Review Version

Long-run and Global R&D Funding Trajectories: The U.S. Farm Bill in a Changing Context

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ABSTRACT (250 words)

Domestically funded (and performed) research and development (R&D) has historically been a major source of productivity gains in U.S. agriculture, and a principal source of R&D spillovers to the rest of the world. In the waning decades of the 20th century, U.S. policymakers opted to ratchet down the rate of growth in public support for food and agricultural R&D. As the 21st century unfolds, slowing growth gave way to real cutbacks, reversing the accumulation of U.S.-sourced public R&D capital over most of the previous century and more. The 2014 Farm Bill did little to reverse these long-run research funding trajectories—politicians apparently ignored economic evidence about the still substantial social payoffs to that research and the consequent slowdown in U.S. agricultural productivity growth associated with the spending slowdown. Meanwhile, R&D spending by other countries has been moving in different directions. We present new evidence that today's middle-income countries—notably China, Brazil and India—are not only growing in relative importance as producers of agricultural innovations through investments in public R&D, they are also gaining considerable ground in terms of their share of privately performed research of relevance for agriculture. The changes in global public *and* private R&D investment trajectories are accelerating of late, and substantive. If history is any guide to the future, these changing R&D trajectories could have profound consequences for the competiveness of U.S. agriculture in the decades ahead.

Key words: public, private, food, agriculture, research, innovation.

JEL codes: O3, O4, Q1

Long-run and Global R&D Funding Trajectories:
The U.S. Farm Bill in a Changing Context

Concerns about our ability to balance the world food equation without plowing in the plant have resurfaced in recent years. Although a recent reassessment of global production and consumption prospects (Pardey et al. 2014) is less concerning than others have reported (for example Brown 2013; The Club of Rome 2012), they observe that the future is unlikely to be like the past in several important respects. While the projected growth in average per capita incomes, the changing demographics (generally aging) of the world population, and the increasing demand for agricultural feedstocks for biofuel uses are important determinants of prospective growth in agricultural consumption in the decades ahead, they are secondary sources of consumption growth. Around 70 percent of Pardey et al.'s (2014) prospective food consumption growth to 2050 is attributable to growth in population. However, future population growth is deemed to markedly deviate from the past: the United Nations (2013) midline estimates have the world's population growing at half the rate during the period 2010 to 2050 (0.80 percent per year) compared with the rate observed for the previous five decades (1.69 percent per year).[1]

While slower population growth translates to slower growth in consumption, global average yield growth is also slowing for many crops, especially relative to the rapid rates seen during the Green Revolution years of the 1960s and 1970s. Slower yield growth, ceteris paribus, translates to slower output growth. To the extent Ruttan (1982, p. 60) was right—in that higher levels of crop yields (or productivity levels more generally) require research to run even harder to stand still and prevent yields from falling—the amount, nature and success of R&D worldwide in sustaining farm productivity is a critical determinant of the future balance to be struck between agricultural production and consumption. These investments in maintenance research, that forestall productivity declines attributable to co-evolutionary pest and disease pressures and changes in climate or other factors that would otherwise cause yields to fall, are in addition to the

[1] The U.N.'s high end estimate has global population in 2100 totaling 16.6 billion (versus 10.9 billion for the midline estimate and 6.8 billion for the low end figure.) All of these estimates involve out-of-sample assumptions about the fertility and mortality rates that underpin these estimates. Holding these underlying parameters at their present rates would put the estimated world population in 2010 at 28.7 billion (United Nations 2013, table I.1).

investments in R&D required to promote and sustain the additional growth in productivity required to feed a global population of 10.9 billion or so by 2100.

Developing an informed sense of these productivity prospects requires an understanding of the global patterns of investment in R&D that are pivotal to promoting growth in agricultural productivity. Decisions about the amount and priorities of U.S. spending on agricultural R&D should be cognizant of the changing global realities of these innovation markets, which are becoming increasingly interconnected via international trade in innovation and the food and agricultural output these innovations make possible. With that firmly in mind, our objective in this paper is to report and evaluate entirely new evidence on the global investments in R&D that affect the productivity performance of the food and agriculture sectors in the United States and worldwide. In so doing we present an assessment of trends in public food and agricultural R&D spending worldwide for the past half a century (specifically, 1960-2009) using a revised and updated version of the InSTePP R&D Series.[2] Evidence of investments on private-sector R&D focused on this part of the world's economy is much more limited. Here we unveil and evaluate summary statistics from the first release version of private spending on food and agricultural R&D worldwide to be included in the InSTePP R&D Series. Research focused on food and agriculture is not the only source of innovation in this sector. The results of public *and* private research in the broader biological and informatics sciences, engineering, ecology, health and numerous other areas of inquiry also show up as innovations in food and agriculture (and vice versa). To gain a more complete insight into the relevant R&D spending affecting U.S. and global food and agriculture we juxtapose the sector-specific R&D spending estimates against entirely new estimates of global total (*all* public and private) R&D spending developed by Dehmer and Pardey (2014) for the period 1980 to 2009.

This comprehensive, cross-sector, cross-country perspective of the world's changing R&D landscape provides a much different perspective on the policy context for public funding of U.S. food and agricultural R&D and the role of the 2014 Farm Bill than if the focus was solely on

[2] InSTePP is the International Science and Technology Practice and Policy center at the University of Minnesota. A prior version of this global public sector series was summarized in Pardey, Alston and Chan-Kang (2013a and b) and Pardey and Beddow (2013). This version supersedes and updates the prior estimates, although the overall patterns observed in the prior releases are preserved. Details of all data sources and estimation methods are in Pardey et al. (2015).

public (or even more narrowly construed federal government) funding for food and agricultural research conducted in the United States. We reveal that the U.S. position in this global R&D landscape has changed in substantive ways, especially over the past decade, partly as a result of investment decisions taken by governments and private entities elsewhere in the world, but also as a consequence of changed investment priorities in the Unites States.

The Global Geography of R&D in 2009

In 2009 the world invested $1.1 trillion (2005 PPP prices) in all forms of R&D conducted by the public and private sectors (Figure 1, Panel a). Public and private research focused on food and agriculture (Figure 1, Panel b) totaled $60.9 billion that same year, or just 5.6 percent of the all-research total. The United States still has a dominant position in terms of total R&D spending worldwide, accounting for about one-third of the world's total spending on R&D in 2009. The high-income group of countries (including the United States) accounted for 78.3 of the all-R&D total. In contrast, the middle-income countries accounted for about one-fifth of the total and the 28 low-income country share was just 0.3 percent. Although there are huge spatial disparities in the funding and conduct of R&D worldwide, Dehmer and Pardey (2014) show that the geography of overall R&D funding—and, inevitably, the location of innovation that funding brings about—is trending towards the larger (and generally faster growing) middle-income countries.

[Figure 1: *Public and private R&D worldwide: Total, and food and agriculturally-related, 2009*]

The geography of R&D focused on food and agriculture is different (Figure 1, Panel b). In brief, the U.S. share of total public and private R&D is much smaller (17.6 percent, versus 33.4 percent for all R&D) and the global share of food and agricultural R&D conducted in other rich countries is also smaller (37.9 percent, versus 44.9 percent for all R&D). Public and private agencies in the middle-income countries now spend $25.7 billion (42.1 percent) on food and agricultural R&D, compared with a corresponding 55.5 percent market share for the high-income countries. Moreover, just three countries (Brazil, India and China) account for 68.5 percent of the (public and private) food and agricultural R&D by *all* the middle- and low-income countries combined.

Like the geography of food and agricultural production itself, food and agricultural R&D is highly spatially concentrated. In 2009, just 10 countries accounted for 65.6 percent of the value of agricultural production (FAO 2014), while 73.9 percent of the food and agricultural R&D was conducted by the top 10 R&D performing countries (with 59.0 percent of that food and agricultural R&D undertaken in the top five performing countries).[3]

The Shifting Global Landscape of Food and Agricultural R&D Spending

The more-notable trends in global food and agricultural R&D spending are a) a substantial rise in the share of that spending being conducted by middle-income countries, and a decline in the rich-country share, b) an increase in the global share being conducted by the private sector, especially among the high-, and, of late, middle-income countries, and c) an exceptionally small and slightly declining share of global spending taking place in the low-income countries, with very little of that spending conducted by the private sector.

Global Public Research—The Rise of the Middle-Income Countries

After adjusting for inflation, public spending on food and agricultural R&D rose worldwide from an estimated $5.4 billion (2005 PPP prices) in 1960 to $33.6 billion in 2009 (an average rate of increase of 3.36 percent per year). There are distinct geographical differences in the pattern of growth of public spending over the past half century. The rate of growth in rich country spending peaked in the 1960s and 1970s and has fallen since then, averaging just 0.99 percent per year from 2000-2009 In contrast, spending grew by 5.7 percent per year from 2000-2009 for the middle-income countries, compared with an average of 4.3 percent per year for the 1960-2000 period. The low-income countries increased their public agricultural R&D spending by about 3.2 percent per year since 1960, which failed to keep pace with growth elsewhere in the world, such that their share of the global public total has trended down for the past half century.

These income-group trends belie substantial variation in the evolving pattern of investment in public food and agricultural R&D at the country level. For instance, while real spending by the rich-country group grew on average after 2000, albeit much more slowly than in previous decades, inflation-adjusted spending actually shrank for 16 (48.5 percent) of the countries in this

[3] The world's largest agricultural producers by value in 2009 (in descending order) were China, United States, India, Brazil, Indonesia, France, Pakistan, Germany, Argentina, and Turkey. The largest agricultural R&D performers (public plus private R&D (again in descending order) were China, United States, Japan, India, Brazil, Germany, France, Korea, United Kingdom, and Spain. Eastern European and Former Soviet Union countries are excluded. We include only 124 countries for which agricultural R&D data are available.

group during that period, including the United States. In contrast, among the rapidly growing middle-income group, 16 countries grew on average by more than 5 percent per year after 2000—including China (9.9 percent per year), Turkey (8.1 percent per year), and India (5.2 percent per year)—and 17 countries grew between 2 and 5 percent per year.

Internationally conceived agricultural R&D performed by way of the 15 research centers of the Consultative Group on International Agricultural Research (CGIAR) accounted for just 0.9 percent ($0.53 billion, 2005 PPP dollars) of this global R&D total in 2009 (Figure 1). CGIAR spending constituted 1.6 percent of the public sector total in 2009, or about 3.1 percent of the corresponding developing-country total of $17.3 billion. Although inflation adjusted spending by the CGIAR, and its predecessor institutions, grew by 1.11 percent per year from 1980 to 2009 to total $529 million in 2009, it has not kept pace with the growth in either public sector R&D spending—2.3 percent per year real growth for public R&D, over the same period—or private sector R&D—an average of 4.0 percent per year growth by the private sector over the period 1980-2009 versus 1.22 percent per year by the CGIAR).

Public versus Private Research Worldwide

For much of modern history, the preponderance of formal global food and agricultural R&D was conducted by public agencies, including government research labs and academic institutions (with a comparatively minor share undertaken by non-governmental organizations).[4] Figure 2 reveals that even this stylized fact is changing. Worldwide, private sector food and agricultural R&D spending has risen faster than public spending (3.4 versus 2.6 percent per year from 1980 to 2009), so that the privately performed share of food and agricultural R&D has increased from about 36 percent in 1980 to 44 percent in 2009. Notwithstanding this significant structural change, a substantially smaller share of the sector's R&D is still conducted by private firms compared with R&D generally, which was 66 percent in 2009 according to Dehmer and Pardey (2015).

[Figure 2: *Global R&D trends for food and agriculture, 1960-2009*]

[4] Prior to the advent of publicly funded research, beginning in the early 19th century Germany with the development of research universities and the subsequent establishment of "agricultural experiment stations" in Scotland and England towards the middle of that century (Russell 1966; Ruttan 1982), informal private innovation (in the form of tinkering and trial and error efforts by farmers and other individual inventors) predominated.

Most of the world's private food and agricultural R&D spending was historically concentrated in and targeted towards the rich-countries, but that too is now beginning to change. In total, the share of global private sector spending on food and agricultural R&D in high-income countries was 65 percent in 2009, down from 85 percent in 1980. The United States alone accounted for 33 percent of this private R&D spending in 1980. That shared peaked in 1997 at 37 percent and has slid since, down to 23 percent by 2009. Notably, that same year, Brazil, India and China combined conducted more private food and agricultural R&D than the United States: $7.7 billion versus $6.2 billion for the United States. This is a dramatic and historical shift in the global food and agricultural R&D landscape. Three decades ago, in 1980, total private spending by these three countries was but a fraction (26 percent) of the corresponding U.S. figure ($2.9 billion).

[Figure 3: *Global per-capita income trends in private food and agricultural R&D, 1980-2009*]

Private sector spending on food and agricultural R&D in low-income countries is minuscule; accounting for just 0.06 percent of global private sector spending in 2009 and just 1.7 percent of the total (public and private) sector spending in this part of the world. As Pardey and Beddow (2013) discussed, the more limited private-sector participation in agricultural research done in or for developing countries stems from several factors. A significant share of food produced in developing countries is consumed by the household that produced it. Even when commodities enter the marketing chain, they are often purchased in less processed forms for preparation and eating at home. Consequently, a much smaller share of the food bill in developing countries accrues to postfarm food processing, shipping, and merchandising activities, areas where the incentives for private innovation are relatively pronounced. Likewise, on the supply side, purchased inputs (such as herbicides, insecticides, improved crop varieties or animal breeds, and all sorts of agricultural machinery) constitute a comparatively small share of the total costs of production in many agricultural market segments in many parts of the developing world. While this is likely to change as incomes rise and infrastructure improves, the pace of change will be gradual in the poorest areas, where (semi-)subsistence farming still predominates. The cost of doing business in places with small and often remote farms subject to poor market access, lack of farm credit, and limited communication services also undercuts private participation in agribusiness, in turn reducing the private incentives to invest in R&D targeted to these markets. In addition, a plethora of regulations, many times inefficiently enforced, combined with an uncertain and incomplete legal environment (especially related to contract law and intellectual property protection) make it difficult for local and multinational private interests to profitably penetrate agricultural markets with new seed, chemical, or other agricultural technologies in substantial parts of the developing world.

The standout public and private sector trend in these data is China. R&D done by China, and thus the BIC aggregate, shrank substantially throughout the 1960s; a response to the turmoil of the Great Leap Forward and the subsequent Cultural Revolution. As Fan and Pardey (1992) described, during 1960–1961, one third of the CAAS (Chinese Academy of Agricultural Sciences) institutes were moved to rural areas or disbanded and the Academy's total number of staff declined by 70 percent from 7,500 to 620 personnel. From a 50-year low of 3 percent of global public agricultural R&D spending in 1968, China's share of the total grew steadily to 10.7 percent in 2001 and thereafter grew rapidly to 19.5 percent by 2009.

Reforms to the Chinese "science and technology management system" launched in March 1985 spurred efforts to commercialize and increasingly privatize R&D activity throughout the country (Fan et al. 2006).[5] Public agricultural research institutes established commercial enterprises (not all of whom were related to food and agriculture and not all of whom undertook R&D) and shareholder companies in the seed, food, chemicals and agricultural machinery markets grew—many, at least initially, were spun off from development firms founded by public research institutes—, as did state-owned enterprises operating in this same economic space. Multinational agribusiness companies made tentative R&D moves into China, although marketing, regulatory, intellectual property rights, and other institutional barriers dampened the inflow of foreign direct investment in the food and agricultural sectors generally, and for R&D in particular, at least in the early phases of the reform (Rozelle, Pray and Huang 1999; Koo et al. 2006). The benefit-cost calculus of multinational firms conducting R&D within China appears to be changing. In recent years a number of multi-national firms with interests in food and agriculture opened sizable R&D facilities in China, including Hormel Foods (in 2008), BASF (2012), Syngenta

[5] Not all these and subsequent reforms to the country's R&D system had desirable outcomes, as Cao et al. (2013) describe.

(2012), Pepsico (2012), General Mills (2014), and Cargill, although the extent of their spending focused on food and agricultural R&D in China is difficult to discern.[6]

Multinational agribusiness firms are also judiciously increasing their R&D presence in other foreign markets, for example Cargill also has R&D operations in Brazil and Syngenta, Pioneer-Dupont in India and Nestle in Chile, China, Nigeria, and India. As food and agribusiness markets continue to grow and formalize—typically characterized by intensification of agricultural production methods and a growth in post-farm value adding activities—the off-shoring of R&D by U.S. and European based firms adds to the overall growth in R&D from domestic firms operating in these emerging markets. Thus the empirical and anecdotal evidence reinforce the notion that we are in the midst of a modern historical transition whereby the geographical locus of innovation in food and agricultural markets is shifting well beyond the borders of the rich countries that have historically dominated research in this sector.

US R&D Spending Patterns

The U.S. has lost substantial global market share regarding public and, of late, also private spending on R&D related to food and agriculture. Part of these structural shifts stem from policy and market developments in the rest-of-the-world. Part of these shifts are the outcome of public and private decisions and developments within the United States, to which we now turn.

R&D Within the U.S. Public Sector

The conduct, orientation and funding of U.S. public food and agricultural R&D has changed dramatically over the past half century. Research conducted by the United States Department of Agriculture (USDA) and the state agricultural experiment stations (SAESs) accounted for roughly equal shares of public food and agricultural research spending until the early 1940s, after which the SAES share grew to 73 percent of the public total by 2009 (Figure 4). Agricultural

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[6] For details on Hormel Foods see http://www.hormelfoods.com/Newsroom/Press-Releases/2008/02/20080228; BASF, http://www.greater-china.basf.com/apex/GChina/en/content/BASF-China/1.1_About_Us/About_BASF_in_Greater_China/Research_and_development; Pepsico, http://www.bloomberg.com/news/2012-11-13/pepsico-opens-china-r-d-center-as-competition-heats-up-with-coke.html; Syngenta, http://www3.syngenta.com/country/cn/cn/products_solution/biotech/sbcen/media_center/Pages/121017.aspx, General Mills, http://www.generalmills.com/ChannelG/NewsReleases/Library/2014/July/china_tech_center.aspx; and Cargill, http://www.cargill.com/company/research-development/facilities/ap-innovation-center/index.jsp.

production and the public spending on research that supports the sector is spatially concentrated. In 2009, just 10 states accounted for almost 53 percent of total agricultural production by value and accounted for 46 percent of the spending on research performed by the SAESs.

[Figure 4: *U.S. public agricultural R&D by performing agency, 1890-2009*]

U.S. funding priorities for R&D have also changed substantially over the years. Significant investments in maintenance research are required just to maintain farm productivity and prevent it from falling. However, as other agendas such as research on health, nutrition, the environment, and biofuels gained ground, the share of SAES research directed to enhancing the productivity of U.S. farmers—or simply sustaining past farm productivity gains via maintenance research—declined from an estimated 65 percent of the total in 1976 to only 56 percent in 2009 (Pardey et al. 2015).

The structure of support for publicly performed food and agricultural R&D has also undergone major changes. While research conducted in USDA labs has been, and still is, almost entirely reliant on federal government funding—$1.47 billion (or 96 percent) of the total of $1.53 billion of that research in 2009 was so funded—the current sources of support for research conducted by the SAESs is markedly different from the past. The state government share of total SAES funding fell dramatically from an average of 57.7 percent in 1970 to just 38.3 percent in 2009. In 37 states, state-sourced support constituted a smaller share of total SAES funding in 2009 compared with 1970, and for 15 states (inflation adjusted) state funding fell in absolute (not just relative) terms. As a consequence, in 1970, on average, states provided $3.0 for every dollar of federal support to the SAESs, but by 2009 only $1.01 of state funding flowed to the SAESs for every dollar of federal funding.

[Figure 5: *Shifting sources of funding for U.S. public food and agricultural R&D, 1890-2009*]

Any increase in SAES funding that has occurred came from two sources. Gradually over time funding from industry, self-generated, and miscellaneous sources has risen in both absolute and relative terms, accounting for $860 million (23.7 percent) of total SAES funding in 2009, versus just $301 million (11.4 percent) in 1970. Funds from federal government agencies has been the major source of additional funds flowing to SAES research in the past few decades, and in 2009 accounted for 38 percent of the overall funding to the SAESs (compared with 19 percent in

1970). For 11 states the federal government accounted for the majority of overall SAES funding in 2009 and for 27 states provided more funding than the state government. Thus while an increasing share of U.S. public food and agricultural research has taken place in state agencies, state governments have ratcheted down their support for the SAESs at the same time the federal government has upped its contribution.

Historically, the USDA was the primary federal government agency channeling funds to the SAESs, mostly through the National Institute for Food and Agriculture, NIFA (previously the Cooperative State Research Education and Extension Service, CSREES), but that too has changed. In 1975, the USDA disbursed about 74 percent of the federal funds flowing to the SAESs through a combination of formula funds, grants, and contracts, but by 2009 that had declined to about 50 percent. A wide range of federal agencies now disburses the other half of federal funds, including NSF, NIH, DOE, DOD, the U.S. Agency for International Development (USAID), and others. The NIFA share of federal funding for SAES research also declined (from 66 percent in 1975 to 39 percent in 2009), such that NIFA now oversees just 16 percent of total SAES funding.

U.S. Private versus Public R&D Developments

Growth in the private participation in U.S. food and agricultural R&D has been unfolding for at least the past half century. During the early 1950s the public-private spending split averaged 57 to 43 percent (Figure 6, Panel a), but by 1974 the private sector outspent public R&D agencies. Since then the private share has grown to 61 percent by 2009; still short of the private share of overall R&D in the United States (66 percent in 2009).

[Figure 6: *U.S. public and private food and agricultural R&D spending, 1950-2009*]

Changes in the appropriability of the returns to investment in food and agricultural R&D no doubt spurred some of these developments. The use rights and associated rents from developing and deploying innovations changed as a consequence of changes in public policy and associated legislation—such as the 1980 Bayh-Dole Act, the 1988 Federal Technology Transfer Act, the 1995 National Technology Transfer and Advancement Act, and other legislation that affects the ownership of and access to inventions emanating from federally sponsored research—along with changes in patent law and practice—such as the *1980 Diamond v. Chakrabarty* and the *J.E.M.*

Ag Supply, Inc v. Pioneer Hi-Bred, Inc decisions of the Supreme Court, to name but two of a host of relevant cases law (Alston et al. 2010 chapter 7; Pardey et al. 2013). Market changes also played a role in shaping the returns to inventions—such as the increased concentration in seed and other agricultural input markets (see, for example, Fernandez-Cornejo 2004)—as did changes in the science itself—notably the development of modern bio-informatics and bioengineering tools that enabled new gene discovery, gene manipulation, and the development of transgenic bio-engineered crops (NRC 2010).

A naïve notion is that the stalled or shrinking support for public agricultural R&D is of little farm productivity consequence given the rise in private sector R&D oriented to food and agriculture. For sure, for some R&D (notably crop varietal development in some crops targeted to some locales) private effort has substituted for hitherto public effort. However, significant shares of private sector R&D has little if anything to do with sustaining or increasing farm productivity—for example, 36 percent of the private spending in 2009 was concerned with (post-farm) food, beverage and tobacco research. The farm-related agricultural and chemical R&D component (including varietal improvement, farm chemicals, veterinary medicine, crop and livestock management and other such research) was 46 percent of the total, while the machinery related share was 19 percent. Whether private R&D is a complement or a substitute to public R&D is tricky to assess (see, for example, Fuglie and Toole 2014 and the references cited therein). The appropriate division of labor between public and private research is sensitive to evolving intellectual property regimes, changes in commercial opportunities (associated with changes in market structure, trade regimes and the like), and commensurate changes in the pace and nature of scientific progress (both at home and abroad). In general, it is likely that the food and agricultural R&D undertaken by U.S. firms is much more heavily focused on research with nearer term commercial consequence than the counterpart public R&D, just as U.S. private research overall is much more development oriented (79.5 percent development research, 16.0 percent applied and 4.4 percent basic in 2011) than public R&D (25.5 percent development, 27.0 percent applied and 47.5 percent basic in 2011) according to NSF (2014, Table 4-3). From that perspective, public R&D is more of a complement to private R&D, such that a decline in the performance of public research will have consequences for the longer-run rate of innovation in U.S. agriculture.

Farm Bill and Other U.S. Implications

While Pardey, Alston and Chan-Kang (2013) inferred from the returns to research evidence that a doubling of funding to public food and agricultural R&D may be justified, the 2014 Farm Bill made little movement in that direction.[7] Based on CBO (2014) estimates, R&D funding made available by way of the 2014 Farm Bill represented a nominal increase of just $130 million per year over the life of the legislation, equivalent to an average annual increase of only 2.8 percent of total U.S. public R&D spending for food and agriculture (relative to the 2009 total).[8] Moreover, the failure to significantly refinance public food and agricultural R&D is apparently not a matter of limited funds, it is more a matter of political priorities. For every additional dollar invested in R&D over base line funding by way of the 2014 Farm Bill, the CBO estimates that 30 to 50 additional dollars are slated for public subsidies for new crop insurance and "shallow loss" risk management programs.

Important as the Farm Bill funding is to U.S. food and agricultural R&D, the amount and effectiveness of funding for food and agricultural R&D is also affected by a host of other factors. Some relate to the ways by which these funds are disbursed, including the balance between competitive and non-competitive modes of allocation, and the associated procedural and institutional details.[9] Other legislative, legal and especially intellectual property rights policies and practices affect innovation incentives generally, and food and agricultural R&D in particular.

As the new data presented here make clear, the performance, prospects and (economic) consequences of (public) food and agricultural R&D in the United States are increasingly shaped by developments elsewhere in the world. While the United States is arguably still the

[7] See Hurley, Rao and Pardey (2014) for a recent summary and assessment of the returns to food and agricultural R&D evidence.

[8] This includes a limited, one-off, startup allocation of funds in the amount of $200 million made available by way of the newly formed Foundation for Food and Agricultural R&D, FFRA, equivalent to only $40 million a year over the anticipated five-year life of the bill. The FFRA is a non-profit entity with a mandate to solicit non-federal (including private) funding, which is then matched with federal government funding to underwrite research focused on addressing key problems of national and international significance. The FFRA has real potential for reshaping public-private partnerships in U.S. food and agricultural R&D, but unfortunately the limited funding authorized by Congress is likely to severely curtail this potential. For example, Pardey, Beddow and Buccola. (2014) noted that "The private sector has shown a willingness to fund publicly performed food and agricultural R&D (investing $296 million in SAES research in 2009; 8.2% of the SAESs total that year versus 4.9% of the total in 1975)."

[9] See (NRC 2014) for a detailed review and suggested reforms of the USDA's competitive R&D funding program, the Agriculture and Food Research Initiative, AFRI, established in the 2008 Farm Bill.

predominant source of innovation in global agriculture, the tide appears to be turning. Over the past several decades, and especially the most recent decade, other (particularly the rapidly growing middle-income) countries have gained significant ground, especially in terms of their shares of total food and agricultural R&D spending. This is not only a consequence of their more rapid rates of growth in public R&D spending, which have been evident for some time, but also a more recent, and potentially equally profound, uptick in the rate of investment in private food and agricultural R&D. If this continues, which seems likely, it is bound to change the global landscape of innovation in food and agriculture. With other key agricultural producers giving serious policy attention to and sustained public support for their domestic research systems, waiting five years for the 2019 Farm Bill to revitalize support for U.S. publicly-performed food and agricultural R&D is a risky course of action for the prospects of both domestic and global agriculture.

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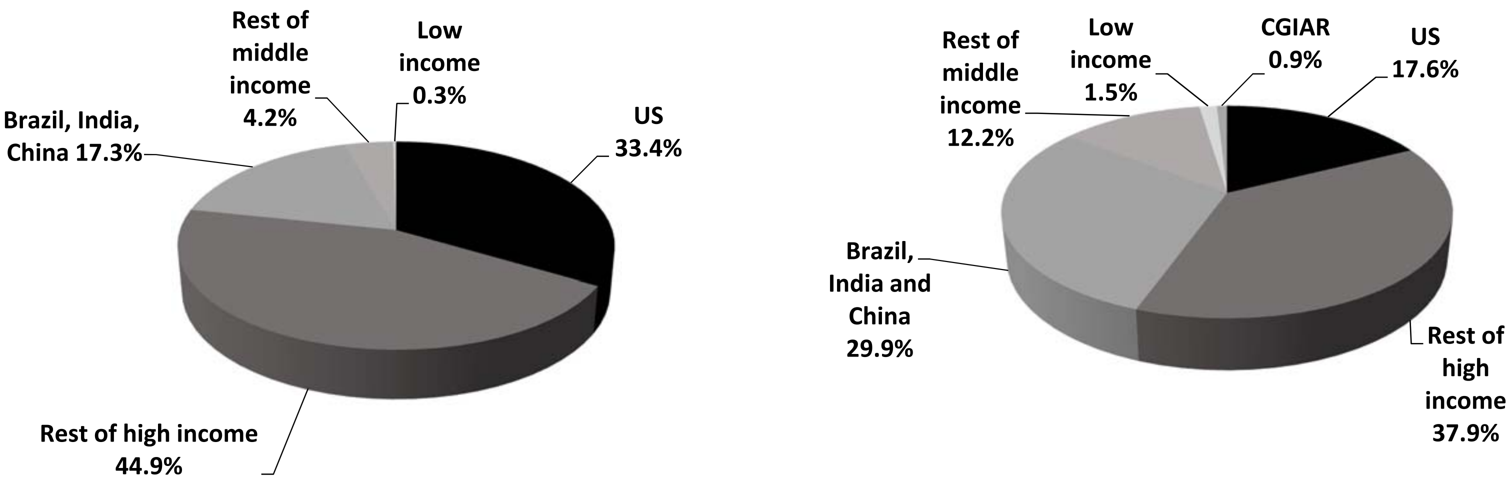
Figure 1: Public and private R&D worldwide: Total, and food and agriculturally-related, 2009

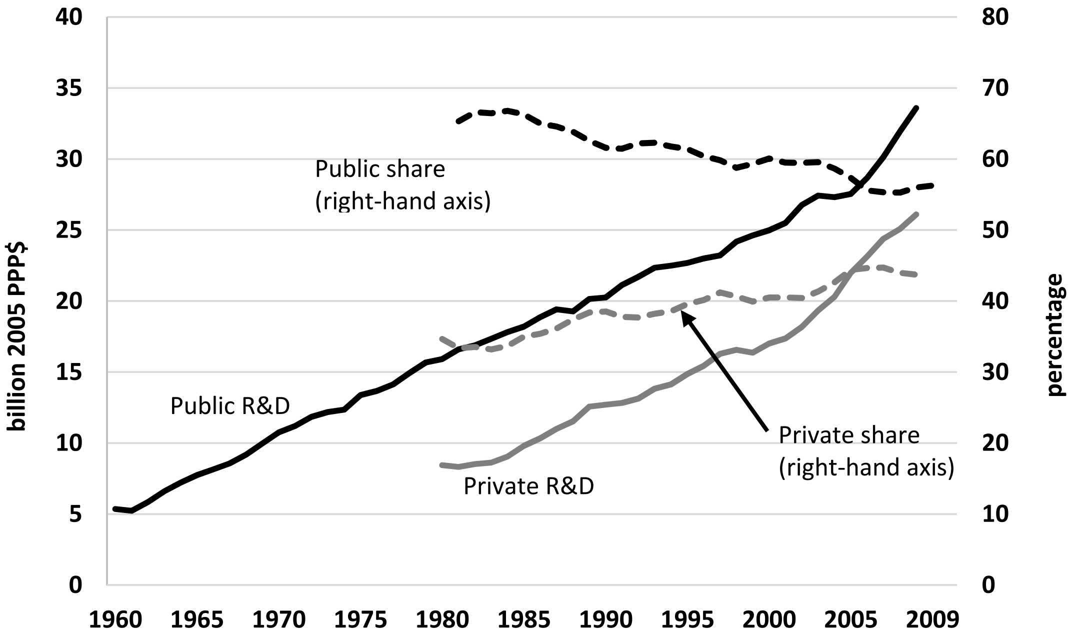
Panel a: Total R&D

Panel b: Food and Agricultural R&D



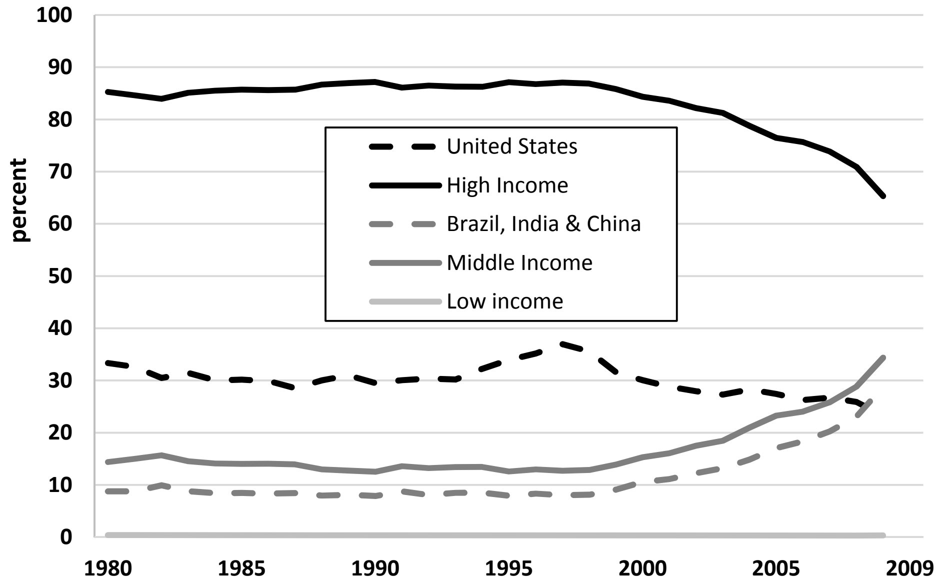
Source: InSTePP R&D Series, version 3.2.

Figure 2: Global R&D trends for food and agriculture, 1960-2009



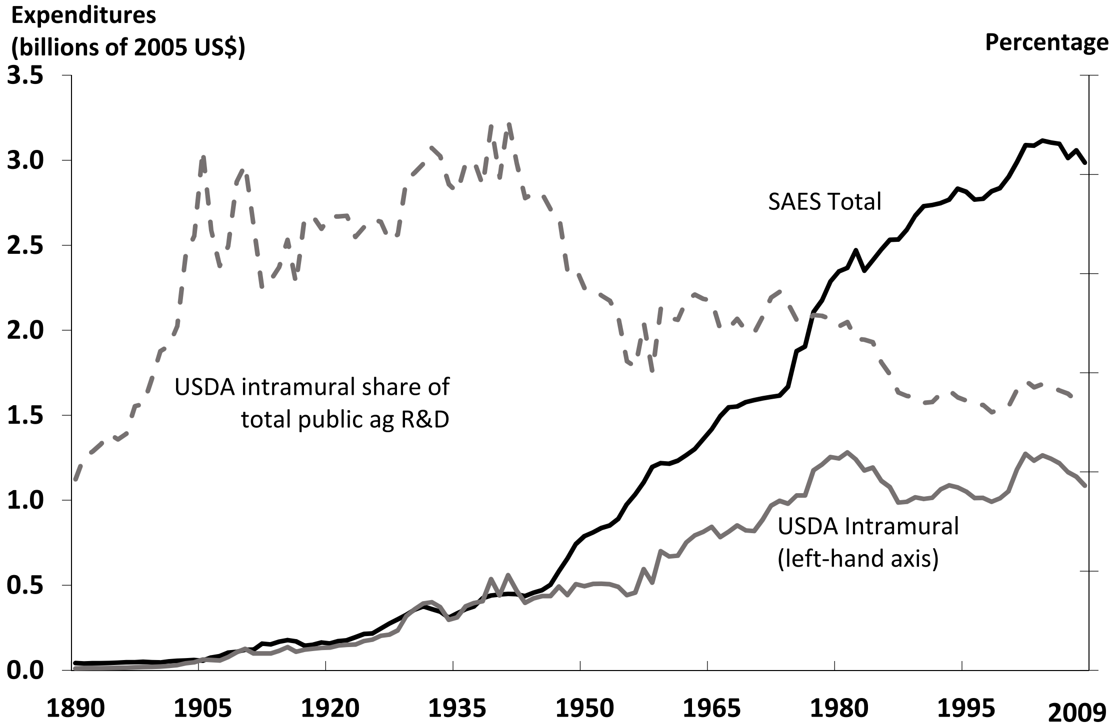
Source: InSTePP R&D Series, version 3.2.

Figure 3: Global per-capita income trends in private food and agricultural R&D, 1980-2009



Source: InSTePP R&D Series, version 3.2.

Figure 4: U.S. public agricultural R&D by performing agency, 1890-2009

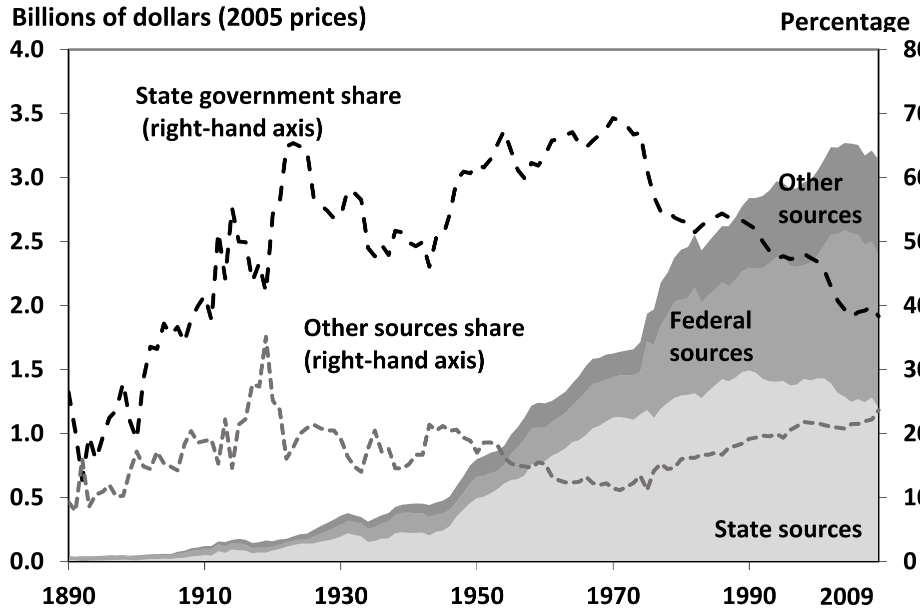


Source: Adapted from Pardey, Alston and Chan-Kang (2013).

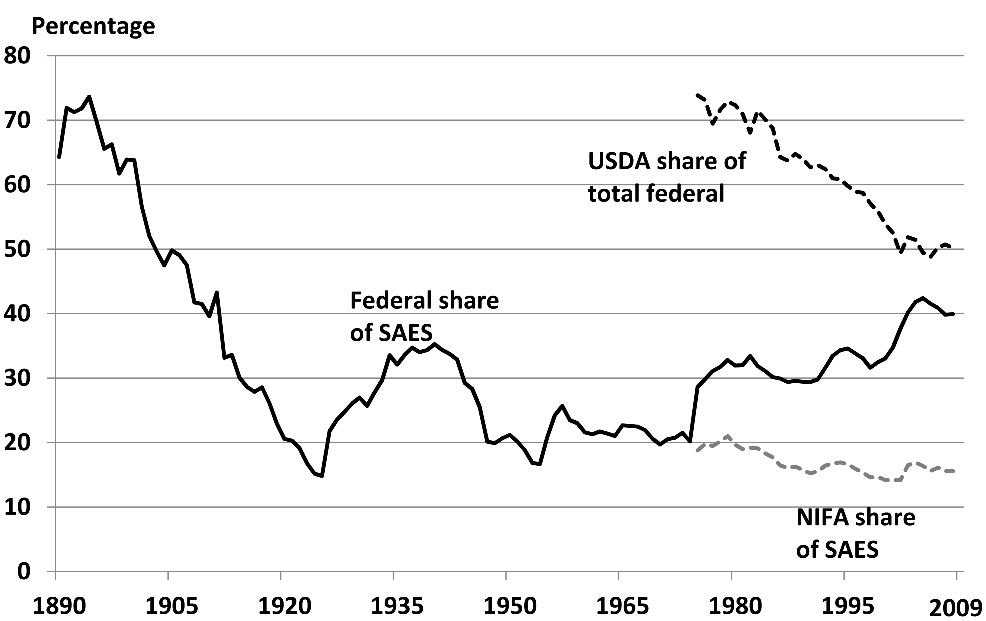
Note: SAES data are for the 48 contiguous states and exclude forestry R&D.

Figure 5: Shifting sources of funding for U.S. public food and agricultural R&D, 1890-2009

Panel a: SAES funding sources



Panel b: Federal funding for SAES research

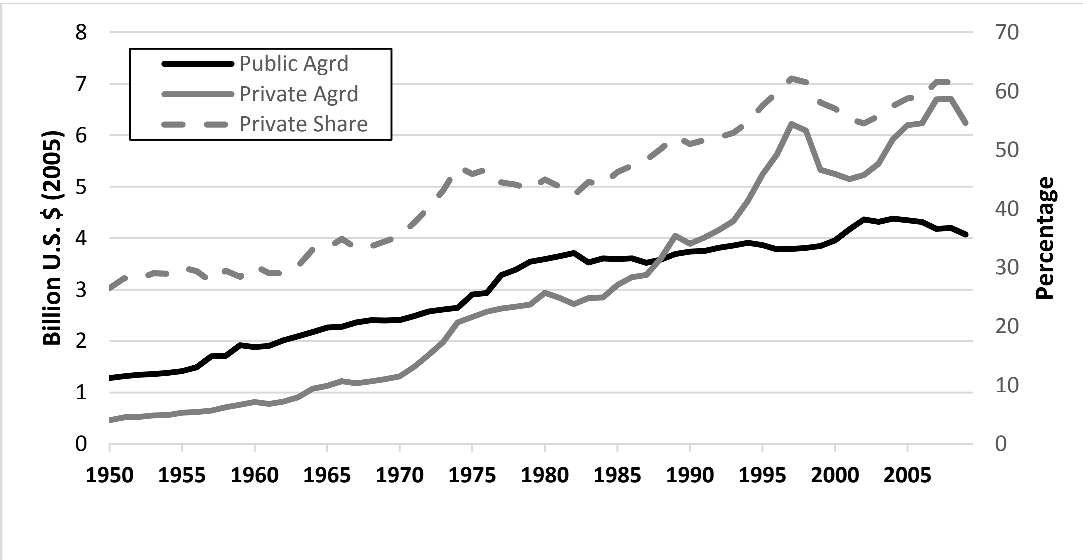


Source: Adapted from Pardey, Alston and Chan-Kang (2013).

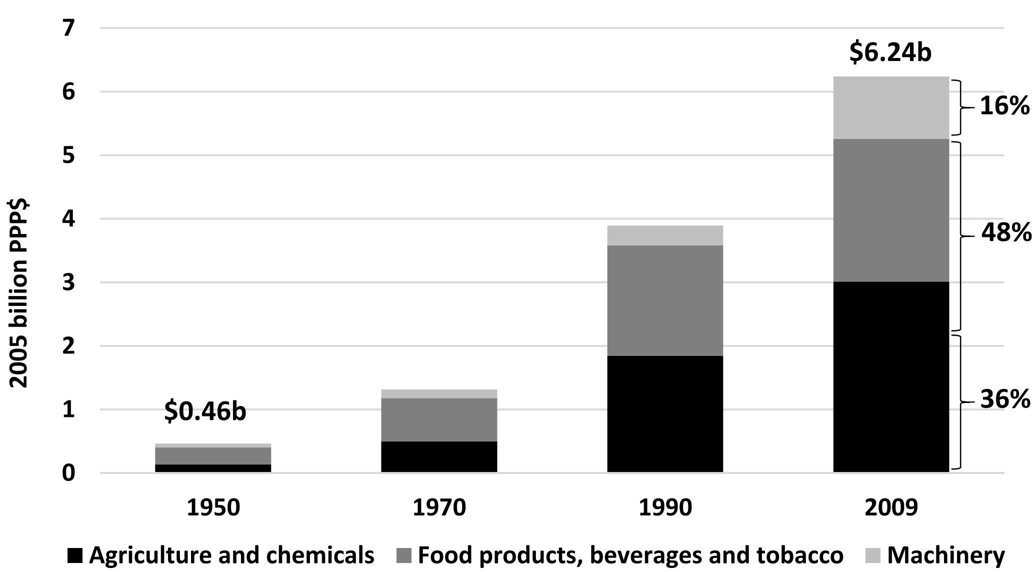
Note: SAES data are for the 48 contiguous states and exclude forestry R&D

Figure 6: Private performance of food and agricultural R&D in the United States, 1950-2009

Panel a: R&D spending trends



Panel b: R&D by industry orientation



Source: InSTePP R&D Series, version 3.2.