ESCOP Science & Technology: http://escop.info/committee/scitech/

01/04/2021
4 pm ET, via Zoom
(https://us02web.zoom.us/j/81648064495?pwd=VFZYMmtLNm1PWFBaMllzK05uZkh0UT09) or 1 669 900 9128 Meeting ID: 816 4806 4495 Passcode: 103979)

Committee Members:

Chair: Jody Jellison (NERA) **Past Chair:** Laura Lavine (WAAESD) **Delegates:** Alton Thompson (ARD) John Yang (ARD) Joe Colletti (NCRA) Bill Barker (NCRA) Indrajeet Chaubey (NERA) Mark Hutton (NERA) Susan Duncan (SAAESD) Nathan McKinney (SAAESD) Gene Kelly (WAAESD) Chris Davies (WAAESD) **Executive Vice Chair:** Bret Hess (WAAESD ED) Saige Zespy (WAAESD Recorder)	**Liaisons:** Robert Matteri (ARS) Wendy Powers (ECOP) Tim Conner (NIFA) Jim Farrar (NIPMCC) Tim Killian (SSCC)

Agenda:

1. **Welcome** – Jellison
2. **Roll Call** – Hess
3. **Approval of meeting notes from 12/07/2020** – Jellison
4. **Liaison Updates, as needed**
   - ARS
   - ECOP
   - NIFA
   - NIPMCC
   - SSSC
5. **Infrastructure Supportive Information** – Jellison
   January 11, 2021 -- 4:00 - 5:00 p.m. (EST) -- *Agricultural Research Infrastructure Advocacy (ARIA) Webinar*
   Audience: ESS, AHS, ACOP, ECOP, CARET, and interested allies
   Register in Advance
6. **Next Scheduled Meeting(s) –** Jellison
   4-5 pm Eastern the first Monday of every month through September 2021
   February 1, March 1, April 5, May 3, June 7,
   July 5, August 2, September 6

Did You Know?

The U.S. Land-grant University system is a world-wide leader in agricultural R&D. Federal research funds have been leveraged to enable our scientists to address the grand challenges facing our agricultural and food systems. A significant issue faced by the Land-grant University system is the need for substantial investment in a degrading agricultural research infrastructure.

The Clear Benefits

The Land-grant University system has a history of sustained scientific research productivity capable of addressing emerging issues and creating effective solutions, strategies, and technologies that ensure food safety, advance biosecurity for disease and pest outbreaks, mitigate climate impacts, increase agricultural productivity and sustainability, and safeguard human health. Imagine how much more productive our scientists could be with universally updated facilities. An investment in agricultural research infrastructure positions the Land-grant system to meet future challenges, embrace future opportunities, and ensures the ability to respond to a changing globe.

Failure to Invest?

Failure to invest has dire consequences. We are on the brink of infrastructure system failure. A recent comprehensive evaluation performed by Gordian (A National Study of Capital Infrastructure at Schools of Agriculture: A 2020 Update) identified $11.5 billion in deferred maintenance, a 36.9% increase from an estimate made five years ago. The time to act is now! Construction costs continue to increase and we risk being left behind our global competitors. The rapid rise of spending on food and agricultural research and development (R&D) in China coupled with declining investments by the U.S. is destined to propel China past the U.S. If this trend continues, there will be profound implications for the size, shape, and accessibility of the global stocks of scientific knowledge that underpin food and agricultural sectors worldwide[1]. China could supplant the U.S. as the leading world power in food and agricultural research. The notable changes in food and agricultural R&D between China and the U.S. also have domestic and international economic development implications where the fortunes of many of the world's poorer countries continue to look bleak[2]. Moreover, climate change is remaking the world order. According to the New York Times[3], "Russia hopes to seize on the warming temperatures and longer growing seasons brought by climate change to refashion itself as one of the planet's largest producers of food." Shifting global capacities for agriculture as a result of climate change must be addressed now. Failure to act is not an option if the U.S. is to maintain its position as the global leader food and agriculture! If we do not address the problems now, the solutions will become more intractable, the costs greater, and the human, social, economic, and environmental damage irreparable[4].

Why Invest?

Investment in agricultural research infrastructure is akin to the space race from the 1950s. Do we want to compete? Agricultural productivity and resilience are fundamentally linked to our ability to understand biological systems and develop technical- and knowledge-based solutions in the context of economic, social, and environmental constraints and opportunities. Not surprisingly, investment to agricultural R&D is closely linked to agricultural productivity in high income countries. Investing in research infrastructure will prevent the rest of the world advancing agriculture and its attendant economy beyond the U.S. While investment in transportation and other infrastructure is critical, an abundant, secure, and resilient domestic food supply is of even greater importance. With 42.2 million U.S. citizens facing food insecurity, public support is essential to ensure food and nutrition security for all! Investment in agricultural and food systems must be prioritized. Thankfully, the private sector has been investing. The private sector accounts for 2/3 of total agricultural and food R&D spending in both China and the U.S.[1] In real terms, however, U.S.

private investment has mostly stagnated in the last decade[5]. A report published by the Economic Research Service[6] showed that investments in agricultural R&D not only have been the primary drivers of long-term growth in agricultural productivity, but the investment also improves overall economic value because it enables expansion of output and withdraws resources such as labor and capital from the sector for use elsewhere in the economy. Accordingly, agricultural and food R&D activities are important economic drivers of regions. In a comprehensive meta-analysis of hundreds of publications on returns to agricultural R&D, world-renown economists Alston and Pardey found median reported benefit-cost ratios of 12:1 and an annualized internal rate of return of 32%[7]. Jin and Huffman indicate a real social rate of return to public investments in agricultural research of 67%[8]. Because the social benefits exceed potential profits, the new technological opportunities opened by public research could stimulate more private R&D[5]. Infrastructure investments will also have an immediate stimulatory effect on local economies, creating jobs and enabling communities to rebound from pandemic related economic stress. Public investment in agricultural research infrastructure will directly benefit struggling communities throughout the nation while enabling the U.S. to remain competitive and the world's leader in food and agricultural innovation.

Where to Invest?

Agriculture is place-based. What happens in the Pacific Northwest does not translate to the Midwest, Northeast, or South. Climate, soils, and other natural resources are very different from location to location. People and needs are different. The solution cannot be universalized in a "one-size-fits-all" approach. While all pieces are interconnected and serve to support one another, the system must be further developed. Threats are wide-ranging and disruptive (e.g., COVID-19 and climate change). Solutions are place-based. Adequate infrastructure must be available across the country. An investment in the agricultural infrastructure associated with our state-based Land-grant University system is the most effective way to meet state, regional, and national needs. This investment needs to be both diverse and inclusive of different regions, commodities, and size and type of institution, supporting both delayed maintenance and new opportunities. Clearly, the pandemic has shown a disproportionate negative impact on diversity, equity, and inclusion. What can we do in the agricultural and food research arena to ensure that we help reduce the wealth gap for education, health, and food and nutrition security? The 1994, 1890, and 1862 Land-grant Universities, Hispanic-serving institutions, along with other public universities with colleges of agriculture could benefit from a collaborative approach to the grand challenge through enhanced research infrastructure. We educate the next generation of agricultural workers and scientists and are the bridge to rapid adoption among farmers and the larger agricultural community.

Works Cited

[1]Chaia Y., et al. 2019. https://doi.org/10.1016/j.foodpol.2019.101729.

[2]Dehmer S.P., et al. 2019. https://doi.org/10.1371/journal.pone.0213801.

[3]New York Times. https://www.nytimes.com/interactive/2020/12/16/magazine/russia-climate-migration-crisis.html.

[4]The Challenge of Change: Harnessing University Discovery, Engagement, and Learning to Achieve Food and Nutrition Security. https://www.aplu.org/projects-and-initiatives/international-programs/challenge-of-change/#:~:text=APLU%20established%20the%20Challenge%20of,global%20food%20needs%20by%202050.

[5]Clancy, M., et al. 2016. https://www.ers.usda.gov/amber-waves/2016/november/us-agricultural-r-d-in-an-era-of-falling-public-funding.

[6]Heisey, PW. and K.O. Fuglie. 2018.. https://www.ers.usda.gov/publications/pub-details/?pubid=89113.

[7]Alston, J.M. and P.G. Pardey. 2020. http://www.nber.org/papers/w27206.

[8]Jin, Y. and W. E. Huffman. 2016. https://onlinelibrary.wiley.com/doi/abs/10.1111/agec.12206.

Introduction

As part of the Land-grant University system Agricultural Experiment Stations and agricultural research programs at universities and historically black and tribal colleges have a history of sustained scientific research productivity capable of addressing emerging issues and creating effective solutions, strategies, and technologies. Federal research funds provided through USDA NIFA to support capacity of the Land-grant University system have been leveraged by the Land-grant University system to addresses the grand challenges facing our agricultural and food systems. The system of Land-grant Universities conducts research to provide evidence-based information in support of local, regional, national, and global communities across a range of areas, including agriculture, health and nutrition, and economic development. The coordinated work meets the diverse and changing needs of communities, particularly related to food and agricultural systems. The Land-grant University network plays meaningful roles in economic development efforts in distressed communities by responding to urgent and emerging issues in the agricultural economy and food supply chain and delivering practical tools, technologies and information to farmers, ranchers, and forest landowners. Below are a few examples of critical issues the Land-grant University system is addressing by leveraging capacity research funds provided through USDA NIFA. Additional details about the ongoing efforts are available via the resource links. Additionally, a list of participating institutions was provided for multistate projects to illustrate the breadth of nationwide collaboration necessary to address many of the grand challenges.

Responding to Crisis, such as the COVID-19 Pandemic

Decision-makers and producers need up-to-date, factual information on the impacts of the COVID-19 pandemic on agriculture and trade, unemployment, businesses and public health. Though information on the pandemic has quickly proliferated, industry and individuals are challenged to know where they can find reliable, science-based information on which to base effective action. A new web hub, "COVID-19 Pandemic: Research and Resources" developed by the Center for Agricultural and Rural Development at Iowa State University, in partnership with the Department of Economics, provides science-based information to examine and track the pandemic's impacts on agriculture, business, communities and individuals across local, regional, and global economies. The hub includes research papers and graphs, tables and maps that show the scale and extent of the pandemic's impact. Additional timely resources include an interactive tool to estimate total losses to Iowa's corn, soybean and ethanol markets due to COVID-19, and relevant queries from the Department of Economics" "Ask an Economist" service. The hub for "COVID-19 Pandemic: Research and Resources" has quickly become an important resource for those seeking insights into the pandemic's economic and social impacts and offers critical, science-based resources to help policymakers, businesses and producers make more informed decisions during this unprecedented time in our history.

Resource Link
https://landgrantimpacts.org/impacts

Providing Innovations that Ensure Food Safety

In the US, an estimated 48 million people get sick each year, and 3,000 die from foodborne illnesses. Related medical expenses total over $55 billion annually. Food recalls due to contamination occurring at any point in the food system can cost companies millions of dollars in direct expenses. A multistate research project hosted in the Southern region titled "Enhancing Microbial Food Safety by Risk Analysis" is developing comprehensive risk-based strategies that control foodborne pathogens in all foods and at all points in the food system. Since 2000, a multidisciplinary team of researchers and Extension educators from 39 institutions across the country[1] have worked together to address food

safety concerns. Collaboration has led to inventive strategies that can help prevent food safety threats before they become dangerous and costly. Researchers have studied how microbes react to their environments and designed models that anticipate how foods might be contaminated. Collaborative research, development, and education efforts are improving food safety and reducing the risk of contamination by pathogens that cause serious illnesses for tens of millions of Americans each year as well as significant economic damage to food companies.

Participating institutions: Auburn University; University of Arkansas; University of Arkansas, Pine Bluff, California Cooperative Extension; University of California, Davis; Clemson University; Colorado State University; University of Connecticut-Storrs; Cornell University-Geneva; Cornell University; University of Delaware; University of Florida; University of Georgia; Idaho Cooperative Extension; University of Illinois; Purdue University; Iowa State University; Kansas State University; University of Kentucky; Louisiana State University; LSU Agricultural Center; University of Maine; Maine Cooperative Extension; University of Maryland; University of Massachusetts; Michigan State University; University of Minnesota; Mississippi State University; University of Missouri; University of Nebraska; Rutgers University; New Mexico State University; New Mexico Cooperative Extension; North Carolina State University; North Dakota State University; Ohio State University; Oregon State University; Pennsylvania State University; University of Puerto Rico; University of Rhode Island; University of Tennessee; Texas A&M University; Texas AgriLife Research; Virginia Polytechnic Institute and State University; Washington State University; Wayne State University; University of Wisconsin; and University of Wyoming.

Resource Links
https://www.mrfimpacts.org/single-post/2019/10/28/Managing-Food-Safety-Risks-S-1056-2013-2018
https://www.nimss.org/projects/14836

Identifying Biosecurity Technologies to Prepare for Disease and Pest Outbreaks

Viral diseases cause billions of dollars in annual losses to livestock production in the US. In addition to the threat to animals, we have seen the devastating effects when viruses jump from animals to humans as is the case with zoonotic viruses such as SARS and the COVID-19 coronavirus. Scientists at Tennessee State University Agricultural Research and Extension Center have addressed this issue by searching for antiviral molecules that exist naturally in the wild. Omega-type interferons were isolated from pigs and cattle and refined using bioengineering procedures. These compounds have adapted over time to confront ever-changing viral threats. Several of the interferons have shown superior antiviral activity in laboratory tests. Some of them have broad activity to fight viruses not only in pigs, but potentially in humans as well. In cell and tissue-based tests, several of the new omega interferon molecules have 100 to 1,000 times greater activity than the conventional interferon alpha type. These new interferon molecules are now being released for use in research applications and a process has been initiated for animal tests and antiviral development.

Resource Link
https://landgrantimpacts.org/impacts

Mitigating Climate Impacts on Food Production and Developing Sinks for Greenhouse Gas Emissions

By reducing greenhouse gases, agriculture could alleviate the impact of global warming all over the world. In addition, agricultural producers will also be assisting themselves in preventing the predicted disruption of climate due to global warming such as drought that could result in devastating crop losses that would limit the individual farmer's ability to make a living and seriously jeopardize agriculture's ability to feed the world. Scientists at the Illinois Agriculture Experiment Station study genetic components of natural selection that may play a major role in adaptation to climate change as genetics are the key to increasing stress tolerance such as what occurs during climate change. This information may allow plant breeders to produce food and energy crops that will continue to show increasing yields in changing climates.

Resource Link
https://landgrantimpacts.org/impacts

Emission of the greenhouse gas methane by ruminant livestock contributes to climate change and is a loss of potential energy for the animal. The long-term goal of a research program at the Langston University Agricultural Research Station is to develop practical and sustainable means of minimizing greenhouse gas emission by domestic ruminant livestock to lessen the contribution to climate change and elevate efficiency of production. For example, scientist determined consumption by goats and sheep of lespedeza, a forage high in condensed tannins, has resulted in appreciable and consistent decreases in methane production.

Resource Link
https://landgrantimpacts.org/impacts

Increasing Agricultural Production Efficiency

One of the biggest deterrents to fresh fruit consumption is poor quality and fruit that is unappealing to consumers. A multistate research project hosted in the Northeastern region titled “Protecting Fresh Fruit Shelf Life and Quality” involves researchers at land-grant universities working with government partners in the US and Canada to address these concerns and find effective ways to protect fresh fruit shelf life and quality. Growers who have adopted research-based storage recommendations have seen reduced fruit losses and higher profits. For example, a major local pear packer in the Pacific Northwest documented a nearly $2,000,000 annual increase in market value and an almost $800,000 reduction in repacking costs for a single pear variety. Growers in the Mid-Atlantic who followed University of Maryland recommendations for preventing internal breakdown reduced losses from 100% in 2015 to none in 2016. Preventing fruit damage and disease during storage not only saves growers millions of dollars, but also gives consumers more reliable access to high-quality fruit.

Participating institutions: Auburn University; University of California; Cornell University; University of Florida; University of Hawaii; University of Maine; University of Maryland; University of Massachusetts; Michigan State University; University of Minnesota; Mississippi State University; North Carolina State University; Rutgers University; and Washington State University.

Resource Links
https://www.mrfimpacts.org/single-post/2019/03/13/Protecting-Fresh-Fruit-Quality-Shelf-Life-NE-1336-2013-2018
https://www.nimss.org/projects/view/mrp/outline/15116

Specialty crops include fruits, vegetables, tree nuts, dried fruits, and nursery plants. Faced with labor shortages, global competition, demand for higher quality, and concern about environmental impacts, the specialty crop industry is urgently seeking automated devices to help with growing, harvesting, handling, and processing. A multistate research project hosted by the Western region titled "Automation for Specialty Crops" involves researchers at land-grant universities working together to develop automated systems that work well for specialty crops. With this collaborative approach, the cost burden of research and development is lifted from a single specialty crop sector and major advances are being made. Over the last five years, researchers identified key parameters associated with specialty crop production and developed sensors to detect and measure these parameters. Researchers designed mechanized devices and partnered with manufacturers and farmers to commercialize and implement new technologies. Automation is helping the specialty crop industry overcome labor shortages, make smart management decisions, conserve resources and meet growing demand. These advances are resulting in significant savings for growers and consumers and improved sustainability for the industry.

Participating institutions: University of Arizona; Auburn University; University of California-Davis; Colorado State University; University of Florida; University of Georgia; University of Hawaii; Iowa State University; University of Kentucky; Michigan State University; Mississippi State University; Oklahoma State University; Oregon State University; Pennsylvania State University; Pennsylvania Cooperative Extension; Texas AgriLife Research; Washington State University; Washington Cooperative Extension; and West Virginia University.

Resource Links
https://www.mrfimpacts.org/single-post/2019/05/24/Automation-for-Specialty-Crops-W-2009-2013-2018
https://www.nimss.org/projects/15436

To address the complex challenges facing livestock production and balance environmental, economic, and social sustainability, a multistate research project hosted by the Southern region titled "Animal Production Systems: Synthesis of Methods to Determine Triple Bottom Line Sustainability from Findings of Reductionist Research" includes a team of researchers from 15+ land-grant universities looking at the broader, system-wide impacts of new technological innovations, practices, and policies. The transdisciplinary research involves a holistic approach to all facets of sustainability including building databases, evaluation of whole systems, protecting the air and water, reducing odor and gas emissions, creating renewable energy, and managing livestock disease. Consensus on conclusions and recommendations by this team of scientists on advances in those areas will improve the sustainability of the livestock industry, ensuring a steady supply of meat and dairy products, reducing economic losses, and minimizing environmental impacts.

Participating institutions: Iowa State University; Michigan State University; Mississippi State University; North Carolina State University; North Dakota State University; Texas AgriLife Research; The Ohio State University; University of Arkansas; University of California, Davis; University of Idaho; University of

Illinois; University of Kentucky; University of Minnesota; University of Nebraska; University of Wisconsin; Virginia Polytechnic Institute and State University; and West Texas A&M University.

Resource Links
https://www.mrfimpacts.org/single-post/2019/09/25/Sustaining-Livestock-Production-S-1032-2013-2018
https://www.nimss.org/projects/view/mrp/outline/15636

Photosynthesis is essential to life on Earth. It uses sunlight, carbon dioxide from the atmosphere, and water to synthesize sugars, lipids, amino acids, and other cell building blocks needed for plant growth. A multistate research project hosted by the Northcentral region titled "Regulation of Photosynthetic Processes" involves researchers at land-grant universities across the nation working to better understand photosynthesis and how it is affected by environmental, molecular, and genetic constraints so that they can improve efficiency and increase plant productivity, which is necessary to meet rising food, fuel, and fiber needs. With their diverse expertise, project members are tackling this global issue with practical solutions for specific crops, regions, and production systems. Researchers' discovery of ways to manipulate or improve photosynthesis helps producers meet rising demand for food, fiber, and biofuels even as available suitable farmland decreases and climate changes.

Participating institutions: Iowa State University; Kansas State University; Louisiana State University; Michigan State University; Mississippi State University; Montana State University; The Ohio State University; University of California, Berkeley; University of Illinois; University of Missouri; University of Nebraska; University of Nevada; USDA-ARS/Arizona and Missouri; Virginia Polytechnic Institute and State University; and Washington State University.

Resource Links
https://www.mrfimpacts.org/single-post/2019/02/12/Improving-Photosynthesis-NC-1200-2012-2017
https://www.nimss.org/projects/14097

Eliminating Nutrition-based Human Disease and Addressing Obesity

The overarching aim of a research program at the Illinois Agriculture Experiment Station is to prevent the burden of adult obesity among women. Rather than waiting until overweight or obesity develops, the study identified determinants of weight gain prevention and applied principles of weight gain prevention strategies to food-based dietary guidance. The specific purpose of this research project is to identify determinants of weight gain prevention as guided by Social Cognitive Theory. It is hypothesized that compared to a wait-list control group, women who undergo a weight gain prevention intervention designed to increase self-efficacy, self-regulation, outcome expectations, and family and social support regarding weight gain prevention will maintain current body weight over 12 months.

Resource Link
https://landgrantimpacts.org/impacts

The objective of another research project at the Illinois Agriculture Experiment Station is to determine the intention and actual use of diabetes-related apps by diabetes clinicians and health care administrators, which are influenced by various individual and organizational factors. This research provides important qualitative evidence that administrators and clinicians overall feel positively disposed towards using health apps and new mobile technologies and that a future

feasibility study examining health app use in patients with type 2 diabetes at the Riverside Diabetes Wellness Center is appropriate and would be supported in this health care system.

Resource Link
https://landgrantimpacts.org/impacts

Developing Biodegradable Biomaterials and Biofuels for a Sustainable Economy

A new technology developed by Ohio researchers advances the promise of biofuels by using microbes to break down biomass and degradable wastes. In anaerobic digestion, microbes break down biodegradable materials such as corn stover, wheat straw or food waste into biogas, a renewable energy source. The patented research discovery combines anaerobic digestion with another kind of oxygen-less digestion available commercially in liquid form. This results in improved efficiency, lower costs and increased production of biogas. The research also identified food wastes as the most promising feedstock for the new combined technology. Food waste digestion increased the yield of biogas by up to 150% over other sources. Researchers continue to enhance performance and economic feasibility of the technology, with the goal of industry adoption. The technology could improve the value of feedstocks for producers and reduce the amount of wastes previously destined for the landfill.

Resource Links
https://landgrantimpacts.org/impacts
https://landgrantimpacts.org/wp-content/uploads/sites/3/2019/02/Energy_Innovation_2019.pdf

References and Brief Discussion on the Returns to Agricultural R&D

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Prepared for Senior Assoc Dean Joe Colletti, CALS
December 28, 2020

Measuring the returns to research and development (R&D) in any industry is difficult and in agricultural industries the complications arise from various factors not least of which are the lags in adoption of innovations and measuring the benefits of the innovation along the supply chain. Nevertheless such measurements are common and the difficulties surmountable. The two standard agricultural economics textbooks measuring the returns to agriculture are *Science for Agriculture* and *Science Under Scarcity* and these textbooks go into great detail about the specific ways of measuring the returns to R&D and investment in agriculture.[1]

There have been hundreds of studies that attempt such measurements of the returns to agricultural R&D and most studies focus on one or more of three main measures. 1. The benefit-to-cost ratio (BCR) which attempts to measure the benefits of some agricultural innovation or cost such that the benefit is in the numerator and the cost is in the denominator. A BCR greater than one, thus, shows the investment earned more than its cost. 2) Some form of annualized rate of return of the investment (ROR, including the internal rate of return (IRR) and the modified internal rate of return (MIRR)). The ROR is compared with the return from some other use of the funds and if the ROR for agricultural R&D is greater than the ROR for the potentially competing investment then the R&D on agriculture was the better use of the funds. 3) Sometimes the monetary value of the investment is harder to calculate and in such cases a measure of output productivity to input use called factor productivity is derived. Studies using factor productivity techniques usually examine either total factor productivity (TFP) or marginal factor productivity (MFP). These factor productivity methods can also be used in some case to construct ROR.

In numerous studies, it is quite common to find that public and private funding of agricultural R&D is well worth the expense with BCRs much greater than 1, positive RORs much higher than traditional alternatives, and measures of factor productivity showing that values of outputs greatly exceed those of their inputs.

These findings are consistent across nations with the measures coming from the United States regularly showing large BCRs and RORs. It is important to note that it is also quite common to find larger returns to agriculture in developing nations.[2] The main reason for this is that even small investments in

[1] *Science for Agriculture* by Huffman and Everson (1993 and 2006). *Science Under Scarcity* by Alston, Norton and Pardey (1995).
[2] Alston, Pardey and Rao (2020).

developing nations can have extremely large benefits relative to the costs. A salt or drought resistant variety of sorghum or wheat can have a very large impact on profitability in a nation with land scarcity or with little capital.

Returns to Agricultural R&D in the United States.

Two 2020 studies by Professor Julian Alston of the University of California, Davis and Professor Philip Pardey or the University of Minnesota are worth reading because 1) they both analyze previous studies, 2) they are the most recent studies to which I am aware and 3) because Julian and Phil are probably the best economists in the world right now at this type of measurement.

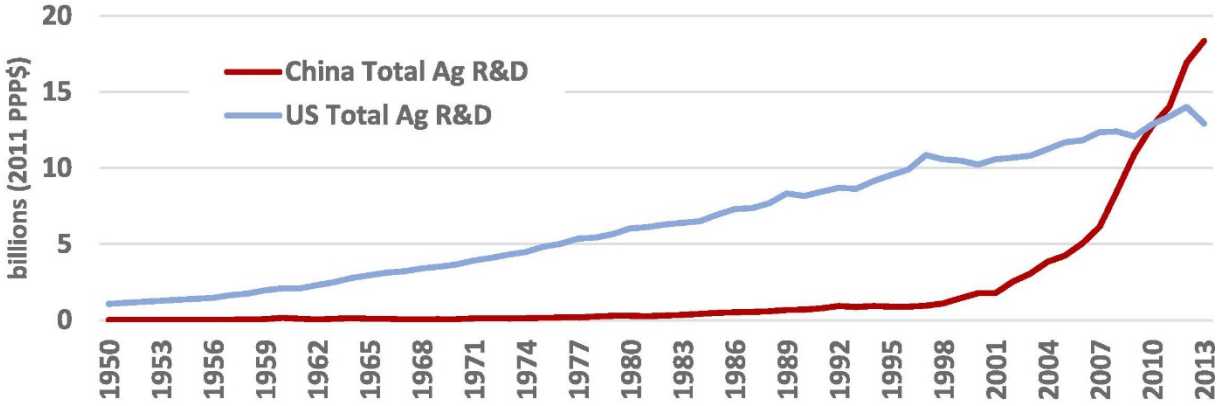
1. **Innovation, Growth and Structural Change in American Agriculture.** This first study is a meta-analysis published in the prestigious *NBER Working Paper Series*. This study examines hundreds of previous publications on returns to agricultural R&D and so is an excellent starting point.
    a. **US RETURNS.** In the United States Alston and Pardey found median reported benefit-cost ratios in the range of 12:1 and an annualized internal rate of return of 32%.
    b. **REST OF THE WORLD**. Alston and Pardey found median BCR of 12.1:1 and IRR of 41.2%.
2. **The Drivers of U.S. Agricultural Productivity Growth**. The second study examines factor productivity showing how greatly investment in agricultural R&D (both public and private) have had huge impacts on productive outputs in the United States. This study is also worth examining because the paper discusses how both public and private investment are waning in recent years. There is often a belief that while public investment has dropped off that private investment has picked up. While this had been true for many decades, as Alston and Pardey show, even U.S. private investment has mostly stagnated in the last decade in real terms.

Chinese versus US Investment.

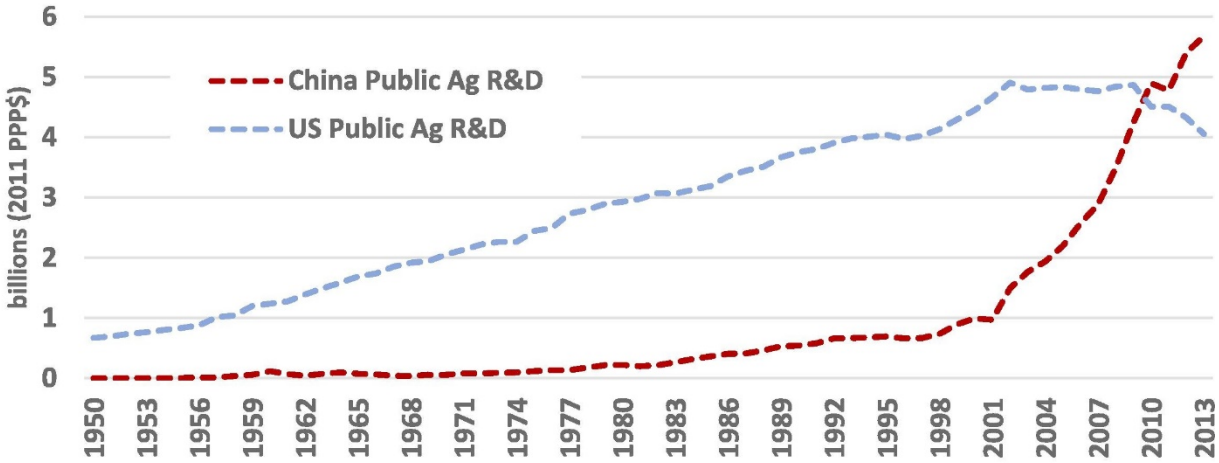
There have not been as many studies specifically comparing Chinese and US investment. Recent studies have shown Chinese public investment in agricultural R&D has surpassed US public investment, although the U.S. still holds a lead in innovation as measured by various means (patents and journal articles for example).[3] Nevertheless, with major investments and purchases of agribusiness firms, China began rapidly catching up in private investment at the beginning of the decade (Hu et al. 2011), and in a recent study by Chai et al. (2019), surpassed the U.S. in private spending as well. While, the U.S. is no longer the leader between the two countries even in private-sector spending, an argument can still be made that the U.S. is more focused on higher value innovations. Regardless the caveats, the takeaway, however, is that while the U.S. spending on R&D is either lagging or holding steady, China shows no incentive to curtail its intensity and is expected to continue to outspend the U.S. in both agricultural as well as food R&D, both in the public and private sectors. The following figures are taken from Chai et al. (2019), figure 2:

[3] Clancy, Fuglie, and Heisey. 2016.

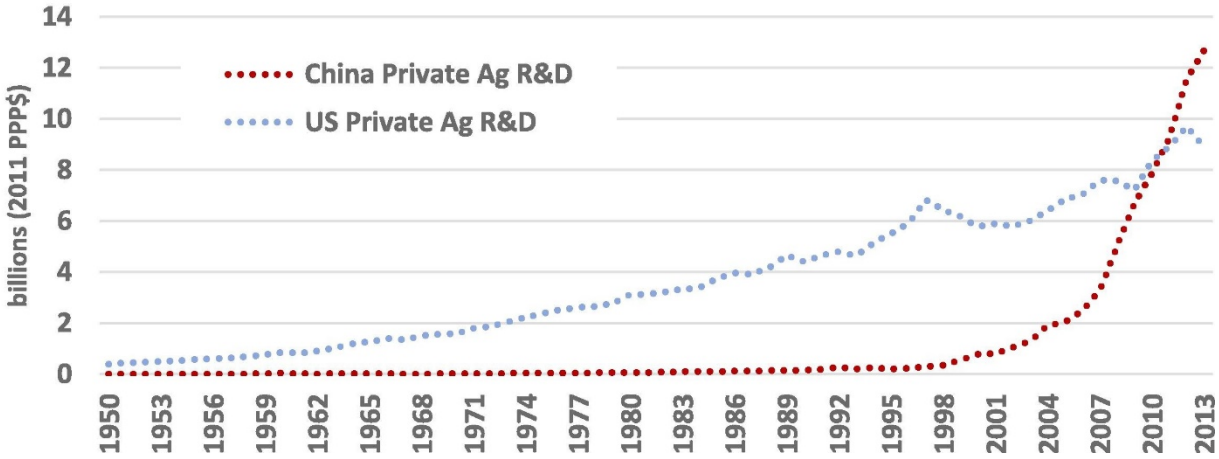
Panel a: Total (public and private) agricultural R&D spending



Panel b: Public sector agricultural R&D spending



Panel c: Private sector agricultural R&D spending



Other recent studies about Chinese investment in agriculture:

- A USDA/ERS study by Gale (2013) discusses how China uses agricultural subsidies and price supports and gets into the details of how China is making its R&D investments.
- An OECD (2018) study examines Chinese R&D and the specifics of the Agricultural Innovation System in China.

Recent studies by Huffman on Returns to Public Funding and Extension.

Although Huffman had many publications over his career measuring the returns to agricultural R&D along with the book cited in footnote 1, his two most recent studies are Jin and Huffman (2016) and Huffman (2016). Both show tremendous returns to public funding of agricultural research. From Jin and Huffman (2016): "The results and data indicate a real social rate of return to public investments in agricultural research of 67% and to agricultural extension of 100+%."

The following table provides the citations and links to the studies discussed above. *References in **bold** most recommended.*

Alston, J.M., P.G. Pardey, and X. Rao. The Payoff to Investing in CGIAR Research. SoAR Foundation. Arlington, Virginia, October 2020.	https://supportagresearch.org/assets/pdf/Payoff_to_Investing_in_CGIAR_Research_final_October_2020.pdf
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