags between receipt and approval. Figure 6 shows this temporal pattern. These trends suggest the possibility of slowing in the rate of innovation.

With the purchase of the Climate Corporation for $930 million in 2013, Monsanto signaled its intent to provide a variety of data-based tools to assist farmers in their management decisions. Also in 2013, DuPont Pioneer entered into a data partnership with John Deere. These developments link large seed-biotechnology companies with tools for precision agriculture, with implications for further biotechnology innovations that are unclear. They also reflect greater investment by these firms in farm management research, which up to now has been more the province of the public sector.

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