FARMJOURNALFOUNDATION

REVITALIZING AGRICULTURAL RESEARCH AND DEVELOPMENT TO SUSTAIN US COMPETITIVENESS

by Philip G. Pardey and Jason M. Beddow

This paper was commissioned by the Farm Journal Foundation.

A NOTE FROM THE FARM JOURNAL FOUNDATION

Over the next few years, we have a unique opportunity to further strengthen US agriculture and transform US agricultural development programs overseas to help foster growing markets and build more stable and secure nations. The 2018 Farm Bill reauthorization presents an opening to reposition US agriculture for the 21st century and deploy the tools needed to strengthen inadequate food systems.

Since the Farm Journal Foundation (FJF) started in 2010, it has sought to bring the expertise of US agriculture to the national policy table, providing a platform for diverse stakeholders across the US agricultural system to contribute their knowledge and ideas to feed a growing global population.

With a longstanding relationship with US agriculture and rural America, the FJF invited renowned experts to suggest approaches to enhance the programs and other tools that policymakers will need to generate better outcomes for US investments in agriculture and global food security. A series of three policy papers were commissioned; one on institutional capacity building, one on agricultural trade technical assistance and one on agricultural research. When considered as a whole, we believe that the papers can facilitate a conversation on how US agriculture can maintain its comparative strength while sharing its knowledge and tools with fellow farmers in developing countries to help drive economic growth around the world, and in the process, create new opportunities for US products in the markets of the future.

We hope that this effort will assist policymakers in promoting a national vision and commitment to international agricultural development in US foreign policy, and continued support for US farmers utilizing US Agriculture's best practices and expertise.

The Farm Journal Foundation would like to express its thanks to its donors, our Farm Teams, HungerU students, partners and colleagues across agriculture who reviewed these papers.

Tricia Beal
Chief Executive Officer
Farm Journal Foundation

The Farm Journal Foundation is a 501(c)3 organization that works with U.S. farmers, ranchers and next generation populations to inform and engage national level policymakers on the important role that the United States can and should play in addressing global food security.

FOREWORD

Today, too few people know where their food comes from and what is required to produce it. Even fewer understand the strong link between hunger, instability and conflict. Widespread hunger and lack of political stability are closely related and key drivers of both conflict and migration – refugees fleeing to Europe and undocumented immigrants entering the United States are but two examples of how people often respond to their inability to feed and protect their families.

As Americans, we have benefitted from decades of low food prices and a safe food supply. Our country's agricultural sector has advanced due to the innovation and dedication of our farmers as well as the US Government's visionary leadership since 1862. Together we have created the most advanced agriculture and food system the world has ever seen; however, many US agricultural institutions are now showing the strains of a mature system. New thinking, resources, and innovation, including improved coordination, will be vital to meet the coming challenges facing our world.

As President of the University of California system, I launched the UC Global Food Initiative in 2014 to focus our UC resources and intellect on one of the critical issues of our time: how to sustainably and nutritiously feed a world population expected to reach at least eight billion by 2025. The governments of China and Brazil are already working hard to bolster their agricultural systems to meet the growing global demand for food; they now spend more than twice the amount the US does on public agricultural research. We need to break out of the 'business as usual' approach and catalyze all relevant players – governments, universities, the private sector, and NGOs – to meet this challenge.

I applaud the Farm Journal Foundation for commissioning this series of reports and taking on the critical issue of how US agriculture can maintain a leadership role in feeding the world. These papers call on the US to both modernize our agricultural system and further link it with national security and development efforts to meet the demands of the future.

As each report demonstrates, no one sector can do it alone; success will require leadership, resources and new models for partnership. Taken together, they kick off a much-needed dialogue on how US Agriculture can maintain its comparative strength, share its extraordinary knowledge, drive economic growth and stability – all while ensuring US competitiveness in tomorrow's agricultural export markets. The issues covered (and the authors) are:

- Agricultural research, written by Dr. Phil Pardey and Dr. Jason Beddow.
- Human and institutional capacity-building, written by Dr. Thomas Jayne, Hon. Chance Kabaghe and Dr. Isaac Minde.
- Agricultural trade technical assistance, written by Mr. Ammad Bahalim and Dr. Joseph Glauber.

We have seen that the nation is ready for new ideas, voices and approaches. The Farm Bill reauthorization in 2018 provides a vehicle for modernizing our approach and improving the efficacy of our US investments both at home and abroad. Let us use these papers, and their recommendations, as a starting point for discussion and to better engage the full breadth of stakeholders within the US agricultural system.

Janet Napolitano
President, University of California

ABOUT THE AUTHORS

Philip G. Pardey is a professor and Jason M. Beddow an assistant professor in the Department of Applied Economics at the University of Minnesota, and both are affiliated with the University's International Science and Technology Practice and Policy (InSTePP) Center (www.instepp.umn.edu). The authors thank Connie Chan-Kang for her assistance in preparing this brief. This report was commissioned by the Farm Journal Foundation. The authors are entirely responsible for the content, but they would like to thank Kathryn Boor, Stephanie Mercier, Saharah Moon Chapotin, Sally Rockey, Robbin Shoemaker, Vince Smith, Eric Witte, and Brian Wright for their insightful comments on earlier drafts of this brief. Jason Beddow died suddenly, in April 2016, as the first complete version of this brief was being finalized.

REVITALIZING AGRICULTURAL RESEARCH AND DEVELOPMENT TO SUSTAIN US COMPETITIVENESS

Philip G. Pardey and Jason M. Beddow

SUMMARY

This paper describes the downward trends in US public agricultural research and development (R&D) funding and argues for a doubling of such spending over the next eight to 10 years to ensure that US agriculture maintains its global competiveness. To address the decline, the US government can reverse current trends in public agricultural R&D spending by creating incentives for increased research funding from state governments and national commodity groups, much as the new Foundation for Food and Agriculture Research is designed to leverage private sector R&D funding. This paper also suggests ways to better coordinate agricultural research activities both between US government agencies and between US and international research institutions, and proposes more precise targeting of USDA funds to those places where agricultural production actually occurs.

INTRODUCTION: WHY SHOULD WE CARE ABOUT AGRICULTURAL RESEARCH?

Innovations generated by agricultural R&D, along with better education to enable best use of the new technologies arising from R&D, have enabled American farmers to produce enough food to feed the people of this country and millions of others around the world, on less land, freeing up resources for other economic and environmental uses. Land devoted to recreational use, such as parks, wildlife preserves, and forests, has increased by over 45 percent in the last 50 years thanks to a 200 million acre reduction in land used for agriculture (Nickerson et al. 2011). Increasing output while using less land requires farmers to use more or better inputs, for example, through adopting improved technologies (such as higher-yielding or improved drought-tolerant crop varieties) and production methods (minimum or no-till cultivation practices). While many US farmers increased the intensity of use of some inputs (e.g., applying more of a particular input, such as fertilizer, per acre), the evidence shows that in aggregate, US farmers now produce more output using less inputs overall. Agricultural productivity has increased markedly (Alston et al. 2010) with aggregate agricultural output increasing by 268 percent from 1949 to 2007 (Pardey et al. 2014). Clearly, R&D is essential for achieving sustainable improvements in productivity and preserving the environmental conditions affected by agriculture such as air and water quality and water use.

Unfortunately, the rapid productivity growth of the US agricultural sector over the past half-century is unlikely to continue. Indeed, growth in US productivity is slowing, and that trend is likely to persist since the US government spending on agricultural R&D has flat-lined. At the same time, other countries have been ramping up public investments in this area. As a result, the US share of global public agricultural R&D has almost halved over the past five decades (Pardey et al. 2016). Continuing to skimp on spending will have detrimental consequences for US agricultural productivity and international competiveness for US farmers and ranchers.

Policy Possibilities

While these developments are cause for concern, it is not too late to reverse them. A number of relatively straightforward policy changes would bolster US leadership in agricultural innovation without significant new appropriations from the federal government. In this paper, we propose two sets of policy changes that hold the most promise to reverse the disturbing trends revealed above:

Funding Innovations

- Federal funding: Refocus Farm Bill priorities.
- State funding: Reengage state government support.
- Enhance private support for publicly performed research.

Institutional Innovations

- Improve interagency collaboration in science spending with food and agricultural implications.
- Facilitate greater international engagement in the agricultural sciences.

Clearly, policy changes involve politics. But before turning to a discussion of these policy options, it is worthwhile to step back from the politics and address the fundamental economic rationale for government involvement in agricultural R&D and the reasons for real concern about current US trends.

THE PUBLIC ROLE: WHY SHOULD GOVERNMENT GET INVOLVED?

Despite recent increases in US private sector involvement in agricultural R&D, which now substantially exceed the public commitment, the government must reverse its recent retreat and revitalize its involvement in agricultural research.

Substantial and socially valuable R&D investment opportunities will not be supported if the research is left entirely in the private domain.

In short, the incentive structure for private sector investment is unlikely to generate the appropriate amount and composition of agricultural R&D, thus necessitating some form of collective action, customarily facilitated by governments. Market failures in agricultural R&D have several dimensions. Notably, those who invest in certain types of agricultural R&D might not be able to fully capture the benefits of that research, including the broad environmental benefits that are intrinsically external to the individual farmer who may pay for or use the results of the research. That is, certain farmers and other firms might benefit from the research even if they do not pay for it directly, and thus there are incentives to "free ride," sharing in benefits without bearing the cost, leading invariably to private sector underinvestment. Furthermore, individual farm operations are almost always too small to carry out robust R&D programs on their own; government investment and collective action among farmers and agribusinesses must usually correct the underinvestment.

Moreover, many of the payoffs from agricultural R&D take decades to materialize, which can undermine private sector incentives to invest given their shorter-term planning horizons. However, even though a long time may pass before the benefits of a specific investment in agricultural R&D are fully realized, the overall producer and consumer returns to these investments are still high (Alston et al. 2010; Hurley et al. 2016). The upshot of these market failures is that substantial and socially valuable R&D investment opportunities will not be supported if the research is left entirely in the private domain (Pardey and Alston 2010).

CHANGING FOOD AND AGRICULTURAL RESEARCH REALITIES

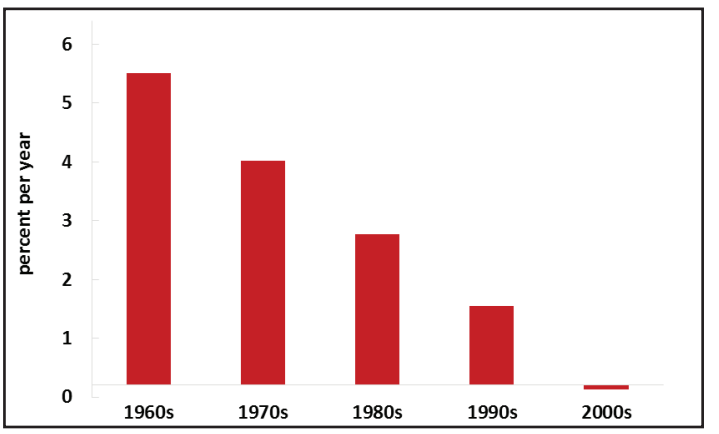
Decisions about the policy approach that best serve society's interests in US food and agriculture must take into account that the domestic and global contours of the R&D investment landscape are now very different than in decades past, a situation that significantly affects US competitiveness.

Public Research Spending Trends

Decades of progressively slowing growth in US public spending (adjusted for inflation) on food and agricultural R&D have given way to cutbacks in real spending in more recent years (fig. 1, panel a). US public on average grew by only 2.4 percent per year from 1960 to 2013. In contrast, public agricultural R&D spending in the rest of the world grew substantially (33 percent) faster at 3.2 percent per year over roughly the same period. As a result, the US share of global public agricultural R&D spending has fallen markedly, from 20 percent in 1960 to 11 percent in 2011.

Notably, key middle-income countries with large agricultural sectors (specifically Brazil, India, and China) collectively overtook the United States in 1998 (Pardey et al. 2016) (fig. 1, panel b). As of 2011, for every dollar the United States invested in public agricultural R&D, those three countries invested $2.35.

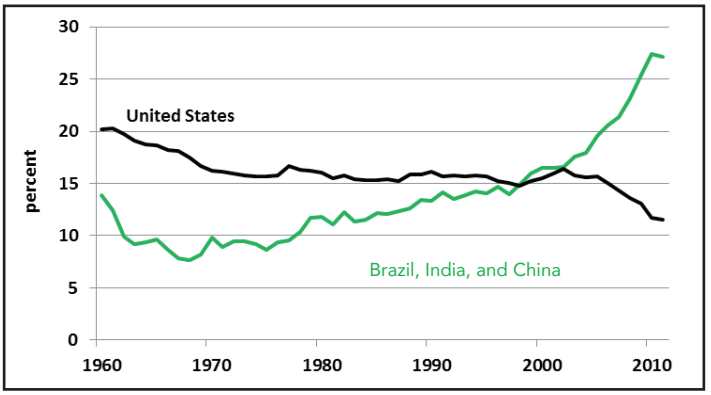
Figure 1: Spending on public food and agricultural R&D
Panel a: US public spending growth rates by decade, 1960–2013



Who Performs and Pays for Public Agricultural R&D?

The split of federal-versus state-support for agricultural R&D has changed dramatically over the past seven decades, with equally dramatic but different changes in terms of who actually does the research. Since 1950, the share of state support for research within the state agricultural experiment station (SAES) system has declined from 62 percent in 1950 to just 36 percent in 2013. Federal funding has picked up most of the shortfall and now accounts for 40 percent of the overall SAES funding, almost double its share in 1950. However, over the same period, more of the research has actually been conducted by state agencies.

Panel b: Shifting global public share of food and agricultural R&D, 1960–2011



Source: InSTePP R&D accounts version 3.8.

Note: Panel a annual average period growth rates calculated using the least-squares method and report real (i.e., inflation adjusted) rates of growth. Data are in US dollars deflated to 2009 prices with implicit GDP deflator from BEA (2016). Panel b R&D shares based on spending denominated in purchasing power parity (PPP) units.

In 1950, 39 percent of publicly funded R&D was carried out by federal USDA labs, while 61 percent was done by state-based land-grant universities and other cooperating agencies. By 2013, the USDA labs' share had shrunk by one-third to 27 percent while the states' share had grown to 73 percent. Support to SAES research through grants and contracts from the private sector now also constitutes an important share of total SAES funding, accounting for 23 percent in 2013.

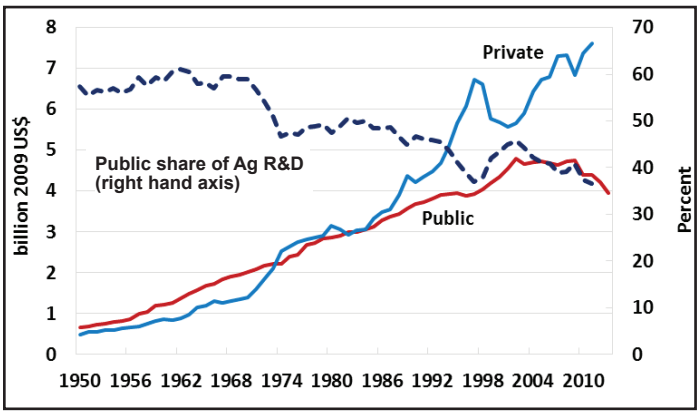
Private Versus Public Research Trends

The private and public shares in total US agricultural R&D have also changed markedly over the past half century (Pardey et al. 2016). In 1950, public agencies spent 34 percent more than private firms on overall food and agricultural R&D. By 2011, that relationship had reversed, with the private sector outspending the public sector by 73 percent (fig. 2).

Part of this growth in the public-private gap reflects a shift in US funding priorities, which has resulted in an initial decline in the growth rate and more recently, an actual decline in public spending levels on the agricultural sciences. These policy actions can in part be ascribed to an expectation that the private sector will fill the void left by these reductions in public spending. This expectation has not been realized, because public institutions tend to undertake more basic and applied types of research for which it is difficult to capture sufficient of the benefits to incentivize the private sector. Instead, the private sector tends to conduct more developmental or nearer-market research that is readily commercialized, but which often relies on breakthroughs achieved by way of the upstream research. The public R&D role must not only continue but expand. The empirical evidence that the economic returns to public R&D remain high provides a clear signal that investments in this area remain insufficient, despite the expanded private commitment to US food and agriculture research in recent decades.

Moreover, the United States is losing ground in terms of its share of global private spending on agricultural R&D. In 1980, private agricultural R&D conducted in the United States accounted for 33 percent of the world total. By 2011, that share had slipped by nearly a quarter. This shift also reflects an increase in domestic spending on private agricultural R&D elsewhere in the world, along with recent decisions by some multinational agribusiness firms headquartered in the United States (and other high-income countries) to shift some of their R&D investments to locations in the agriculturally large and growing middle-income countries.

Figure 2: Spending trends in US public and private agricultural and food R&D

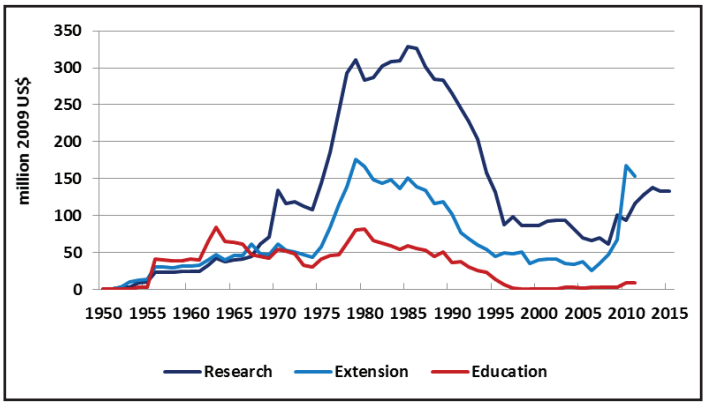


Source: InSTePP R&D accounts version 3.8.
Note: Data in real US dollars are deflated to 2009 prices with implicit GDP deflator from BEA (2016).

US Spending on International R&D Initiatives

For almost half a century, the US government, by way of USAID, has invested in international agricultural research undertaken by a consortium of 15 research centers located throughout the world, organized collectively as the CGIAR. While this research was pivotal to the development of high-yielding wheat and rice varieties that spurred substantial growth in Asian and Latin American agriculture during the 1970s (dubbed "The Green Revolution" by the USAID Administrator at the time), it also yielded sizable benefits for the United States. CGIAR-bred wheat and rice varieties have been widely and successfully planted by US farmers, who by 1996 had reaped more than $3.7 billion in added value to the US economy, an astonishing return to taxpayers on the $134 million of US investment in CGIAR wheat and rice research to that point in time (Pardey et al. 1996).

Figure 3: US spending on international food and agricultural R&D, 1950–2015



Source: Authors estimate using data from Alex (2012) for 1950–2010; post-2010 is derived from unpublished USAID data. Note: Data in US dollars are deflated to 2009 prices with implicit GDP deflator from BEA (2016). Research funding includes estimate of support to national and international (e.g., CGIAR) research agencies.

Decades after the Green Revolution, the worldwide benefits of international support for agricultural R&D continue to flow, including to the United States. Rust in wheat is a devastating fungal pathogen that afflicts crops around the globe. US wheat farmers are at risk: almost all US wheat is grown in climatic zones susceptible to the disease (Pardey et al. 2013b). In 1998, a new variant of stem rust first appeared in Uganda. Dubbed Ug99 (1999 being the year the strain was scientifically characterized), this strain has since spread, undermining wheat yields throughout East Africa and beyond. Over the past decade, the work of USDA scientists at the Cereals Disease Lab in St. Paul, Minnesota—in close collaboration with the efforts of SAES and CGIAR scientists and national research partners in Africa and elsewhere in the world—has been pivotal in identifying the changing pathogenicity of Ug99, paving the way for breeding disease-resistant varieties. USDA scientists continue to play a pivotal role in this research, which is funded through a variety of sources, including USAID's Feed the Future program, similar aid programs of governments elsewhere in the world, and private foundations. The US research program is therefore helping to ameliorate production problems in Africa, while at the same time helping to insure against prospective crop losses here in the United States should history repeat itself and the new rust strains begin cropping up on US farm fields.

The US government has been investing in international research and associated education and extension activities for some time (fig. 3). But that commitment has waxed and waned over the years. It was initiated in the 1960s in response to growing global food security concerns, helping to fuel the Green Revolution, and surged again in the 1970s in response to global food price spikes. Investments in international agricultural R&D peaked in inflation-adjusted terms in the mid-1980s, but subsequently dropped precipitously. Global food price spikes in 2008 led to some recovery in this form of spending, but in real terms US spending on international research still falls far short of the 1986 peak, even though globally, agriculture has to feed 2.4 billion more people than in the mid-1980s, and pressures on crucial agricultural assets such as land and water have intensified. Despite increased US support for CGIAR research in very recent years, the United States, through USAID, accounted for only 16 percent of CGIAR funding in 2014 compared with a peak of almost 30 percent in 1982.

PUTTING POLICIES INTO PRACTICE

A number of US public policies collectively shape the overall incentives to invest in and perform research of relevance for food and agriculture. They include the Farm Bill, annual appropriations for foreign aid budgets, funding for non-USDA federal agencies such as NIH, NSF, and others, and legislation related to the scope and nature of patents and other forms of intellectual property. So what can be done to reshape US public policies in ways that would reposition and re-energize the domestic and international agricultural R&D capacities of the United States? Here we propose some salient US policy changes and focus on a set of potentially consequential funding and institutional innovations.

Fund innovations to double investments in public food and agricultural R&D over time.

All available evidence indicates that the economic returns to US producers and consumers from publicly performed agricultural R&D are exceptionally large: on the order of

20 dollars of social benefit for every dollar spent (Alston et al. 2010). Such high returns strongly signal that the United States under-invests in agricultural research, leaving important research projects unfunded. The necessary boost to agricultural R&D funding should occur gradually, allowing the relevant institutions to ramp up activities in ways that avoid any wasteful spending. Reversing the long-term decline in spending on US public agricultural R&D should be underwritten by federal and state taxpayers as well as private agricultural sector interests, as all three parties stand to reap substantial rewards from the research that private market forces alone are unable to deliver. Below are some suggestions to leverage existing authorities and funding for food and agricultural R&D.

Refocus Farm Bill priorities.

Though an important step, the $200 million allocated for agricultural research through the new Foundation for Food and Agriculture Research provided in the Agricultural Act of 2014 is not enough to stem the rundown in US public agricultural research capacity that has occurred over recent decades (Pardey et al. 2014). "The additional R&D funding authorized in the 2014 Farm Bill falls far short of doubling public support for the agricultural sciences. It constitutes an average nominal increase of just $130 million per year, equivalent to an average annual increase of only 3 percent of total US public R&D spending for food and agriculture (as compared to 2009 spending levels)." With the January 2016 budget outlook by the Congressional Budget Office (CBO) pointing to increasing budget deficits and rising national debt over the coming decade (CBO), calls to increase overall federal government spending on Farm Bill programs, even for a crucial area like agricultural research, seem destined to fall on deaf ears. Actually needed, however, is a realignment of congressional priorities on recurring agricultural R&D spending, rather than a net increase in funding for US agricultural programs.

So what can be done to reshape US public policies in ways that would reposition and re-energize the domestic and international agricultural R&D capacities of the United States?

Reengage state government support.

The trends described above show a distinct and broad-based decrease in state government funding for state-performed agricultural R&D, while the share of SAES funding from federal sources has increased. There are several reasons why this is so. Some of the USDA-administered funds made available for SAES research require matching state funding to secure the federal support. However, the share of these matched formula funds in the total USDA funds flowing to the SAESs has fallen over time; almost 87 percent of total USDA support to the states in 1970 was matched by the states, declining to just 35 percent in 2009. This shrinking share of formula funds was due to two reasons, an increase in competitive grants funding and funding made available to the SAESs by way of USDA contracts for specific research projects, and an increasing share of funding flowing to the SAESs from other federal agencies such as NIH, NSF, and DOE, much of it competitive funding not requiring a match. In 2013 state governments committed just $0.89 on average for every dollar of federal funding made available for research conducted in the SAESs, compared with $4.36 of state funding per federal dollar in 1925. There are several ways in which the mix of federal-state support can be rebalanced.

Expand the scope or size of the state matching requirements to secure federal funding for SAES research.

The composition of state and federal funding for SAES research varies considerably among the states. In 2013, 32 state governments contributed less than one dollar for every federal dollar, 12 states contributed between one and two dollars, and only four states provided more than two dollars of funding for each federal dollar directed to the SAESs. Expanding the scope or size of the state matching requirements to secure federal funding for SAES research is one practical way of rebalancing federal and state support for SAES research. It could also serve to better align the locus of where research is performed with where a specific agricultural production activity occurs, with potential for achieving increased efficiencies in the productiveness of R&D given the strong site-specific attributes that often affect agriculture and its associated environmental impacts. This improved alignment will also expand public support for this type of spending.

Revisit the basis of the "formula funds."

Politics hinders efforts to reach an allocation of research resources that make economic sense. A state is unlikely to be the most "efficient jurisdiction" for a particular set of R&D services, where efficient jurisdictions are defined according to the largely interstate geographical range of production supported by those research services. Agricultural production is unevenly distributed across the United States, so that striking a more efficient geographical balance of funding would entail shifting existing federal funding from some states to others. A practical way forward is to revisit the basis of the "formula funds," perhaps

putting more, or even exclusive, weight on the relative value of agricultural production as the basis for cross-state allocation.[1] Combined with more stringent state matching requirements, moves in this direction could strike a more appropriate balance between federal versus state funding, where efficient financing principles would call for financing "local" public goods using "local" taxes.

Re-allocate federal support between states to make more effective use of scarce R&D dollars.

Tackling this spatial resource allocation problem leads to another political challenge: Is 50 (one for each state) the optimal number of experiment stations for the United States? While farmers reap some of the benefits of R&D, consumers are also significant beneficiaries in the form of access to cheaper, safer, and more varied choice of produce. The "beneficiary pays" principle of public finance is based on the notion that *all* US consumers (and thus federal taxpayers) should underwrite public agricultural R&D, even though all states may not share equally in the distribution of those research dollars. With agricultural production spread unevenly over the geographical (and political) landscapes, the "efficient jurisdiction" concept introduced above suggests the need to improve the alignment between where the majority of US agricultural production is located and the allocation of federal agricultural research dollars, especially in an environment with scarce financial resources available for such work.

While farmers reap some of the benefits of R&D, consumers are also significant beneficiaries in the form of access to cheaper, safer, and more varied choice of produce.

Enhance private support for publicly performed research.

If we apply the basic logic of the "beneficiary pays" principle, those who benefit from a program should pay for it. The innovations spurred by agricultural R&D improve food quality, decrease food prices, and protect the environment from the negative externalities associated with agriculture. Since all consumers benefit from agricultural R&D investments, general tax revenues should at least partially fund them.

However, farmers also clearly benefit from innovative agricultural technologies that improve productivity, reduce risk, and decrease production costs. As such, farmers—and agribusiness in general—may appropriately have roles in funding agricultural R&D. US farmers already engage in collective action to fund activities that benefit agricultural producers. In recent years, these collective "check-off" arrangements have garnered annual funding of around one billion dollars. Some of the check-off boards provide funds to support R&D, but the share varies substantially across various commodity sectors. Most of the remaining funds are used for short-term promotional activities (Alston et al. 2005; Lee et al. 1996).

Legislation that provides incentives for industry to impose a research levy scheme where the funds are focused specifically on R&D and managed outside existing US check-off programs in ways that optimize the innovative "bang for the buck"—perhaps along the lines of the very successful, farmer co-funded Research Development Corporation model launched by the Australian Federal Government in the late 1980s (see Alston et al. 2012)—would be a straightforward way to enable (and induce) producers to collectively co-finance the research that benefits their enterprises.

To make the program palatable to grower groups (and recognizing that US consumers and taxpayers also gain from agricultural R&D via safer, more abundant and affordable food), the federal government should offer matching funds (up to some predetermined limit), thus splitting the R&D burden between producer research levies and general tax revenues. Including other industries that benefit from agricultural R&D in the scheme (such as input suppliers and food processors) would allow for even more agricultural R&D and, if implemented wisely, substantially correct the persistent underinvestment in agricultural R&D (Pardey et al. 2013). The federally-matched, research levy scheme introduced by the Australian government decades ago is a successful and now significant source of funding for public research carried out by universities and other government institutions in that country.

INSTITUTIONAL INNOVATIONS

Reversing the long decline in funding for publicly performed US food and agricultural R&D will be a step in the right direction toward maintaining the sustainable productivity performance of US agriculture. Improving the effectiveness by which these funds are mobilized and spent is also possible, requiring adoption of the complementary institutional innovations outlined below.

Improve interagency collaboration in R&D spending with food and agricultural implications.

Both the relevance of R&D in food and agriculture and the economic and societal consequences of innovations in these sectors extend well beyond the domain of the USDA. For example, food and agriculture directly affect nutrition and therefore human health, and so it follows that

coordination of research enabled by such entities as the USDA and the NIH must be improved. In recent years, the NIH has committed around $1.5 billion dollars annually to nutrition research and training (NIH 2015) compared with approximately $300 million per year of human health, nutrition, and food safety R&D undertaken by the USDA and the SAESs in 2013. Despite recent interagency deliberations between the USDA and the NIH (and other agencies) (see ICNHR 2016), these two agencies are presently investing just $3.4 million annually in jointly managed nutrition-related research.

The scale and importance of the social and economic issues involved—notably the increased health costs stemming from obesity and other nutrition-related problems—support the case for a much larger commitment of R&D resources and improved interagency collaboration. Such collaboration would also be helpful in other research topics that cross agency jurisdictions, such as remote sensing technology and climate impacts that involve scientists within both USDA and other agencies such as the Department of Defense (DOD), the National Science Foundation (NSF), and the National Aeronautics and Space Agency (NASA). Improved data capture and sharing tools across agencies could better reveal and leverage cross-agency complementarities in food and agriculture related R&D.

Facilitate greater international engagement in the agricultural sciences.

Addressing global hunger concerns via R&D enabled growth in agriculture around the world has clear US national security and humanitarian rationales. Furthermore, a comparison of public agricultural R&D in the United States and the rest of the world shows that the geography of innovation is shifting offshore, increasing opportunities for scientific and technological spill-ins to the United States. Finally, as the stem rust example above makes clear, the crop and animal disease problems (as well as food safety issues) originating elsewhere can directly and dramatically impact US producers and consumers.

Reversing the long decline in funding for publicly performed US food and agricultural R&D will be a step in the right direction toward maintaining the sustainable productivity performance of US agriculture.

Among the host of policy changes that would likely improve outcomes of US international engagement in food and agricultural R&D, two largely budget-neutral options, one involving USAID and the other the USDA, stand out. Over the past several years, there has been a dramatic shift in the orientation of USAID support to CGIAR research. In 2011, around 64 percent of that support was directed to longer-run R&D activities with especially large social and economic payoffs, and the residual went to a host of (often shorter-term) economic development activities. Over the subsequent years, CGIAR funding by way of USAID country missions rose much faster than funding from more centralized USAID agencies such as the Bureau for Food Security. As a consequence, by 2015, the R&D-oriented share of funding to the CGIAR (from both mission and more centralized sources) had dropped to around 42 percent of the USAID total, thus significantly shifting the balance of USAID support away from the central "research-for-development" raison d'être of the CGIAR. USAID should refocus its CGIAR funding on long-term R&D activities and resist the temptation to seek shorter-term payoffs.

Lowering bureaucratic barriers for USDA (and SAES) engagement in international R&D would further leverage USDA research expertise. Section 1402 of the National Agricultural Research, Extension, and Teaching Policy Act of 1977 is still the prevailing legislation for agricultural outreach efforts. That legislation makes repeated reference to "United States Agriculture." Within USDA agencies this wording has the practical consequence of making it difficult for bench scientists to deploy federal government funds in direct support of research done outside (or targeting problems outside) the United States, even if those issues have the potential to affect US producers and consumers. Adding a clause to the law that acknowledges that some US agricultural research must be dealt with at the international level would facilitate more effective deployment of scarce USDA resources.

Manage modes of allocating public agricultural R&D resources.

The President's budget (OMB 2016, p. 305) has proposed an increase in federal funding to agricultural research (from $2.7 billion in 2016 to $2.9 billion in 2017), which if supported by Congress is an initial yet incomplete step toward redressing the chronic underinvestment problem. How and to what areas these funds are allocated matters as much as the amount. In its score for the 2014 farm bill, the Congressional Budget Office indicated that 74 percent of the additional agricultural research (Title VII) mandatory funds for research were earmarked for organic and specialty crops R&D. Such earmarks affect the dispersal of these funds to the extent that the perceptions of scientific opportunity by USDA and SAES researchers and the technical judgment of NIFA (National Institute of Food and Agricultural) R&D funding managers are curtailed relative to the influence of political operators. It also limits the opportunity for a fully effective operation of the scientific marketplace via NIFA's flagship competitive grants program (Agriculture and Food

Research Institute), wherein scientific ideas are solicited, peer reviewed, and, for the lucky one in 10 proposals submitted, funded. One useful and potentially game-changing policy innovation in the 2014 Farm Bill was the creation of the Foundation for Foundation for Food and Agriculture Research, to which Congress awarded $200 million of startup funds, which can only be dispensed if a one-to-one match of non-federal funds can be obtained. This funding model, or variants thereof, should not only be maintained but expanded in the upcoming farm bill.

The lack of a well-informed and articulated strategic vision, combined with bureaucratic inefficiencies (including those arising from overly prescribed, idiosyncratic, and inconsistent calls for research funding applications), raises the transactions costs incurred by competitive funding processes and mutes the operation of the scientific marketplace. NIFA has suffered from both of these problems (NRC 2014), but has implemented steps to address these issues and streamline the whole process (NIFA 2015). NIFA's streamlining efforts should continue, along with the development of a strategic vision for US public sector spending on agricultural R&D.

While the upside of competitive funding processes is that they solicit new scientific ideas that have not been envisioned by farmers, politicians, or bureaucrats (Wright 1983), their downside is that they are costly due to the time and resources devoted to preparing and reviewing proposals. Striking the right balance between the associated costs and benefits involved in allocating R&D funds to individuals (via, for example, AFRI) versus institutions (primarily via the formula funds) is difficult. Through competitive grant programs conducted over the past several decades, federal government support to SAES research has shifted substantively from institutions to individuals. Not only has that shift inadvertently and deeply undercut the extent of matching support from state governments to SAES research—as the amount of formula funding has shrunk relative to competitive funding from the USDA and others—it has also induced a shift away from (longer-term) programmatic research toward (shorter-term) project research. It still takes seven to 10 years of R&D to turn out a new wheat or corn variety, and the lags in deploying and, as necessary, adapting new agricultural technologies as they are adopted over diverse climatic zones are often decades long.

It still takes seven to 10 years of R&D to turn out a new wheat or corn variety, and the lags in deploying and, as necessary, adapting new agricultural technologies as they are adopted over diverse climatic zones are often decades long.

Making the right decision on what and how to fund agricultural R&D is difficult and involves continuous monitoring, assessment, and active management. To do this requires putting in place effective data capture and sharing protocols and investing resources in an ongoing evaluation of the effectiveness of US agricultural R&D spending. Some efforts in this area are underway, but more could and should be done to improve overall accountability and, in particular, the efficacy of the allocation of public agricultural R&D resources.

THE BOTTOM LINE

The reduced financial support for public agricultural R&D in the United States over the past several decades suggests a creeping policy and political complacency about the long-term implications of this trend. The overall pace of US agricultural productivity growth has been slowing in parallel with the decline in public agricultural R&D spending, while the pressures to address evolving agricultural pest and disease problems with increasingly constrained land and water assets are growing. Maintaining agricultural producer performance, sustainably, will not happen absent adequate funding and improved institutions to allocate and deploy the dollars dedicated to public food and agricultural research. Failing to reverse these R&D funding trends is an unacceptably risky scenario for the United States.

ENDNOTES

1. These formula funds are disbursed to the states under various allocation rules that are still in force. The 1935 Bankhead-Jones Act imposed a formula that tied SAES support to each state's share of the nation's rural population; a more complicated formula was used in the Research and Marketing Act of 1946, with part of the funds divided equally among states, part distributed on the basis of rural population, and a third part based on farm population. The 1955 Hatch Act amendment included a similar formula that replaced the original Hatch, Adams, and Purnell Acts; formula funding also found its way into the 1962 McIntire-Stennis Forestry Research Act and the Research Facilities Act of 1963. The periodic Farm Bills reauthorized federal support for the SAESs thereafter.

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