Revitalizing the Slow Magic of US Agri-Food Research

By Philip G. Pardey

April 2023

Key Points

- US public investment in agri-food research and development (R&D) has lost considerable ground over the past two decades, exacerbating the shrinking US share of global agri-food R&D spending to such an extent that America now lags well behind China.
- The knowledge capital arising from public agri-food spending spurs innovation that promotes productivity and enhances the global competitiveness of US agriculture; improves the resilience of agriculture to changing climate, market, and pest pressures; and is key to reducing farming's environmental footprint.
- Prioritizing the long-term, multifaceted benefits from public spending on agricultural R&D over doling out federal dollars to favored farms will benefit the agri-food sector, the economy in general, and the environment.

Agri-food research and development (R&D) is slow magic.[1] Typically, it takes many years before R&D's economic and environmental effects are first realized. Then these effects play out over long periods. Thus, just like efforts to mitigate the effects of climate change, investing in R&D is not a quick fix.

However, patience pays. There is compelling historical evidence that public investments in agri-food R&D have generated high social payoffs, and there are no signs that the returns to more recent research have diminished in any way.[2] If anything, increased competitive pressures; challenges farmers now face from changes in climates, markets, and agricultural pests; and growing imperatives to reduce agriculture's environmental footprint are likely to enhance the social returns to present and future R&D.

Whether these prospective future returns will be realized hinges largely on current decisions about public spending on agricultural R&D. For almost 20 years, the US has scaled back its public commitments to agri-food R&D. If this trend continues, then US agriculture, the country's food supply, and the climate, water, and other environmental factors that are closely intertwined with agriculture will be further compromised and put at ever-increasing risk.

As I illustrate below, it takes time before agricultural R&D has its impact on the ground. Thus, there is real urgency to redress the large funding shortfall that has accumulated over the past decades and to do that in ways that sustain the commitment to higher levels of funding so it better aligns with the longer-run realities of R&D rather than the shorter-term vagaries of political cycles. The good news is that payoffs to investments will accrue for some time, often decades. Thus, R&D spending has some permanency in the stream of payoffs that flow to society.

In many ways, R&D spending is analogous to investments in capital infrastructure. Agricultural R&D spending creates a stock of knowledge capital—or, in concrete terms, an accumulation of useful new ideas embodied in professional publications, patents, and tacit technical and scientific know-how—that drives agricultural innovation and the subsequent stream of benefits.

US Agri-Food Spending Trends

During the first two-thirds of the 20th century, the US agricultural economy forged ahead. Rising rates of farm productivity growth went hand in hand with a big wave of technological progress and improved farming practices, fueled by growing public investments in agricultural R&D. The expanding footprint of agricultural land stalled, saving natural landscapes and the biodiversity they support, while food prices fell in real terms and the share of US household expenditures spent on food also diminished.[3]

By the mid-century, increases in public R&D spending took place as privately funded (and conducted) agri-food R&D also began to ramp up (Figure 1, Panel A). Some private R&D was probably a substitute for research previously done by public agencies, but much public R&D involves basic, precompetitive research—that is, research whose social benefits are hard to capture by private concerns. Thus, public and private research are often synergistic; that is, public R&D largely complements and then spurs subsequent private innovation that would otherwise not take place.

As the 20th century ended, the realities for US agricultural R&D and US agriculture began to change, but not for the better. Productivity growth (measured as the change in the ratio of aggregate agricultural output to the aggregate use of inputs) began to slow following a mid-century surge.[4] Agri-food R&D spending by private firms overtook publicly performed R&D by the early 1970s and continued growing, although at a gradually slowing pace.

In contrast, the rate of growth of public spending began to substantially slow in the 1980s and then stopped, with inflation-adjusted public spending peaking in 2002. There then followed a secular and sizable reduction in support. As a result, by 2019 (the latest year of available time series data), real US spending on public agri-food research had fallen to levels that had not been seen since 1974, almost five decades ago (i.e., back to the level indicated by the dashed vertical line in Figure 1, Panel A).

Downsizing in public support for agricultural R&D has occurred for both federal and state research agencies. In 2019, public funding for US Department of Agriculture (USDA) research had shrunk back to levels last seen in 2013 (Figure 2). Public support for state agricultural experiment stations (SAESs) has declined to 1976 levels, while federal support for SAESs has fallen to 2000 levels.

Reductions in support from state governments to the SAESs have been even more pronounced; funding levels in 2019 had declined to levels last observed in 1957, six decades ago (Figure 2 and Figure 1, Panel B). Almost all state governments have reduced their support for agricultural R&D, and in many states, cutbacks have been especially severe. Currently, state government support has fallen well below the notional minimum required one-to-one match for some forms of federal support. In 2019, with respect to SAES research, nationally the average state government match for every federal dollar was only 68 cents, and matching in 37 states had fallen below the one-to-one state versus federal funding threshold.

While US legislators have been scaling back their funding commitments to agricultural R&D for almost two decades, other countries have been doubling down. China began to outspend the US in 2012 and in 2018 invested $1.34 for every US dollar spent on public agri-food research (Figure 3).[5] Collectively, Brazil, China, and India surpassed US investment levels almost two decades ago in 2004.[6] In 2018, those three economies jointly outspent the US on public agri-food research, investing $2.90 for every one US dollar.

Globally, the US has fallen well behind where it once was. In 1960, the US alone accounted for 15.5 percent of the world's total spending on public agri-food research; in 2018, that share had dropped to 9.2 percent.

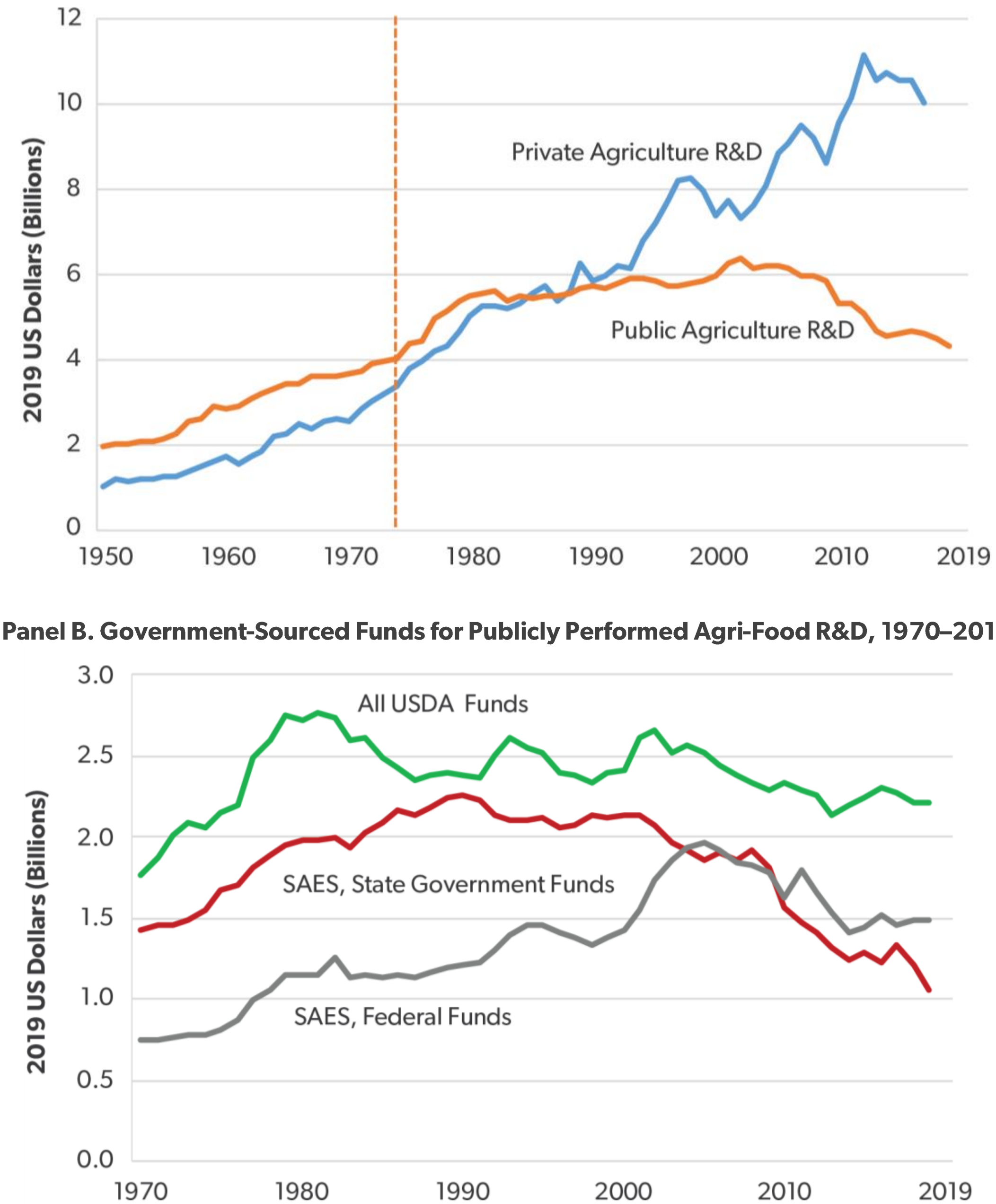
Research as Knowledge Infrastructure

There is compelling economic evidence that the technological innovations and improved know-how arising from investments in R&D are one of, if not

Figure 1. US Public and Private Agri-Food R&D Spending and Source of Funds

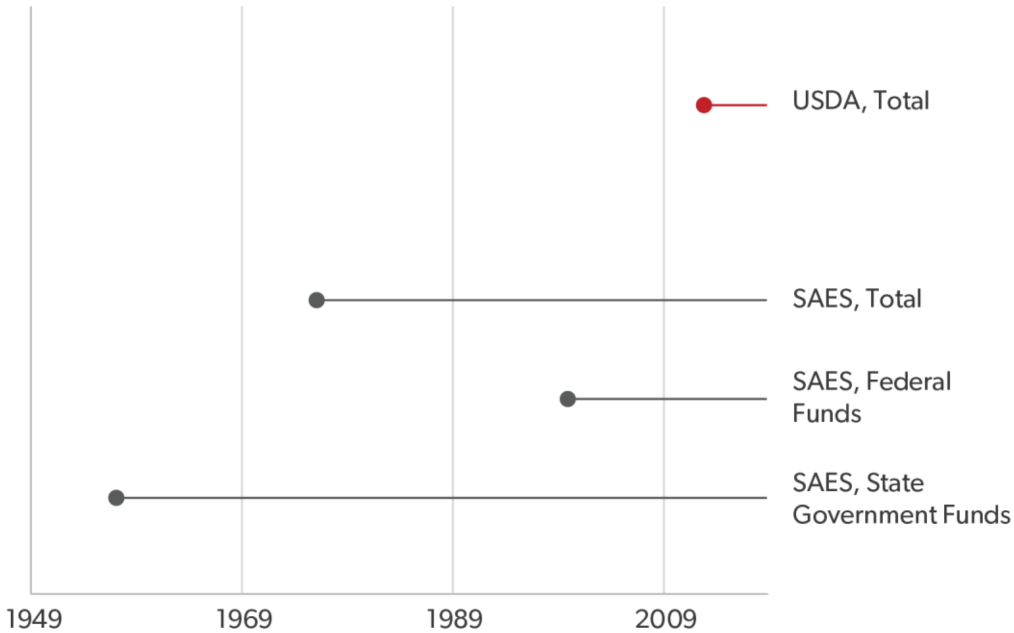
Panel A. Publicly and Privately Performed Agri-Food R&D, 1950–2019

Panel B. Government-Sourced Funds for Publicly Performed Agri-Food R&D, 1970–2019



Note: Agricultural R&D series were deflated using International Science & Technology Practice & Policy (InSTePP) R&D deflator series. Forestry research is excluded. The vertical line in Panel A indicates the year when public agricultural R&D spending was equivalent to spending in 2019. In Panel B, "All USDA Funds" indicates intramural USDA funding and SAES funding sourced from National Institute of Food and Agriculture (NIFA) and other USDA sources.
Source: Author's calculations based on International Science & Technology Practice & Policy data series on agricultural R&D.

Figure 2. Dropping Back Relative to the Past: Public US Agri-Food Research Spending and Source of Funds



Note: SAES spending here includes forestry research. "SAES, Federal Funds" is SAES spending sourced from federal funding (administered by NIFA and all other federal agencies). "SAES, State Government Funds" is SAES spending sourced from state government appropriations. "USDA, Total" is total USDA intramural research. The circle on the horizontal line shows the latest year when R&D spending was previously as low as the 2019 spending.
Source: Author's calculations based on International Science & Technology Practice & Policy and US Department of Agriculture Current Research Information System data series.

the most, significant drivers of economic growth and improvements in well-being.[7] If history is any guide to the future, technological innovation will also play a pivotal role in ensuring the US agricultural economy continues to thrive while serving as part of the solution to the multiple environmental challenges we now face (including global warming and deteriorating soil and water quality).

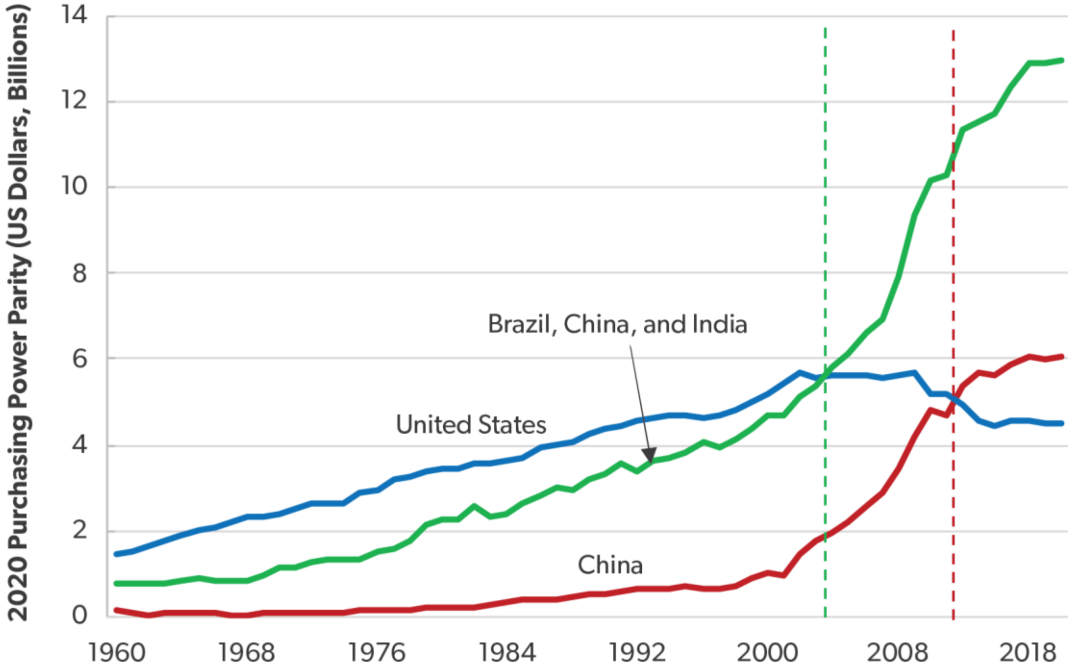
Producing agricultural innovations takes time. It also requires more time to move these innovations along the complex technical and commercial pathways that lead to economic and environmental impacts.

For example, the time taken to conduct the plant breeding required to develop a new crop variety (often called the research lag) is around eight to 15 years (depending on the crop in question) using conventional breeding methods and three to seven years using so-called speed-breeding methods involving molecular markers, in vitro culture methods, and other techniques. The next phase (the development lag) takes several more years, as selected varieties are field-tested under different growing conditions and undergo further rounds of screening and selection before the seed becomes commercially available. It can then take decades for each variety to be adopted by farmers at scale, eventually to be dis-adopted as new varieties take their place.

That timeline ignores the pre-breeding or more basic research, often done by public agencies, involving gene discovery, gene function, and so on, which reveals genes with desirable traits such as tolerance to drought or heat or resistance to particular pests and diseases. Thus, for example, the relevant R&D story that gave rise to hybrid corn technology began at least 20 years before commercial planting of hybrid corn became significant—and 40 years before the adoption process had been completed in the sense that the percentage of corn planted to hybrids had reached a stable maximum or ceiling rate of adoption.

To empirically assess the lengthy relationship between R&D spending and economic and environmental impact, economists use the notion of stocks of R&D knowledge. Today's crop breeders

Figure 3. Falling Behind the International Competition: Public US Agri-Food Research Spending



Note: The vertical lines represent the first year when contemporary spending in China and, collectively, Brazil, China, and India first exceeded total US agricultural R&D spending.
Source: Author's calculations based on International Science & Technology Practice & Policy data series on agricultural R&D.

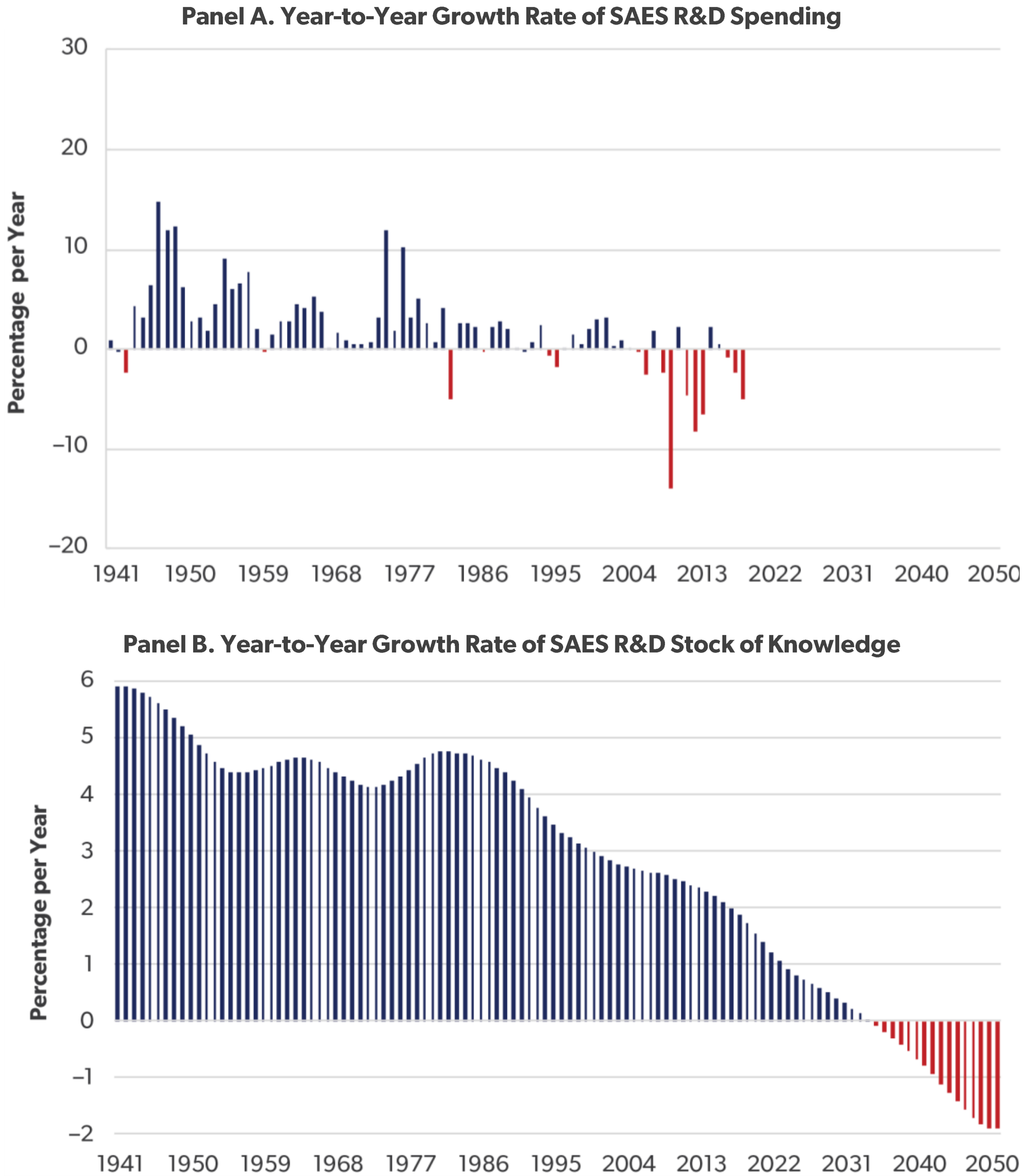
and other scientists stand firmly on the research findings of those who preceded them, so research is seen as a *cumulative* production process. These new ideas and innovations accumulate into a stock of usable knowledge, parts of which continually become obsolete as new research findings replace them or shifts in the external environment (e.g., changes in climate) undermine the productivity value of past innovations.

These stocks of useful knowledge can be thought of as research infrastructure. Like new roads or bridges, they take time to build and sometimes require maintenance, but eventually they will be made redundant by new additions to the stock of knowledge. Like physical infrastructures, the more intangible forms of knowledge capital generate benefits for society for decades after the original investments are made. Nevertheless, as with bridges and buildings, we can skimp on and defer maintenance costs for a while, but eventually agricultural knowledge infrastructures must be refurbished, or replaced, to maintain and increase the benefits they provide.

The US has been skimping on its public research infrastructure maintenance and development bill for several decades, and now the country's agri-food knowledge infrastructure needs refurbishment and revitalization. The R&D challenge currently facing agriculture is also doubly difficult. That challenge is the unprecedented pace and nature of the changes in climate and other environmental factors (e.g., soil and water) on which food production is so reliant. This means that significant parts of the existing stock of research knowledge are rapidly becoming obsolete. New knowledge and technologies are required to address the emerging environmental realities US farmers face.

Figure 4, Panel A plots the year-on-year change in public support to US agri-food research since 1941, measured in inflation-adjusted dollars. Blue bars indicate an increase in spending; red bars indicate a reduction in public spending. There was an obvious sea change in the pattern of spending growth after 2006 from blue to red bars. However, during 1941–1984 when R&D spending growth was mostly positive, the longer blue bars and less

Figure 4. US Agri-Food R&D Realities: Shrinking Spending and a Declining Rate of Knowledge Accumulation



Note: Stock of knowledge—representing a weighted sum of R&D spending over the previous 50 years and reflecting the lengthy time for R&D spending in any given year to realize its full economic impact—was projected to 2050 assuming a no-growth, inflation-adjusted scenario in SAES R&D spending after 2019.
Source: Author's calculations based on unpublished International Science & Technology Practice & Policy and US Department of Agriculture Current Research Information System data series.

prevalent red bars indicate that growth averaged 4.32 percent per year.

Beginning in 1984, the blue bars shortened, and the red bars became more prevalent. This illustrates that the first spending growth slowed sharply and then trended downward, so that growth after 1984 averaged –0.47 percent per year. Dramatically, during the 94 years before 1984, there were only 16 years in which public support declined (i.e., just 17 percent of the time). After 1984, spending declined in

Table 1. Projected Public R&D Spending and Knowledge Stock Scenarios

Public Research Spending Scenarios			Public Agri-Food R&D Spending		Stocks of Agri-Food Knowledge	
	Scenarios	Rate of Change	2019	2050	2019	2050
		Percentage per Year	*2019 US Dollars (Millions)*		*2019 US Dollars (Millions)*	
	Declining Stocks					
1	No Change	0.00	3,110	3,110	3,752	3,534
2	Positive Growth	0.81	3,110	4,001	3,752	3,612
3	Negative Growth	–2.86	3,110	1,283	3,752	3,316
	Growing Stocks					
4	Setting Aside Past Cutbacks	0.81	5,197	6,686	3,778	5,160
	Standing Stocks Still					
5	Break-Even Growth	2.08	3,110	5,933	3,752	3,752

Note: Public R&D spending (excluding forestry) and stock of knowledge were projected to 2050 using various scenarios. The "No Change" scenario holds 2019 spending unchanged through 2050. "Positive Growth" projects spending from 2020 to 2050 using the 1990–2005 average annual growth rate in public agriculture R&D spending. "Negative Growth" projects spending from 2020 to 2050 using the 2005–19 average annual growth rate in public agriculture R&D spending. "Growing Stocks" projects public agricultural R&D from 2005 at the average annual 1990–2005 growth rate. "Standing Stocks Still" is the projected annual growth in spending required for the 2050 stock to equal the 2019 stock of R&D knowledge.
Source: Author's calculations based on unpublished International Science & Technology Practice & Policy and US Department

14 years (40 percent of the time), often with back-to-back years in which funding was cut.

Figure 4, Panel B shows the consequences of the rundown in R&D spending. The stocks of agri-food knowledge that once annually grew by 4 percent or more have been increasing at ever slower rates since the mid-1980s. Even if Congress (and state governments) simply arrested the downward trend in inflation-adjusted public spending (which the proposed 2024 budget fails to do) and froze agri-food R&D spending at 2019 levels, the projected stock of knowledge would start shrinking in 2035. This doesn't square. As the productivity, sustainability, and competitiveness concerns confronting US agriculture continue to grow, the ability to develop and deploy new technologies to address them is being undermined in the current policy environment.

What to Do?

Public investment in US agri-food research has dropped well back from its peak levels in the early 2000s and now trails well behind the investments of its principal international competitors, including and perhaps especially China. The obvious solution is to revitalize public investment in agri-food R&D, which raises the questions: How much to invest? And how to pay for it?

How Much to Invest? There are two practical ways to address the "how much" question. Research by its nature produces winners and losers. From a public policy perspective, the meaningful metric is whether the *overall portfolio* of research projects yields a healthy return.

Looking across the totality of hard-nosed, economic assessments of the social returns to past agri-food R&D, a large body of published evidence indicates that overall, public agri-food research pays handsome dividends to the taxpayers who fund it. Based on 796 return-on-investment estimates reported in 66 studies, the benefit-cost ratio (BCR) for US R&D investments has a median value of 7.5:1.[8] Allowing for the fact that research takes time to do and time to yield its stream of dividends, a 7.5:1 BCR means that a dollar invested today on agri-food research yields future returns equivalent to about $7.50 of today's dollars by way of improved agricultural productivity, reduced farm production costs, and lower food prices for consumers. On economic grounds, a 7.5:1 BCR supports at least doubling the current investments in agri-food research.[9]

Another approach to rightsizing the public commitment to US agri-food research is to consider projected shortfalls in spending and knowledge stocks using recent history as a guide to future outcomes. Table 1 presents several scenarios of a projected future for US agricultural research to the middle of this century, the relevant timescale from a research-impact perspective.

Scenario 1 assumes spending is frozen (in inflation-adjusted terms) at its 2019 level until 2050. Given the past two decades of reductions in R&D spending, this is insufficient to arrest the decline in knowledge stocks, which shrink by 5.8 percent by 2050. In fact, in Scenarios 1 to 3—all projected variants of recent past spending trends—by 2050 the stock of agri-food knowledge declines relative to today's stock.

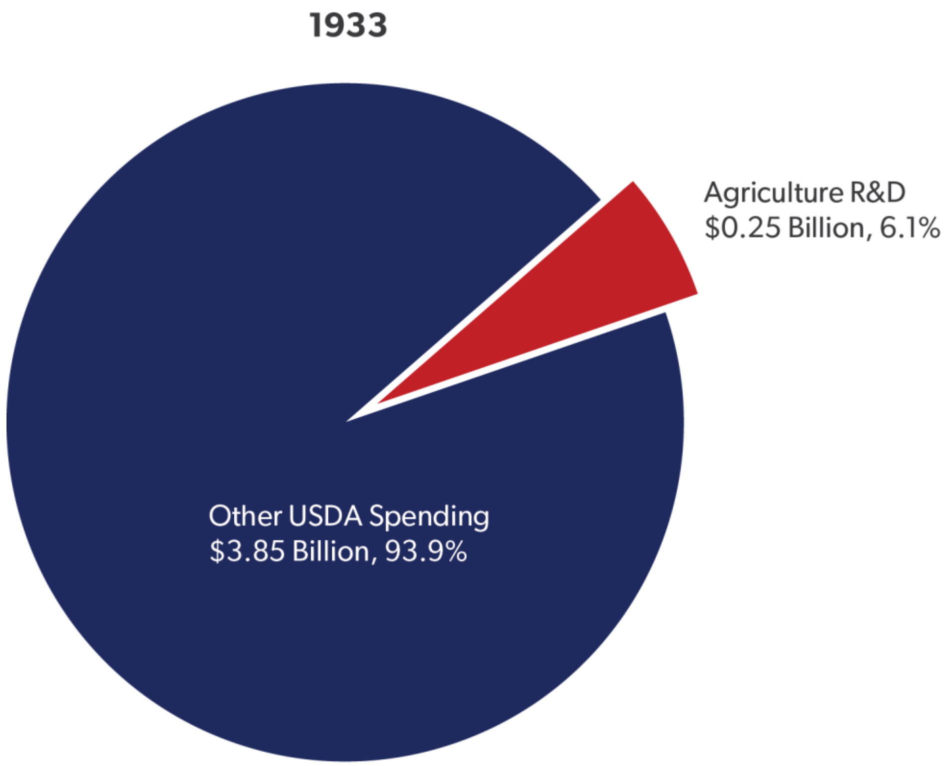
Scenario 4 gives an indication of the detrimental long-term consequences of recent rundowns in R&D spending. If we had avoided the government spending cuts since 2005 and kept public R&D spending growing at its 1990–2005 pace from 2005 to 2050, spending in 2050 would be $6.69 billion (67 percent higher than in Scenario 2, which includes the recent rundown in spending). Further, the stock of knowledge in 2050 would be 43 percent larger than the level projected under Scenario 2. Scenario 5 shows that, going forward, to refurbish the damage already baked in to the country's agri-food knowledge infrastructure and future productivity performance from past spending shortfalls would require a 2.08 percent per year inflation-adjusted rate of increase in R&D spending, just to avoid 2050 knowledge stocks falling below current levels.

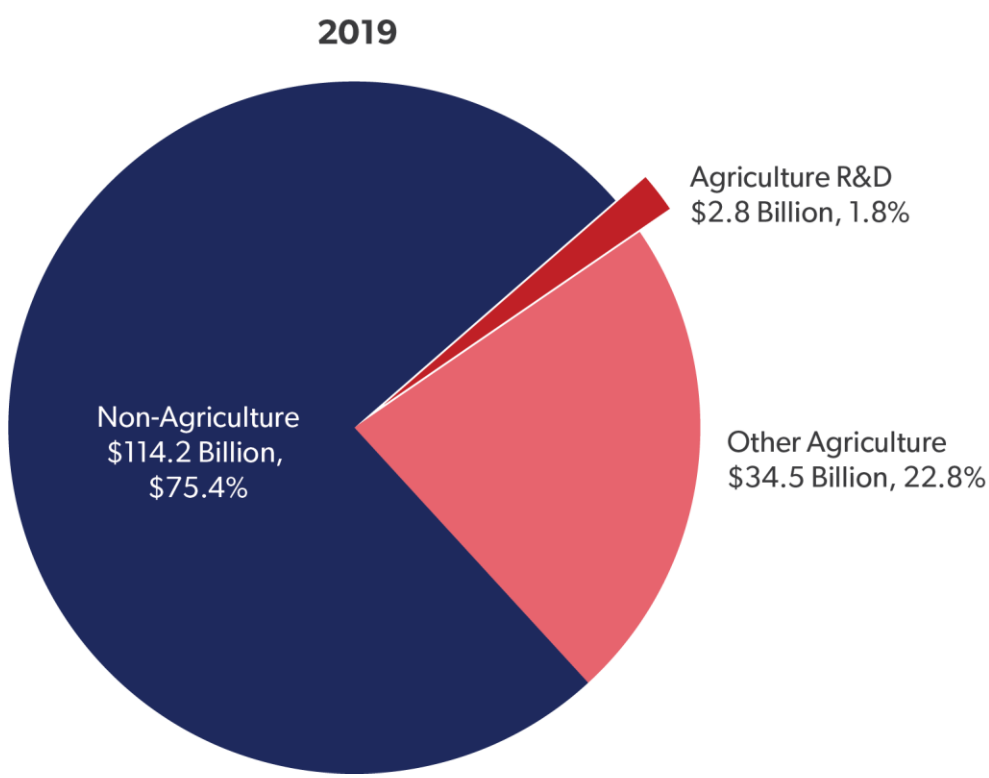
How to Pay for It? Fortunately, Congress has a ready means of shrinking farm budgets and dealing with macro budget deficit concerns while doubling down on R&D. In its early years of operation, half the USDA's budget was directed toward R&D, in line with the agency's founding charge "to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture."[10] In 1933, when the Agricultural Adjustment Act came into force—the first federal legislation to explicitly provide price supports for major row crops—R&D spending still constituted 6.1 percent of the agency's total budget (Figure 5). By 2019, the R&D share had shrunk to just 1.8 percent of the total USDA budget and 8.1 percent of the agriculturally oriented aspects of the budget, setting aside nutrition assistance and other such spending.

Reducing politically popular price support payments (that favor just some, usually the larger and wealthier farms) and redirecting part of those savings to R&D will both reduce government deficits and revitalize R&D investments that return economic and environmental value to the populace at large.[11] Done right, federal agri-food R&D dollars could be distributed to the states in ways that also revitalize the large rundown in state government support for SAES research.[12] That would be an economically efficient approach to slicing up the farm bill pie.

Failing to refurbish the stock of US agricultural knowledge capital is already having real-world consequences in terms of declining rates of agricultural productivity growth and increasing pest and environmental risks—risks that will only magnify in the decades ahead absent the research-driven discoveries required to successfully tackle these pressing real-world issues.

Figure 5. Slicing Up the USDA Spending Pie, 1933 vs. 2019





About the Author

Philip G. Pardey is a professor in the Department of Applied Economics, founding director of the International Science & Technology Practice & Policy center, and director of the GEMS Informatics Center, all at the University of Minnesota.

Notes

1. Philip G. Pardey and Nienke M. Beintema, *Slow Magic: Agricultural R&D a Century After Mendel*, International Food Policy Research Institute, October 26, 2001, https://pdf.usaid.gov/pdf_docs/Pnacn063.pdf; and J. M. Alston et al., "The Slow Magic of Investments in Innovation: Insights from Agricultural vs Industrial R&D Models," *Annual Review of Resource Economics* (forthcoming).

2. Xudong Rao, Terrance M. Hurley, and Philip G. Pardey, "Are Agricultural R&D Returns Declining and Development Dependent?," *World Development* 122 (October 2019): 27–37, https://experts.umn.edu/en/publications/are-agricultural-rampd-returns-declining-and-development-dependen.

3. US Department of Labor, US Bureau of Labor Statistics, *100 Years of U.S. Consumer Spending: Data for the Nation, New York City, and Boston*, May 2006, https://www.bls.gov/opub/100-years-of-u-s-consumer-spending.pdf.

4. Such aggregate productivity growth rates are called multifactor productivity growth measures because they take account of both changes in output and changes in the use of many inputs, including land, labor, machinery and equipment, and agricultural chemicals. See Philip G. Pardey and Julian M. Alston, "Unpacking the Agricultural Black Box: The Rise and Fall of American Farm Productivity Growth," *Journal of Economic History* 81, no. 1 (2021): 114–55, https://experts.umn.edu/en/publications/unpacking-the-agricultural-black-box-the-rise-and-fall-of-america.

5. Yuan Chai et al., "Passing the Food and Agricultural R&D Buck? The United States and China," *Food Policy* 86 (July 2019), https://www.sciencedirect.com/science/article/abs/pii/S0306919218308728?via%3Dihub.

6. Philip G. Pardey, "Recent Trends in Global Agri-Food R&D Spending: Risky Realities?" (presentation, UN Food and Agriculture Organization 2022 Science and Innovation Forum, October 19, 2022).

7. Julian M. Alston and Philip G. Pardey, "Innovation, Growth, and Structural Change in American Agriculture," in *The Role of Innovation and Entrepreneurship in Economic Growth*, ed. Michael J. Andrews et al. (Chicago: University of Chicago Press, 2022).

8. This is based on US-specific data found in Julian M. Alston, Philip G. Pardey, and Xudong Rao, *The Payoff to Investing in CGIAR Research*, Supporters of Agricultural Research Foundation, October 2020, https://static1.squarespace.com/static/6346ea27d121155417d78c6a/t/63e57157e347cf41fc8a95ba/1675981149886/Payoff_to_Investing_in_CGIAR_Research_final_October_2020.pdf; and Terrance M. Hurley, Xudong Rao, and Philip G. Pardey, "Re-Examining the Reported Rates of Return to Food and Agricultural Research and Development," *American Journal of Agricultural Economics* 96, no. 5 (October 2014): 1492–504, https://onlinelibrary.wiley.com/doi/abs/10.1093/ajae/aau047.

9. Alston, Pardey, and Rao, *The Payoff to Investing in CGIAR Research*; and Hurley, Rao, and Pardey, "Re-Examining the Reported Rates of Return to Food and Agricultural Research and Development."

10. Act of Establishment of the Department of Agriculture, 12 Stat. 387 (May 15, 1862), cited in Wayne D. Rasmussen and Gladys L. Baker, *The Department of Agriculture* (New York: Praeger, 1972), 243. The act states that the agency's main charge was "to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word, and to procure, propagate, and distribute among the people new and valuable seeds and plants."

11. For more discussion on the nature and trade-offs involved in farm bill spending prioritized to farm subsidies versus agricultural research and development, see Philip G. Pardey and Vincent H. Smith, *Waste Not, Want Not: Transactional Politics, Research and Development Funding, and the US Farm Bill*, American Enterprise Institute, December 11, 2017, https://www.aei.org/research-products/report/waste-not-want-not-transactional-politics-research-and-development-funding-and-the-us-farm-bill.

12. For an expanded discussion on this specific policy aspect and related agricultural research policies, see Philip G. Pardey, Julian M. Alston, and C. Chan-Kang, *Public Food and Agricultural Research in the United States: The Rise and Decline of Public Investments, and Policies for Renewal*, AGree, 2013; and Philip G. Pardey and Julian M. Alston, *For Want of a Nail: The Case for Increased Agricultural R&D Spending*, American Enterprise Institute, July 12, 2011, http://www.aei.org/paper/economics/fiscal-policy/federal-budget/for-want-of-a-nail-the-case-for-increased-agricultural-rd-spending.