The growing role of the private sector in agricultural research and development world-wide

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ABSTRACT
The private sector is playing an important role in developing technologies to raise productivity in agriculture. This paper presents new estimates of private agricultural and food R&D spending trends over the past 25 years. Global private spending on agricultural R&D (excluding R&D by food industries) rose from $5.1 billion in 1990 to $15.6 billion by 2014. Private R&D investment accelerated as agricultural commodity prices began to rise in 2003. Although the companies that account for most agricultural R&D spending are based in developed countries, their technologies have considerable and growing importance for developing countries. Some implications of these trends for public R&D policy are discussed.

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1. Introduction
Raising investment in agricultural research and development (R&D) to raise productivity of the world’s farms, especially in developing countries, is thought to be essential for long-term global food security (Alston et al., 2009; Lobell et al., 2013). Although historically (due to market failures and the small size of agricultural firms) the public sector led investment in agricultural R&D, private agribusiness is playing an increasingly important role (Fuglie et al., 2012). Recent estimates of global spending on food and agriculture R&D found that private R&D has grown faster than public R&D, and in developed countries private spending now exceeds that by the public sector (Bienkema et al., 2012; Pardey et al., 2015a).

How relevant is this trend for raising agricultural productivity in developing countries? One limitation of many global assessments is that estimates for the private sector combine R&D spending on food manufacturing and agricultural inputs. But detailed studies have shown that R&D by food companies is heavily oriented toward improving manufacturing processes and developing new food products. Except in some vertically integrated sectors like poultry, food R&D has limited relevance for production agriculture (Conner, 1981; Galizzi and Venturini, 1996; Fuglie et al., 2011). More relevant for agriculture is R&D spending by agricultural input manufacturers – seed, chemical, pharmaceutical, and machinery companies that invest in R&D to improve the quality of farm inputs. In an assessment of agriculturally-related R&D by agribusinesses, Fuglie et al. (2011) estimated that private agricultural R&D world-wide nearly doubled between 1994 and 2010, from $5.6 billion to $11.0 billion per year. Although more than 95% of this R&D was by companies based in developed countries, many of these companies operated global research networks to adapt and extend their technologies to serve global markets.

This paper extends Fuglie et al.’s (2011) results on global private agricultural R&D spending to cover the years from 1990 to 2014. Having more up-to-date data provides insights into how international agribusiness responded to the rise in commodity prices since 2007. Generally, we would expect higher commodity prices to lead to greater farm demand for yield-increasing technologies, and thus greater R&D spending by agricultural input manufacturers to meet this demand. However, given the long lead times between new R&D spending and technology development and adoption, we would except a strong R&D response only if the price increases were expected to persist rather than be cyclical.

Private agricultural R&D is defined as R&D by the business sector to develop new technologies for crop, livestock and aquaculture production. The business sector includes private and state-owned enterprises so long as they sell their products to the market. It excludes R&D by institutions financed by producer groups or industry associations as well as R&D by private universities.
The paper also revisits the question of how relevant private agricultural R&D might be for developing countries. Most private agricultural R&D is by companies located in high-income countries, although some of this is targeted to markets in developing countries. R&D spending by firms in emerging economies is also growing. This paper uses two methods to allocate private agricultural R&D spending to markets in high income and developing countries. First, R&D spending is assumed to be targeted to the country or region in which each company is headquartered. Second, R&D is allocated to the country or region where each company sells its products. The second measure assigns a significantly larger share of private agricultural R&D to developing countries. The paper also examines how national policies in developing countries can incentivize private R&D, including by foreign multinational corporations, in their countries. Drawing on evidence from case studies presented in Pray and Fuglie (2015) and recent developments in agribusiness, the strategies pursued by the three largest emerging economies – China, India and Brazil – for acquiring agricultural technology services from the private sector are compared.

The paper concludes with a summary of key findings and discussion of their implications for science policy.

2. Methodology

For most countries, official estimates of private investment in agriculturally-related R&D are not comprehensive, if they exist at all. For countries that do report private agricultural R&D, it usually only covers R&D spending by firms in the farm sector (i.e., firms which primarily produce crop and livestock commodities). This misses most of the R&D by chemical, pharmaceutical, machinery, and biotechnology firms which develop and manufacture inputs for use by farms for agricultural production. This omission characterizes the private agricultural R&D data reported for European countries by the Eurostat and OECD databases. Only a few countries report private R&D spending by “socioeconomic objective,” i.e., by the sector of intended use. The U.S. National Science Foundation (NSF), for example, occasionally reports R&D spending by firms in the manufacturing and service sectors that is intended for agriculture, but excludes agricultural firms from its surveys. Thus, it misses R&D spending by crop seed and animal breeding companies (which are classified as agricultural because they sell agricultural seedstock, although they are not “farms” in the usual sense). Fuglie et al. (2011) found R&D by seed companies to be the largest and most rapidly expanding component of private agricultural R&D spending in the United States.

To remedy this gap Fuglie et al. (2011) constructed a new and unique dataset on private agricultural R&D spending world-wide. First, they identified the major firms conducting research on agricultural inputs and then tracked each firm’s spending on agricultural R&D over time. The sum of R&D spending among these firms, plus an allowance for R&D spending by small and medium-sized firms, provided an estimate of total private R&D for agriculture.

Firms were classified into seven input sectors: three for crop inputs (seeds/biotechnology, pesticides, and fertilizers), three for animal inputs (animal breeding, health, and nutrition for food animals and aquaculture), and the farm machinery sector. Industry associations and private consulting firms specializing on agricultural input markets were contacted to identify leading firms in each input sector. For publicly-traded firms, annual financial filings usually contain data on sales and R&D (unless R&D is an insignificant part of costs, in which case it is unlikely to be reported). Firms that manufacture products for both agricultural and non-agricultural sectors usually report sales by business segment but may not report agricultural R&D separately from other R&D. For firms that did not report agriculturally-related R&D separately from their total R&D spending, agricultural R&D was estimated either by contacting the firms directly for this information, reporting R&D across the firm’s business segments in proportion to sales, or using an industry-average research intensity (R&D as a fixed percentage of sales). Similar approaches were used to obtain estimates of R&D spending by privately-held firms that did not publish financial reports (although many such firms report sales and R&D information on their websites, at least for current years).

While Fuglie et al. (2011) were able to identify several hundred companies world-wide doing some formal agricultural R&D, they found that the largest 5–10 firms in each sector accounted for 80% or more of total R&D in that sector. Thus, trends in private agricultural R&D spending are driven by the investment decisions of a few large firms. Since most of the large firms publish audited financial reports annually, the aggregate R&D estimates should be reasonably accurate. Moreover, since R&D spending is often given a different tax treatment from other types of costs, firms are required to report R&D using standardized accounting criteria. Situations in which this approach does less well is when R&D in a sector is dominated by many small firms or when the dominant firms in a sector are privately-held and don’t disclose financial information. In the 1990s, many biotechnology start-up companies invested in agricultural R&D, and it is difficult to get an accurate estimate of R&D spending by these firms (though they appear to make up a small part of the industry total). A similar situation may exist today regarding R&D for precision agriculture by IT firms, which is discussed later in this paper. The animal breeding sector is one in which there is a high degree of concentration (a few firms dominate poultry and pig breeding worldwide), but which are mostly privately held and don’t make public their financial information.

The present study uses the same approach as Fuglie et al. (2011) and extends the estimates from 1990 to 2014. In the course of the current investigation several new firms were identified that have significant agricultural R&D programs. The present study also draws upon new evidence on private agricultural R&D spending in India (Pray and Nagarajan, 2014)3 and China (Bryant, 2007; Hu et al., 2011; Zhi, 2013; CCM, 2014; Harkell, 2015).4

In total, the present study tracked the agricultural R&D spending of 324 companies world-wide (Table 1). This includes 182 companies that were operating in 2014 and 142 legacy firms

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Footnote continue

Intelligence (a division of Informa plc), Cropnosis for crop sectors, Vetnosis for the animal health sectors, and VDMA for farm machinery. Agricultural input firms may also publish special reports of their industries or include information of their markets and major competitors in their annual reports. In particular, Alltech publishes an annual survey of the global animal feed industry and PotashCorp publishes annual overviews of the global fertilizer industry.

3 The author would like to extend a special thanks to Carl Pray and Latha Nagarajan for making available their firm-level data on agricultural R&D spending by private firms in India.

4 Agricultural input industries in China have been highly fragmented, composed of many small manufacturers with little or no internal R&D (Pray and Fuglie, 2001; Bryant, 2007; Zhi, 2013). Companies with significant intramural R&D spending only appeared in the late 1990s. The estimates of private R&D by Chinese companies in the paper incorporate newly available estimates of R&D by leading Chinese seed companies from a survey conducted by the Ministry of Agriculture (reported in CCM, 2014) and by animal health companies from a survey by the China Veterinary Drugs Association (reported in Harkell, 2015).
(firms that operated at some time during 1990–2013 but had been acquired by or merged with another firm or had otherwise exited the agricultural input sectors). About 70% of these firms (226) conducted research on crops (seeds, agricultural chemicals, or crop nutrition), about 20% (62) focused on animals or fish (breeding, health, or nutrition), and the rest (40) were manufacturers of farm machinery (Table 1A). Regionally, about three-quarters of the firms were based in either USA-Canada or Europe-Middle East, 24% in the Asia-Pacific countries (Japan and India, especially), and about 3% in Latin America. No Africa-based firms with significant agricultural R&D were identified in the survey (Table 1B). The company representation for Latin American appears low, but, as will be described later in the paper, private agricultural R&D is likely high because of significant investment by foreign multinational companies in this region.

Table 1B lists 110 companies in the database that were estimated to have spent at least $10 million on agriculturally-related R&D in 2014. Five companies (four in the crop sector and one farm machinery company) had agricultural R&D budgets greater than $1000 million. Most companies focused their agricultural R&D on either crops, animals or farm machinery, although a few had significant R&D in both crops and animals. R&D by farm machinery companies is also mostly focused on crop operations, but for expository purposes it is left as a separate category.

The list of companies in Table 2 contain several from developing countries. One of these largest in ChemChina, a Chinese manufacturer of agricultural and other chemical products. But the animal R&D assigned to ChemChina in Table 2 is actually by its subsidiary Adisseo, a France-based animal nutrition company that requires R&D spending by indigenous African companies appears to be quite small, with most spending far less than $1 million annually on R&D. The one exception may be Pannar, a South African seed company that operates in several African countries. However, no financial data is publically available for Pannar. Pannar was acquired by DuPont in 2013.

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Table 1A
Number of companies in the R&D database.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Current in 2014</th>
<th>Legacy companies</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop R&amp;D</td>
<td>105</td>
<td>121</td>
<td>226</td>
</tr>
<tr>
<td>Animal R&amp;D</td>
<td>45</td>
<td>17</td>
<td>62</td>
</tr>
<tr>
<td>Farm machinery R&amp;D</td>
<td>36</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>182</td>
<td>142</td>
<td>324</td>
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</tbody>
</table>

* Sum is less than total because companies may conduct R&D in multiple sectors (i.e., four companies conducted R&D in both the crop and animal sectors).

Table 1B
Companies by region based on country of incorporation.

<table>
<thead>
<tr>
<th>Region</th>
<th>Crops</th>
<th>Animals</th>
<th>Farm machinery</th>
</tr>
</thead>
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<tr>
<td>USA-Canada</td>
<td>92</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>Europe-Middle East</td>
<td>70</td>
<td>32</td>
<td>13</td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>55</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Latin America</td>
<td>9</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Total World</td>
<td>226</td>
<td>62</td>
<td>40</td>
</tr>
</tbody>
</table>

None of the companies in the database are based in Africa.
using the national ratios of market US$ and PPP$ exchange rates for 2005 from the S. implicit GDP price index (2005 constant PPP$, nominal US$ expenditures were

To obtain global expenditures in nominal US$, this study used current market exchange rates to convert foreign revenues and expenditures.

3.1. R&D investment trends by global agribusiness

3. Findings

3.1. R&D investment trends by global agribusiness

The study finds that between 1990 and 2014, private agricultural R&D spending world-wide more than tripled, from $5.1 billion to more than $15.6 billion per year in nominal US dollars (Table 3), or from $6.4 billion to $12.9 billion in constant 2005 PPP$ (Table 4).

Also in 2005 PPP$, total private R&D for both food and agriculture rose from $12.8 billion to $30.8 billion during 1990–2012 (food R&D estimates are only available through 2012). By way of comparison, total global public agricultural R&D expenditures were around $32–34 billion in 2008–2009 in 2005 PPP (Bientema et al., 2012; Pardey et al., 2015a). According to the estimates in Table 3, the growth rate in nominal private agricultural R&D spending accelerated after 2003, from around 3% per year during 1990–2003 to over 7% per year between 2003 and 2014. Trends in private agricultural R&D spending mirrored trends in companies’ revenue from agricultural input sales.

In turn, there is a strong correlation between trends in private agricultural input sales and farm commodity prices: 2002 was the year in which the FAO’s world food price index reached its nadir; afterwards it began to rise, more than doubling by 2008.

Higher commodity prices increased farmers’ ability and willingness to spend more for purchased inputs, including the latest technologies, to raise agricultural yields. With a higher crop price,

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop protection chemicals</th>
<th>Crop seed &amp; biotech</th>
<th>Crop fertilizer</th>
<th>Animal health (food sp.)</th>
<th>Animal genetics</th>
<th>Animal nutrition</th>
<th>Total crop R&amp;D</th>
<th>Total animal R&amp;D</th>
<th>Farm machinery R&amp;D</th>
<th>Total agricultural R&amp;D</th>
<th>Total industry R&amp;D</th>
<th>Total food &amp; ag R&amp;D</th>
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</tr>
</tbody>
</table>

* Animal R&D includes R&D on food species only (excluding R&D on companion and equine species).

1. Sum of agricultural R&D and food industry R&D may exceed total because some agricultural R&D is conducted by food companies (e.g., R&D on animal feed).

The value of any yield gain increases. A higher price of corn, for example, would make latest hybrid varieties more profitable to adopt, even though these might cost 20–30% more than older hybrids. But whether higher the revenue earned by input companies would translate into higher R&D investment depends on whether companies view higher commodity prices as long-term or cyclical. It may take several years to realize returns to R&D, and it may not be in a company’s interest to increase investment in R&D only to find demand for new technologies waning by the time that R&D delivers improved products for sale. The strong private sector R&D response, doubling its agricultural R&D spending between 2003 and 2013, suggests that higher commodity prices were expected to persist for some time. In fact, company websites and corporate reports make frequent references to the need to raise long-term agricultural productivity, due to rising populations and limited land and water resources, and such concerns are typically cited as justification for a firm’s investment in agricultural R&D. The bulk of private agricultural R&D is conducted by a relatively small number of companies (Table 5). The 23 “top tier” companies listed in Table 2 (those estimated to have spent at least $100 on agricultural R&D in 2014) together accounted for over 70% of total global agricultural R&D by the private sector. The 110 companies identified in the survey that spent at least $10 million in agricultural R&D in 2014 accounted for 88% of the global total. Admittedly, the estimate for R&D spending by companies with less than $10 million in agricultural R&D is the least precise part of the estimate, since R&D spending by many small companies is not directly observed but imputed. Given the small amount of R&D estimated for companies, even a fairly large error in this estimate would not have a substantial effect on the global total. Table 6 provides an estimate of private agricultural R&D by commodity. This estimate is derived by allocating total R&D for crops and animals in proportion to the share of agricultural inputs...
used by that commodity. The largest private agricultural R&D efforts were for corn ($2,647 million in R&D), soybeans ($1,766 million in R&D), and vegetables and fruit ($1,775 million in R&D). But perhaps a better ranking is to compare R&D spending relative to the gross value of commodity production. Corn, soybeans and other oilseeds rank far above all other commodities in this measure, with private R&D effort amounting to 1.8%, 2.3% and 1.6% of the value of these crops, respectively. For other commodities, including animals and fish, private R&D was less than 1% of the value of production. Important world agricultural commodities not receiving much attention from private R&D include root and tuber crops (potato, cassava, and sweet potato), bananas and plantains, many species of vegetables and fruit crops, small-holder tree crops (coffee and cacao), ruminants, and aquaculture. Regarding aquaculture, most of the private R&D identified in this study was focused on salmonid species (salmon and trout), and private R&D relative to the value of these species is probably around 2%. Private R&D spending on non-salmonid species appears to be quite low.

The great majority of private agricultural R&D spending is by companies based in developed countries, although their aggregate share has fallen over time. Fig. 1 breaks out trends in R&D spending by agricultural input firms and food manufacturing firms based in high-income countries from firms from other countries during 1990–2014. By 2014, about $11.2 billion out of the total $12.9 billion of total private agricultural R&D, or 87%, was by firms based in high-income countries. But this share was down from 94% of total private agricultural research in 1990. However, in food R&D, a rapid rise in reported R&D spending by Chinese firms apparently closed the gap with high-income countries by 2012. Pardey et al. (2015a) report a similar trend in their estimate of private food and agricultural R&D spending in developing and developing countries, but do not break out food R&D from agricultural R&D.9

Although 88% of global private agricultural R&D spending was by companies based in high income countries, a significant part of this R&D is likely targeted toward developing-country farmers. If we assume that companies allocate their R&D around the world in proportion to where they sell their products, the share of private agricultural R&D for developing countries rises to 28% for the top tier companies (Table 7). Moreover, this share was rising over time. By 2014, nearly a fifth of the agricultural input sales of these

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9 Pardey et al. (2015a) estimated global food and agricultural R&D spending by the private sector at $26.8 billion in 2009, which is somewhat higher than this study’s estimate of $23.9 billion for that year (both estimates in 2005 PPP$). A possible reason for Pardey et al.’s higher estimate is that they imputed food and agriculture R&D spending for a much broader set of countries based on an econometric model. Their model assumed that private food and agricultural R&D in a country is correlated with per capita GDP, public agricultural R&D, and total national R&D. They estimated the model using data from middle-income and high-income countries and then used it to derive estimates of R&D spending in low income countries (Pardey et al., 2015b). It is unclear how well this approach predicts R&D spending for countries at substantial different development levels from the observed data, or whether it primarily reflects food R&D or agricultural R&D.
companies was in Latin America alone. While the Latin American-based companies tracked in our survey spent in total only $31 million on agricultural R&D in 2014, R&D spending by multinationals for Latin America could have been as high as $2245 million when allocated proportionally to regional sales of agricultural inputs.

A rare published breakdown of agricultural R&D by region by the Swiss company Syngenta offers an opportunity to assess this approach to allocating R&D by location. In its 2002 Annual Report, Syngenta reported that 54% of its R&D employees (who numbered 4149 at that time) were located in the Europe-Middle East-Africa region, while 27% were in Latin America, 8% in Asia-Pacific countries. In that year, the corresponding geographic segment shares of its agricultural seed and chemical sales were 38%, 36%, 11%, and 15% respectively. Clearly, assigning all of Syngenta’s R&D to Switzerland, or even to Europe, understates its relevance for world agriculture. Allocating its R&D in proportion sales would provide a better approximation, although it would underestimate its R&D spending in its home region – Europe.

### 3.2. Private agricultural R&D in developing countries: the role of technology policy

The evidence above suggests that the private sector is increasingly important for agricultural innovation and productivity growth not only in developed but also developing countries. However, while the data are incomplete, it appears that for many low and middle income countries, there is little evidence of much private investment in agricultural R&D. A recent review article by Pray and Fuglie (2015) found that technology policy can have a significant influence on private agricultural R&D spending in developing countries, including by foreign companies. In particular, they found that policies toward biotechnology, intellectual property rights, and allowing participation of multinational corporations in national agricultural input markets affected the willingness of private firms to invest in agricultural R&D. The paragraphs below draw from their study to contrast different policy approaches pursued by Brazil, India and China to incentivizing private agricultural innovation in their countries, and what lessons this may hold for other developing countries.

Brazil has taken a relatively liberal policy toward multinational participation in their domestic agricultural input markets, allowing foreign companies to operate wholly-owned subsidiaries in the country and acquire domestic companies. Brazil also established intellectual property rights for new crop varieties and regulatory protocols for approving the use of GM crop varieties. Brazil is one of the fastest growing markets for agricultural inputs, and several multinational companies have established agricultural research stations in the country. Agricultural R&D spending by private companies increased from $50 million in 1996 to $377 million in 2012, almost all of which was by foreign companies (Pray and Fuglie, 2015). This amounts to about 20% of total public and private agricultural R&D spending in Brazil in 2012 (public agriculture R&D in Brazil $1560 million that year, according to Pray and Fuglie, 2015).

India’s agricultural input markets were largely closed to the private sector until the 1990s. Reforms in that decade removed import restrictions, established plant breeders’ rights, and allowed domestic and foreign companies to participate in agricultural input markets. Meanwhile, the government reduced its support for or privatized state-owned enterprises that had previously dominated input markets (Pray and Fuglie, 2015). India also permitted the use of GM varieties in cotton. According to a survey of agricultural companies (Pray and Nagarajan, 2014), private agricultural R&D in India increased from $44 million in 1995 to $271 million in 2009, with 38% of this spending by foreign multinationals and 62% by Indian firms. Not only were Indian seed, pesticide, and farm machinery companies able to compete with foreign companies in the Indian market, some had expanded into foreign markets as well. With public agricultural R&D at $895 million in 2009 (ASTI), the private sector accounted for nearly one-fourth of total public and private agricultural R&D spending in India.

Despite being the world’s largest agricultural producer, China has restricted foreign company participation in seed and other agricultural input markets to minority shares in joint ventures with Chinese firms (Pray and Fuglie, 2015). In addition, enforcement of intellectual property laws is seen as relatively weak, approval of GM crop varieties has been limited to cotton, and state-owned companies continue to play a major role in supplying agricultural inputs to Chinese farmers. While many foreign multinationals have engaged in agricultural research in China (often in collaboration with a Chinese institution or company), their agricultural R&D investment in China has been relatively modest. A survey of 1305 Chinese agribusiness firms, including state-owned enterprises and firms with foreign joint ventures, estimated that their combined spending on agricultural R&D (not including funds from the government) was $244 million in 2006 (Hu et al., 2011). With a relatively low level of private agricultural R&D, agricultural research in China continues to be dominated by public institutions. Public agricultural R&D spending in 2006 was $1934 million (Pray and Fuglie, 2015).

Despite low levels of agricultural R&D spending by foreign or domestic firms in China, Chinese companies have used direct acquisitions of foreign companies to gain access to their capacities and technology. Previously mentioned were the acquisitions by the state-owned enterprise ChemChina of the France-based specialty feed company Adisseo (for $500 million in 2005) and the Israel-based agricultural chemical company Adama (for $2.4 billion in 2011). In 2011, the privately-owned Chinese company Shuanghui International acquired the U.S.-based meat processing company Smithfield Foods for $4.72 billion, including its subsidiary Smithfield Premium Genetics, one of the world’s largest privately-held pig breeding operations. In the same year the state-

#### Table 7
Estimates of agricultural R&D of top tier companies by global region in 2014.

<table>
<thead>
<tr>
<th>Region</th>
<th>North America</th>
<th>Europe-Middle East</th>
<th>Asia-Pacific</th>
<th>Latin America</th>
<th>Emerging Markets</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assign company R&amp;D according to country of incorporation</td>
<td>Private R&amp;D by top tier companies (million US$)</td>
<td>6139</td>
<td>5092</td>
<td>524</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% of total</td>
<td></td>
<td>52</td>
<td>43</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Assign company R&amp;D in proportion to regional sales of agricultural inputs</td>
<td>Private R&amp;D by top tier companies (million US$)</td>
<td>4606</td>
<td>3397</td>
<td>1507</td>
<td>2245</td>
<td>3275</td>
</tr>
<tr>
<td>% of total</td>
<td></td>
<td>39</td>
<td>29</td>
<td>13</td>
<td>19</td>
<td>28</td>
</tr>
</tbody>
</table>

Top tier companies include the 23 companies listed in Table 2 that had at least $100 million in agricultural R&D in 2014. Europe-Middle East includes Africa, Emerging Markets: China, India, Turkey, South Africa, Brazil, Argentina, Mexico and other developing countries.
owned Chinese machinery manufacturer Sinomach acquired
McCormick France Corporation, a French farm machinery parts
manufacturer. But by far the most significant potential acquisition
is of Syngenta by ChemChina. In February 2016, ChemChina’s $43
billion offer was accepted by Syngenta and is currently undergoing
regulatory review. Our survey indicates that the agricultural R&D
spending in 2014 by all of these foreign acquisitions was $1.49
billion ($1.38 billion by Syngenta alone).

The experiences of Brazil, India and China outline three distinct
approaches for developing countries to attract and build capacity
in private agricultural R&D. By one measure – total private R&D
investment in the country – Brazil’s open-door policy has been the
most successful. It mobilized the R&D capacity of multinational
agribusiness to make new technologies available to Brazilian
farmers, and at very little direct cost to the Brazilian economy.
India’s economic reforms gradually reduced the role of state-
owned enterprises in supplying agricultural inputs to farmers and
couraged not only domestic but also foreign businesses to fill
that gap. While total agricultural R&D investment in India has
been significantly below that of Brazil (around $271 million per
year in India versus $377 million per year in Brazil in the late
2000s), more than half of that investment was by Indian firms.
Some of these have emerged as multinationals themselves, suc-
cessfully competing with their own brands in international che-
tical, seed, and farm machinery markets. China, despite a much
larger agricultural sector, appears to have mobilized even less
private agricultural R&D spending than India, nearly all of which is
by domestic firms. While China has been less successful in at-
tracting foreign companies to invest in agricultural R&D in China,
it has been able to access foreign technology through direct ac-
quisitions of foreign firms. This strategy may speed up transfer
of technology assets to China and preserve a larger degree of sover-
eign control, but is financially costly to the Chinese economy.

3.3. Venture capital: attracting new entrants and new technologies
to agriculture

The approach taken in this paper to assess the level and di-
rection of agricultural innovation by the private sector has been to
track R&D spending of the major companies in agricultural input
sectors. A limitation of this method is that it may miss new en-
trants, especially by small and medium-size enterprises (SME).
New SME entrants, often funded through venture capital or angel
investors, can be of particular importance for early stage devel-
opment of a new types of technologies. SME’s provide a useful
platform for experimentation and for attracting new expertise and
talent to the field. Similar to the role SME’s played in developing
agricultural biotechnology in the 1980s, they may now be playing
a major role in developing information technology (IT) applica-
tions for agriculture, or what is commonly referred to as precision
agriculture.10

A useful source of information on SME innovation activity is
venture capital (VC) funding. Corporate and institutional investors
make extensive use of VC to explore high-risk but potentially
transformative technologies. VC has arisen has a financing tool for
investors in situations where there are large differences between
what investors and entrepreneurs know about technological op-
portunities, but where entrepreneurs may have few tangible assets
that would enable them to seek traditional forms of capital fi-
nancing (Gompers and Lerner, 1999). While only a portion of VC is
for formal R&D (it also funds scaling up, integrating and field
testing new innovations), trends in VC financing provide an in-
dicator of where the business sector sees potential for new tech-
nologies to have transformative impacts in the economy.

In fact, there appears to have been a sharp rise in venture ca-
pital (VC) financing of SME’s for food and agriculture innovations
in the last few years, at least in the United States. Before 2013, U.S.-
based VC funds for food and agriculture averaged $400–500 mil-
ion per year, but then grew to $800 million in 2013, $2.4 billion in
2014, and $4.6 billion in 2015 (AgFunder, 2016). Table 7 breaks
down how U.S.-based food and agriculture VC was allocated
among several technology areas. Of the total VC of $6.9 billion
during 2014–2015, $2.57 financed new agricultural innovations.
More than $1 billion of this was used to fund 185 projects invol-
volving precision agriculture, including field sensors, satellite ima-
gery, drones and robotics, and decision support tools to translate
“big data” into real-time farm management advice. Many of the
recipients of these funds were small start-up companies, including
a cluster of Silicon Valley IT firms. Another $692 million funded
projects for irrigation technology and management, and $482
million for projects involving biological and chemical treatments,
GM traits and seed technologies to enhance crop nutrition and
health. Although many if not most of the firms and projects funded
by VC can be expected to fail, what could emerge from this in-
vestment is a new IT agricultural input sector with significant
implications for resource use and productivity in agriculture.

4. Summary and implications

The importance of the private sector in developing new agri-
cultural technologies for world agricultural has clearly increased
over the past quarter century. Between 1990 and 2014, private
spending on agricultural R&D rose from $5.14 billion to $15.61
billion per year, an increase of more than three-fold (or two-fold,
in constant PPPS). This is faster than the growth in public agri-
cultural R&D and in high-income countries, now constitutes the
majority of total agricultural R&D (Bientema et al., 2012; Pardey
et al., 2015a). The relevance of private R&D for developing country
agricultural is also growing. Estimates in the paper suggest that as
much as 28% of total private agricultural R&D (amounting to $4.3
billion in 2014) may be targeted toward farming conditions in
developing countries. Moreover, private agricultural R&D spending
was rising faster in developing countries than in developed
countries.

The private sector appears to have demonstrated considerable
agility in raising R&D investments at least partially in response to
the commodity price increases of the past decade. When world
prices for agricultural commodities began to rise after 2002, pri-
ivate investment in agricultural R&D accelerated, with the annual
rate of increase rising from under 3% to over 7% (from 1% to 5% per
year in inflation-adjusted dollars). Given the long lag times to
realize economic returns from R&D investments, it would seem
that private companies interpreted the rise in commodity prices as
signaling a long-term tightening of global food supply-demand
balances and not merely a short-term cyclical phenomenon. Their
willingness to significantly increase spending on R&D suggests
they expected heightened farm demand for productivity-enhanc-
ing technologies to persist well into the future. It will be inter-
esting to see to what extent the recent drop in commodity prices
will affect these expectations and the R&D investment decisions by
these companies. Although data are incomplete, some large firms
announced reductions in their R&D spending in 2015 and 2016.

The growing R&D capacity of the private sector carries im-
plications for public policies toward agriculture and development. One key challenge is adjusting the public R&D portfolio so that is
complements rather than crowds out private R&D. One way
government science agencies and universities accomplish this is by focusing on basic or fundamental scientific research. But contemporary models of scientific and technological development processes suggest that relationships between basic and applied sciences are interactive and complex, and that there continues to be a role for targeted, applied R&D by public institutions, even in developed countries. There are also significant opportunities (and challenges) for mobilizing joint public-private investment in pre-commercial research and enhancing information flows between public and private R&D institutions (Fuglie and Toole, 2014).

An important target for public R&D is to address farmers’ needs in areas where incentives for private R&D are low. From the data presented in this paper, it is apparent that the world-wide coverage of private agricultural R&D remains uneven. Private R&D in developing countries, while growing rapidly overall, has been heavily focused on middle-income countries. Low-income countries, especially those in Africa, have yet to attract substantial private R&D investment in their agriculture sectors. Even among middle countries, the willingness of the private sector to invest in agricultural R&D is conditioned by the policy environment, as the comparative experiences of Brazil, India and China attest to.

An important implication of this evidence is that the enabling environment for the private sector matters. Reasons why private companies have invested few R&D resources into some countries is that the institutions providing intellectual property right enforcement, regulatory frameworks, technology dissemination, farm credit and marketing services, are poorly developed (Pray and Umali-Deininger, 1998). A strong public agricultural research and university system can also be a draw for companies to locate research in a country, as it assures a pool of trained local talent and provides a stronger knowledge base to build upon (Pray and Fuglie, 2001).

Private R&D also appears to be uneven across commodities. While companies are pursuing at least some research on most of the world’s cultivated crops and animal species, private R&D appears to be concentrated on a relatively small number of crops, especially corn and soybeans. Private R&D spending on wheat, rice, vegetables, cattle, pigs, and poultry is also considerable and growing, but still relatively low given the importance of these commodities to the global economy. And there are a range of other commodities where so far R&D investment by the private sector appears to be negligible – roots and tubers, most tree crops, small ruminants, and most species of farm-raised fish, for example. (Table 8).

Some of the public concerns that have been expressed about the rising role of the private sector in agricultural technology development include (i) loss of national control over food systems, especially if foreign multinational corporations become dominate suppliers of inputs to farmers, (ii) growth of monopoly power in input markets that could drive up input prices, (iii) technology determinism, where farmers choices may be limited to technologies favored by private developers, such as hybrid seed and GM crops, and (iv) a preference to serve the needs of large commercial farms at the expense of small holders. While exploration of these issues is beyond the scope of this paper, what is clear from the evidence is that the private sector has made major contributions to raising agricultural productivity in both developed and developing countries. Moreover, the technological portfolios, geographic and commodity coverages, and level of financial commitment of the private sector to agricultural R&D are expanding.

### Disclaimer

The views expressed in this paper are the author’s own and do not necessarily reflect those of the U.S. Department of Agriculture or the Economic Research Service.

### References


#### Table 8

<table>
<thead>
<tr>
<th>Sector</th>
<th>Innovation</th>
<th>Venture capital deals (number)</th>
<th>Venture capital investment (million $)</th>
</tr>
</thead>
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<tr>
<td>Agriculture</td>
<td>Precision agriculture</td>
<td>185</td>
<td>1077</td>
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<tr>
<td>Agriculture</td>
<td>Decision support tools &amp; software</td>
<td>76</td>
<td>424</td>
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<tr>
<td>Agriculture</td>
<td>Drones &amp; robotics</td>
<td>65</td>
<td>502</td>
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<tr>
<td>Agriculture</td>
<td>Sensor &amp; mapping technologies</td>
<td>44</td>
<td>151</td>
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<tr>
<td>Agriculture</td>
<td>Irrigation &amp; water management for crops</td>
<td>27</td>
<td>102</td>
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<tr>
<td>Agriculture</td>
<td>Crop health &amp; nutrition (biologicals, chemicals, traits)</td>
<td>61</td>
<td>482</td>
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<tr>
<td>Agriculture</td>
<td>Indoor &amp; greenhouse agriculture</td>
<td>38</td>
<td>252</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Animal health &amp; nutrition</td>
<td>17</td>
<td>66</td>
</tr>
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<td>Food systems</td>
<td>Food ecommerce marketing</td>
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<td>2023</td>
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<td>Sustainable protein (meat substitutes)</td>
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<td>360</td>
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<tr>
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<td>Food manufacturing technologies</td>
<td>28</td>
<td>135</td>
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<td>Food systems</td>
<td>Food safety &amp; traceability</td>
<td>29</td>
<td>144</td>
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<td>Food systems</td>
<td>Waste technology</td>
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<td>Farm to consumer marketing</td>
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<td>Bioenergy</td>
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<td>679</td>
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<tr>
<td>New uses - industry</td>
<td>Biomaterials &amp; biochemicals</td>
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<td>367</td>
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<tr>
<td>Other</td>
<td>Miscellaneous</td>
<td>85</td>
<td>213</td>
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<td>Total agriculture</td>
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<td>Total food systems</td>
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<td>3036</td>
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<tr>
<td>Total energy, industry and other uses for crop commodities</td>
<td></td>
<td>168</td>
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</tr>
<tr>
<td>Total, all sectors</td>
<td></td>
<td>790</td>
<td>6864</td>
</tr>
</tbody>
</table>


IBGE. Survey of Technological Innovation (PINTEC). Instituto Brasileiro de Geografia e Estatística, Brasília, Brazil.


