Most of the increase in global agricultural production over the past half-century has come from raising crop and livestock yields rather than through area expansion. This growth in productivity is attributed largely to investments in research and innovation (1). Since around 1990, there has been a decline in the rate of growth in yield per area harvested for several important crops (2). In parallel, the rate of growth in public spending on agricultural research and development (R&D) has also fallen, which may account for declining crop and livestock yields rather than increased growth in public spending on agricultural R&D investment by industries (3). This growth in productivity is attributed largely to investments in research and development (R&D) and biotechnology research began to grow rapidly and, by 1998, surpassed other industries’ agricultural R&D spending (see the second chart) (6). For the United States, only about half appears to be agriculturally related, with food manufacturing research focused primarily on the development of new consumer food products (8).

Our survey provides 1994–2010 annual estimates of global private R&D in seven industries supplying agricultural inputs to farms, as well as the food manufacturing industry through 2007 and the biofuel industry for 2009 (6). World inflation-adjusted R&D spending in the seven agricultural input industries combined increased by 43% between 1994 and 2010 (6). All of this growth, however, occurred in industries supplying inputs for crop production, led by the seed–biotechnology companies to improve competitiveness, whereas R&D related to livestock remained essentially unchanged (see the first chart).

Global private investment in food manufacturing research was U.S. $11.5 billion in 2007 and in agricultural input research was $11.0 billion in 2010 (with $8.7 billion of this oriented to crops). Within the agricultural input industries, there have been striking changes in the composition of research investment. This is best illustrated for the United States, which accounts for a little over one-third of global private agricultural input research. In the 1960s and 1970s, agricultural chemicals and farm machinery dominated private agricultural R&D; as late as 1980, these two sectors accounted for more than three-fourths of the total (6). In the 1980s and 1990s, private investment in crop-related seed and biotechnology research began to grow rapidly and, by 1998, surpassed other industries’ agricultural R&D spending (see the second chart) (6). For the United States and globally, private R&D spending on crop seed and biotechnology grew rapidly in the 1990s; leveled off in real terms from the late 1990s until about 2005; then accelerated again, reaching $3.7 billion by 2010.

In recent years, research into biofuels, a new agriculturally related research area, has become increasingly important. In 2009, private companies spent ~$1.47 billion on biofuels-related research globally. More than 75% of these expenditures were in the energy sector, but about $340 million was spent by crop seed–biotechnology companies to improve biofuel feedstocks (9).

Drivers of Private R&D
Factors influencing returns to investment in R&D by private, for-profit firms include market size, technological opportunity, appropriability (the ability of firms to appropriate economic benefits of research), and costs of R&D inputs (10). Across agricultural input industries, market size does not appear to be a good predictor of the amount of R&D invested, as research intensity (research spending as a percentage of net sales) varies widely, from 10.5% in seeds to 0.25% in fertilizers. Research intensity within each industry, how-

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**The Contribution of Private Industry to Agricultural Innovation**

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whenever increased overall R&D spending by firms in order to meet these requirements but may have diminished rates of innovation, as a larger proportion of R&D funds was redirected from discovery research (15–17). In addition, regulations may create barriers to entry for new firms. In crop biotechnology, high fixed costs and long time lags in meeting regulatory requirements reduce incentives for private firms to develop new traits for small, heterogeneous markets, such as horticulture (18).

**Implications**

Growth of private R&D spending for agriculture in the face of slowing or stagnant public R&D resources raises the question of whether private R&D can substitute for public R&D. If so, long-term productivity growth in agriculture may be maintained or revived even as public R&D spending wanes. However, to the extent that technology opportunities created through basic research and the training of the S&T labor force are largely public-sector functions, reduced public-sector capacity may eventually reduce returns to private R&D as well and lead to lower aggregate investments in innovation (19–21). In addition, agricultural biotechnology may need public investment to achieve wide international dissemination, especially in poor countries with limited IP or regulatory capacity (22).

Another issue is whether the concentration in agricultural input industries may have adverse consequences for market performance. In several input industries, a few firms dominate global market sales, account for most of the industry R&D spending, and hold large patent portfolios. These factors may be creating possibly major barriers to entry of new firms and may be limiting market competition (23).

Not only is private agricultural input R&D concentrated among a few firms, it also appears to be focused on fewer commodities, technologies, and markets than public R&D (24). Areas that the private sector has avoided are generally those where profitable opportunities are perceived to be low. However, private R&D appears to be responsive to changing technological opportunities when market and regulatory conditions are favorable, as evidenced by the rapid growth in crop biotechnology and biofuel R&D. Policies to strengthen IP, streamline regulatory procedures, and offer favorable tax treatment for R&D investment can encourage private investment in agricultural innovation. However, lack of sufficient market competition or barriers to entry by new firms could constrain the potential contribution of industry to agriculture.

**References and Notes**

9. This $340M of estimated biofuels R&D expenditure is reflected in estimates for crop seed and/or biotechnology. The eight largest energy research spenders invested more than $6 billion total in R&D in 2009, primarily on fossil fuels. See (6) for details.
13. In 1980, the U.S. Supreme Court ruled in *Chakrabarty* that living material was patentable.
15. Health and environmental risk assessments, product registration, patenting, and regulatory affairs required 34% of agricultural chemical R&D costs (16) and 18% of crop biotechnology trait development costs (27).

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