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The Agricultural Innovation System in the Context of the 2020 Pandemic

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A worthy agricultural innovation system (AIS) is one that that helps an agricultural sector be productive, sustainable and resilient and facilitates reduction in poverty and malnutrition. How can an AIS be made resilient in the context of the COVID-19 pandemic is a question pondered in this note. The key issue will be continued strong investment in knowledge and technology creation that underpins growth in productivity and the active pursuit of mechanisms that make agriculture more resilient to the emerging environments challenges around the world.

1. Introduction

The global food and agriculture system is known for its complexity and imperfections, including persistently stubborn food insecurity. A key subsystem that helps to reduce the extent of food insecurity is the agricultural innovation system (AIS). The AIS is itself a complex system with diverse sub-systems such as agricultural research, agricultural extension and agricultural education all with important links to other systems. The extent of ready documentation of these various sub-systems varies greatly across time and space. As well as being complex, the AIS is imperfect as it strives to cope with the risks inherent in global systems (World Bank, 2012). One such risk is a pandemic fueled by the emergence of a novel pathogen such as COVID-19. This paper explores how the AIS can effectively handle the challenges posed by COVID-19 by considering how national and international institutions can work effectively together in the AIS to tackle the challenges during and after the pandemic, maintaining the productive functioning of the AIS and ensuring its capacity to foster its productivity in the future. Failure to ensure the continuing high productivity of the AIS would have dire consequences for food and nutritional security in coming decades; therefore it is critical to understand quickly how such adaptation can best occur.

A healthy population is a public good attended to at most levels of government, from international through the United Nations' specialized agency, the World Health Organization (WHO), to the national and sub-national such as the State in many federal systems, but most directly at more local levels, for example, LGAs (local government areas; e.g., the counties in systems such as the US). The nature and scope of the restrictions imposed by authorities at the various levels are driven by the evolving perceptions of the spread of infections, which in turn are informed by assessment typically based on some system of required notification of incidence of infectious disease. The quality of these schemes naturally varies greatly around the world. So too do the details of the nature of the restrictions, but they typically are cast in temporal phases of response. Given the diversity of institutional capacity and medical infrastructure around the world, it is hardly surprising that there is little uniformity in the definition of the various phases of official responses. In order to set the context for these responses, the pre-COVID-19 agricultural R&D situation is briefly overviewed, followed by a review of COVID-19 impacts and a discussion of policy options.

2. The Public and Private Research and Innovation Situation Prior to the Pandemic

Public Agricultural Research

High-Income Countries. Until recently, public spending on agricultural R&D in high-income countries has grown at least as fast, or faster, than agricultural GDP (AgGDP). But this trend reversed in many high-income countries following the global financial crisis of 2008-09. Between 2009 and 2013, after adjusting for inflation, total agricultural R&D spending by these countries fell by almost 6 percent (Heisey and Fuglie 2018). Agricultural research intensity (ARI), measuring the share of research expenditures relative to AgGDP (as a percentage), declined from its average of 3% to around 2% in the United States (Heisey and Fuglie 2018). Agriculture is a small sector in most high-income countries in recent times, constituting usually less than 2% of total GDP

(Heisey and Fuglie 2018; Dehmer et al. 2019).

Middle-Income Countries. Unlike the stagnant R&D expenditure growth in high-income countries, agricultural research is growing rapidly in China, Brazil and India that are the large, middle-income countries (e.g., Beintema et al., 2012). Indeed, Chai et al. (2019) and Dehmer et al. (2019) have argued that China is now the world superpower of agricultural research, particularly among those countries in which agriculture is a significant component of the economy, such as China, Brazil and India which have ARIs of about 2.0%, 1.2% and 0.8%, respectively.

Other middle-income countries are not doing as well. Their ARIs are still mostly around 0.5%. There is much scope for growth of investment in these middle-income countries just to meet the long-held rough guideline "goal" (e.g., World Bank 1981) of ARI investments of around 2%.

Low-Income Countries. The ARI for most low-income countries averages less than 0.5% and these national agricultural research systems are mostly small and hardly viable. Some research systems in Africa have been expanding significantly, such as Ghana and Ethiopia (Beintema and Stads, 2017). Funding of other relatively strong national systems, such as in Kenya, Nigeria and South Africa, has been stagnant. Donors play a major role in funding many sub-Saharan African (SSA) agricultural research systems. Many national systems rely on spill-ins of science from the CGIAR and universities in high-income countries and spillins of technology from Chinese and Indian firms.

CGIAR. Given the continuing low levels of investment in absolute and relative terms in public agricultural research in low- and middle-income countries, the role of the CGIAR system in substituting for and complementing national investment is vital (Anderson, Herdt and Scobie 1988; Alston, Dehmer and Pardey 2006), even if still insufficient. The total CGIAR spending (in constant 2016 dollar values) peaked at $1.1 billion in 2014 and has since declined, to $0.8 billion in 2018 (Dehmer et al. 2019). Despite the global financial crisis of 2008-2009 and resultant depression, wealthy countries increased funding for CGIAR research, in large measure because of the food crisis, which pushed up food prices that led to political unrest and increased poverty in poor countries. After reaching the 2014 peak funding declined perhaps-because food prices declined and many donor countries shifted their priorities to other more pressing problems. Bilateral support from wealthy countries other than the U.S. declined particularly rapidly.

Private Agricultural Research

Private research has increased dramatically in recent years, especially in low- and middle-income countries (LMIC) (Pray and Fuglie 2015; Fuglie 2016). Agricultural R&D by private firms worldwide rose from $6.4b in 1981 to $12.9b in 2011 (2011 PPP$) (Fuglie 2016). In high-income countries, private agricultural research expenditures are about 50 percent of total agricultural research. In LMIC countries public research was much more important than private research (Fuglie et al. 2011). In China, expenditures on agricultural research by Chinese private firms, state owned enterprises and foreign firms have grown rapidly, especially in the machinery industry. Chinese investments in 2019 could be nearing $20 billion, or twice the public sector investments of $9.4b (Pray et al. 2020). In Brazil, private agricultural R&D increased seven-fold from $50m in 1996 to $377m in 2012, and now constitutes around 20% of total agricultural research. In India, private agricultural input industry R&D grew from $44m in 1995 to $309m in 2016 (in 2005 $s).

Other developing countries with smaller agricultural economies have also seen an increase in private engagement in agricultural R&D, albeit not as dramatic, for four reasons: First, because of the relatively small size of their agricultural markets, they are less attractive to investors to fund costly research in, or to try to introduce new innovations. Second, complimentary public research investments are often much smaller than in larger economies. Third, many of these smaller countries receive spillins from private R&D in larger neighboring countries. Fourth, the ability of the government to enforce policies (e.g., intellectual property rights) is weaker, further discouraging private investments (Pray, Nagarajan and Byerlee 2016).

3. Preliminary Evidence of Impacts of COVID-19 on Agricultural R&D

Given the continuing evolution of the pandemic around the world, we present preliminary evidence from a review of existing literature including webinars and our analyses of more than 20 interviews and emails with key informants[1] since May 2020. The key informants provided their initial assessments of the impact of COVID-19 on the productivity of research, on government and private funding for research and on technological opportunities for future research and innovation. Respondents included scientists at CIMMYT, ILRI, and CIAT; and key policy makers and scientists in public research systems of Brazil, China, Kenya, India, South Africa and the

1 For reasons of confidentiality, we do not cite our key informants by name.

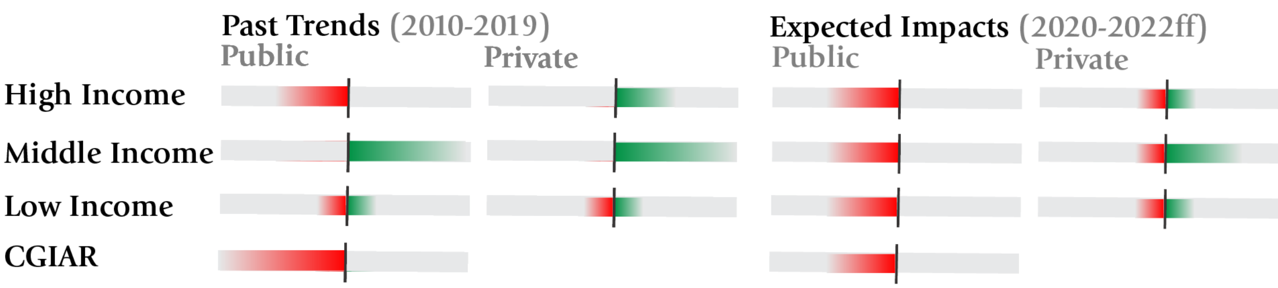
United States. Figure 1 illustrates the R&D expenditure trends and projected impacts, with Figure 2 breaking down the changes by productivity and funding.

Phase 1. Short-term impacts: Limited Immediate Decline in Productivity of Agricultural Research in NARSs and CGIAR. At both the national agricultural research systems (NARSs) and CGIAR institutes the pandemic has reduced the productivity of agricultural research. Respondents noted that the immediate impact in Brazil, China and India seems to have been negative but limited, as the initial shutdown of research was brief. In the initial lock down at Indian Council of Agricultural Research (ICAR) institutes and agricultural universities, scientists lost a month of research during which they were not allowed into their offices and labs. At EMBRAPA in Brazil, the impacts were more severe for researchers who depended on travel and field activities. [2] The governments of China, India, Kenya, Rwanda, Uganda and elsewhere designated agricultural scientists as essential workers with less restriction on coming to offices and travel than the general public were allowed. Despite this flexibility Kenyan and Ugandan scientists report difficulty in travelling to experiment stations and labs (Makoni 2020).

Research leaders from EMBRAPA and CGIAR reported that there were some positive impacts of the lock downs on research output because more publications were completed and research proposals submitted. In addition, research institutes in Brazil increased their visibility through webinars that had up to 5,000 online participants.

CGIAR institutions also reported some declines in some research activity and output. The CIMMYT maize program reported only minor delays in its programs and collaborative work with NARSs because African countries and India declared agricultural scientists to be essential workers.[3] ILRI reports that it is terminating some research programs that were on research stations outside headquarters and is reducing the numbers of scientists and technicians working on some projects. CIAT Nairobi reports that workshops, meetings, field days, and training were slowed down but research on station was maintained and carried out with fewer technicians,[4] operating at about 80% of their usual levels. Agricultural biotech labs of ILRI and CIAT in Kenya and Ethiopia have largely been transformed to test for COVID-19.

Figure 1. R&D expenditure trends and impacts



Note: Shading to the right of the marker (green) denotes positive change, shading to the left of the marker (red) denotes negative change. The length of the bars reflects our estimated magnitude of the change.
Source: Authors interpretation of ranges based on review of literature, interviews and surveys.

Phase 2. Intermediate Impacts: Global declines in government research funding. Most respondents felt that governments in LMIC will reduce agricultural research as the COVID-19-induced recession shifts major expenditures to relief and social safety nets, and the recession reduces government revenues. South Africa's agricultural research budget has already been cut by 20 percent as are all government departments due to the pandemic (Durham 2020; Nordling 2020). Indonesia has announced reductions in agricultural research budgets. EMBRAPA has had its research budget reduced and the government of Sao Paulo is threatening serious cuts in the funding of two of its leading research universities in Brazil (Amigo 2020). Even in China where the government has a major commitment to reduce food imports through technology, respondents predict that agricultural research expenditure will be reduced for at least one year before it starts to grow again.[5] India's budget is likely to decline like China's.[6]

Declining budgets and the threats for further cuts to come have led some scientists to quit. In some severely affected countries, government scientists have not been paid their salaries for weeks or months. The combina-

2 Email exchange with current senior official at EMBRAPA, September 2020.
3 Email exchange with current senior researcher at CIMMYT, May 2020.
4 Email exchange with current senior official at CIAT, June 2020.
5 Email exchange with current academics at Peking University and at Beijing Institute of Technology, August 2020.
6 Email exchange with former head of ICABR, September 2020.

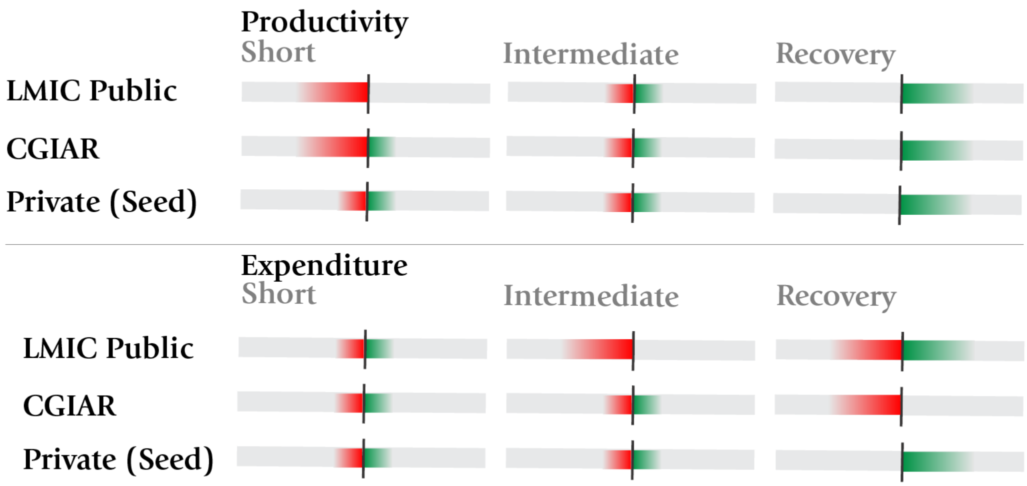
tion of low or no pay, concerns about infections and resultant restrictions on research have led (older) scientists to retire as in South Africa and Kenya. In Brazil, EMBRAPA is providing incentives for older employees to retire early, and many have accepted, easing the difficulties of adapting to the budget cuts.[7]

Phase 3. Recovery: COVID-19 research increases technological opportunities and demand for agricultural research. COVID-19 research will have limited immediate impact on agricultural research innovation according to most scientists interviewed. The field most likely to be affected directly is livestock health, with indirect benefits to digital extension services. New types of vaccines and therapeutics based on DNA, new strategies for speeding the development and improved tests for disease will be available for research and technology development in livestock. The actual COVID-19 innovations being developed for humans could not in themselves be used to improve livestock health, since most livestock are not susceptible to COVID-19. At least one crop scientist felt, however, that there would be some positive impacts for crops and livestock research, for example improving diagnostics for major plant viral diseases, such as in CIMMYT research on Maize Lethal Necrosis in Africa.[8]

There may be some indirect spillovers from medical research. The pandemic is forcing closer relationships between agricultural and medical research, including agricultural research institutes and universities. CGIAR and NARS labs in Africa, Latin America and Asia are being used to support testing for COVID-19. Biological scientists in Uruguay and elsewhere are joining COVID-19 task forces to jointly work on controlling the pandemic with scientists working on basic biological research and on medicine.[9] Indian and Canadian scientists who work on vaccines for livestock are now working on vaccines for the coronavirus.[10]

Demand by national leaders for more local production of food and the government research that can help increase production is increasing in places that are dependent on food imports. For example, China, facing minor disruptions in the food supply chain due to the pandemic and the continued trade war with the U.S., is pushing for more local crop production and likely to increase government agricultural R&D as soon as next year in order to be more self-sufficient in maize and soybeans (Xinhua 2020).

Figure 2. Change of R&D productivity and funding relative to pre-COVID-19



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Source: Authors interpretation of ranges based on review of literature, interviews and surveys.

Private Sector Research with a Focus on the Seed Industry. The impact of the pandemic on private research and innovation appears to be similar to the impact on government research according to interviews with officials from key firms, company annual reports and two published surveys of agribusiness firms operating in Asia. The firms suffered limited reductions in the productivity of their research and innovation on major field crops due mostly to travel bans which prevented, for example, the movement of seeds for field trials which postponed a season of experiments. A major Indian-based seed company reported that its research and marketing was temporarily disrupted by the pandemic but soon recovered. It did not expect to reduce its R&D in the immediate future.[11] Research by Chinese

7 Email exchange with current senior official at EMBRAPA, September 2020.
8 Email exchange with current senior researcher at CIMMYT, May 2020.
9 Email exchange with former senior official at CIAT, September 2020.
10 Email exchange with former official of Indian Council of Agricultural Research, September 2020 and discussion with a Canadian professor at ICABR 2020 online conference, October 2020.
11 Authors interview with current official at Rasi Seed, August 2020.

companies selling seeds of major field crops was also little affected by the pandemic. Demand for firms' innovations was strong. Their seed sales were good because the pandemic came early in the year, affecting only the early-season rice planting in southern China. Even for that crop, the seeds had already been sold although the distribution of seeds to farmers was slowed.

In Africa the negative impact of COVID-19 on research by the seed industry appears to be limited because there were few disruptions in research, production or demand for seed. Seedco International, the biggest African seed company, had a major increase in profits for the year ending March 2020 just before the pandemic hit (AfricaInc 2020). Officials from Bayer Crop Sciences in Africa reported limited disruption of its research program and expected no immediate reduction in research expenditure while they wait and see how African governments and the economy respond to the pandemic.[12]

One recent study by the Asia Pacific Seed Association (APSA) presents a more negative situation in Asia. A survey in May 2020 of 59 companies in the Asia-Pacific region found that 60% of companies reported no or small effects on R&D, while 5 percent reported strong negative effects. Of the 15 companies outside the region about 80% had no or small effects. At an APSA meeting about the report, "several presenters described reduced staffing in R&D facilities, difficulties reaching field trials or even finding hotel accommodation near their field trials. This has slowed innovation and is likely to delay the introduction of new varieties to the market in the near future." (Schreinemachers et al. 2020) Although demand for seed fell sharply particularly for vegetable seed early in the pandemic, by May 2020 these seed companies already noticed demand coming back.

A recent study of 800 European firms operating in Asia and Africa provides some support for this idea that the impact on agribusiness R&D and innovation may be short term. Eighty percent of the firms are planning to expand their operations in Asia with 30% planning to expand their R&D (UNIDO and ITPO 2020).

4. Policy options for strengthening the research and innovation system in developing countries

LMIC governments and donors have adopted policies responding to health and financial challenges of the COVID-19 pandemic but only sort term support for food supply chains. By May 2020, Resnick (2020) finds that in the COVID-19 responses of African and Asian governments agricultural support is limited and biased towards the short term: "Lower visibility but higher return investments, such as agricultural research and development or extension, will likely continue to be sidelined in a time of scarce resources" (Resnick 2020, p. 112). Research institutes and extension services are experimenting with various way to meet the financial challenges and technological opportunities that are emerging. Their responses may provide guidance for other research systems on how to keep their research systems productive

Policies to Strengthen Public Research. Immediate policy interventions are needed to help research systems keep running during the first phase of the pandemic. Most governments have identified agricultural scientists and technicians as essential workers, which allows them more flexibility of movement to offices, labs and fields than is permitted for the general public. With this flexibility from the government, research institutions need to develop short-term plans to keep their most productive research activities functioning and develop research procedures to keep scientists, technicians and supporting staff safe. For example, ILRI closed down swine research programs, labs and research plots far from their headquarters to focus on more essential research programs with reduced health risks to their staff.

National research programs in Africa were able to keep staff safe and meet government regulations by having scientists work at home and upgrading their IT infrastructure. Research programs, such as the Pan-Africa Bean Research Alliance (PABRA) organized by CIAT, have substantially increased the networking capacity for their scientists, keeping them safe, while continuing productive research and capacity building.[13]

Agricultural research resources have been shifted in the crisis in ways that may have reduced agricultural research output in the short run but could strengthened agricultural research after the immediate crisis. The most notable examples are the biotechnology labs with polymerase chain reaction (PCR) machines and other related research capacity becoming important components of national COVID-19 testing programs. In Kenya and Ethiopia, CIAT and ILRI labs strengthen their capacities with additional donor support (e.g., from Germany). In India four national livestock research labs under ICAR are engaged in testing as well as developing therapeutics and vaccines for COVID-19.[14] Similar agricultural labs throughout Latin America are also making this shift.

12 Authors interview with current official at Bayer Crops Sciences, September 2020.
13 Email exchange with current researcher at CIAT, June 2020.
14 Email exchange with former senior official at ICAR, September 2020.

Research systems are also using the budget crisis as an opportunity to reduce the number of relatively unproductive scientific staff to save money and increase research efficiency. Early retirement programs, as with EMBRAPA, allowed organizations to preserve most of its important research programs through the initial rounds of budget cuts.[15]

As the immediate threat to research output eases, research systems have also changed research priorities to meet the new goals of their key stakeholders — farmers, processors, NGOs and urban consumers — who can lobby for government spending. For example, in the Republic of South Africa, scientists in the government's Bio-Innovate program are now conducting applied research to help develop more jobs in the bioeconomy and veterinary scientists are combining with medical researchers to develop a One Health program working jointly on vaccines for humans and livestock (Durham 2020).

In addition, institutes may find new funding opportunities if they shift their research priorities towards innovation that increases the resilience of food systems. This includes research to reduce losses to pests and disease, provide techniques to resist abiotic stress and remove loses in food supply chains. This pandemic, which coincides with locust plagues in East Africa and South Asia, has created demand from farmers and from their governments for greater locust and disease resilience in the food supply systems in Africa and some poorer countries of Asia. Donors are also increasing their emphasis on resilience. A recent report supported by IFAD emphasizes the role of public research institutes to "build back ways that will enable greater resilience and equity in the way rural economies and food systems operate" (Woodhill 2020, p. 20).

Policies to preserve and strengthen private research. Public and private research groups and some government officials are working on regulatory changes to reduce barriers to approval of new technology. In India the government has streamlined the approval process for new agricultural technology by digitizing the application and payments to get regulatory approval for new plant varieties and other technologies. India is also reducing or eliminating some of the in-person visits required for testing and approval of varieties (Babu and Dassani 2020). Change to streamline approval of new plant varieties was already underway in Kenya, but the pandemic has further accelerated reduction of visits. The Asia Pacific Seed Association (APSA) report also emphasizes the importance of recent changes that have streamlined seed regulations (Schreinemachers et al. 2020).

In Asia other policy changes have increased the incentives for agribusiness research. India has strengthened the corporate tax incentives for private agricultural R&D allowing companies to write off 300 percent of their R&D expenditures against their corporate income tax. In addition several important countries such as India and China are allowing "illegal" GM varieties of maize and soybeans to spread this year and are working to deregulate GM maize and soybeans in response to elevated concerns for more self-sufficiency in major food and feed crops.

In China the demand for improved seed sales was increased by renewed government price support for maize production. Both seed and biotech companies are increasing their research, seed production and marketing activities because the long-awaited approval of GM maize and GM soybean for cultivation in China looks probable next year (Deng 2020).

Multinational seed firms in Africa, told us in interviews that the pandemic has caused them to review their research and technology transfer programs in Africa. Two important factors are the strength of the country's public research systems and public-private research collaborations such as the TELA Maize Project in East Africa (Oikeh 2020).

5. Conclusion

This review was motivated by concerns that the COVID-19 pandemic will damage the ability of the agricultural innovation system to serve the needs of future generations and their food security. There are certainly many challenges being created by the pandemic, but early decisions seem generally to be in the right direction. In a time of pandemic, novel modifications to research protocols are being invented, and adaptive responses are being invoked to try to maintain rates of progress in knowledge generation, and thus eventually to likely high rates of return to research investment.

There is evidence that government research budgets are already declining as a result of the pandemic-induced recession in many LMICs. So, persistence in seeking funds will be needed. This is an opportunity to shift research priorities to take advantage of the opportunities to improve research productivity using advances in the biological sciences and information technology. Changing research priorities can help generate new sources of funds by conducting applied research in public-private partnerships eliciting support from private input firms, and by focusing on resilience and sustainability that are

15 Email exchange with current senior official at EMBRAPA, September 2020.

attractive to urban populations, governments and donors. It is to be hoped that governments, donors, and private firms will continue to allocate sufficient resources to the vital task at hand.

Acknowledgments

This working paper is made possible through generous support of the American people provided to the Feed the Future Sustainable Intensification Innovation Lab (SIIL) through the United State Agency for International Development (USAID) Cooperative Agreement AID-OAA-L-14-00006. The contents are the responsibility of the authors and do not necessarily reflect the views of the USAID or the United States government.

References

- AfricaInc. 2020. "Seed Co International Profit Rise by 62% Coupled with Strong Product Demand." 2020.
- Alston, Julian M., Steven Dehmer, and Philip G. Pardey. 2006. "International Initiatives in Agricultural R&D: The Changing Fortunes of the CGIAR." In Agricultural R&D in the Developing World: Too Little, Too Late?, edited by Philip G. Pardey, Julian M. Alston, and Roley R Piggott. Washington DC: IFPRI.
- Alston, Julian M, Philip G Pardey, and Xudong Rao. 2020. "The Payoff to Investing in CGIAR Research." Arlington, VA.
- Amigo, Ignacio. 2020. "In Brazil's Wealthiest State, Scientists Fear a Budget Plan Could Cripple Research." Science. 2020.
- Anderson, Jock R., Robert W. Herdt, and Grant M. Scobie. 1988. "Science and Food: The CGIAR and Its Partners." Washington DC.
- Babu, Suresh Chandra, and Vaishali Dassani. 2020. "COVID-19-Induced Policy Reforms in India: Overcoming Implementation Challenges." Inter Press Service News Agency. 2020.
- Beintema, Nienke, and Gert-Jan Stads. 2017. "A Comprehensive Overview of Investments and Human Resource Capacity in African Agricultural Research." ASTI Synthesis Report. Washington DC.
- Beintema, Nienke, Gert-jan Stads, Keith Fuglie, and Paul Heisey. 2012. "ASTI Global Assessment of Agricultural R&D Spending: Developing Countries Accelerate Investment." Washington DC.
- Chai, Yuan, Philip G. Pardey, Connie Chan-Kang, Jikun Huang, Kyuseon Lee, and Wanlu Dong. 2019. "Passing the Food and Agricultural R&D Buck? The United States and China." Food Policy 86.
- Dehmer, Steven P., Philip G. Pardey, Jason M. Beddow, and Yuan Chai. 2019. "Reshuffling the Global R&D Deck, 1980-2050." PLoS ONE 14 (3): 1–12.
- Deng, William. 2020. "On the State of GM Maize Seeds in China." Presentation from July 24th 2020.
- Durham, Ben. 2020. "Michigan State University Webinar on The Impact of COVID-19 on Global Agriculture Research Systems."
- Fuglie, Keith. 2016. "The Growing Role of the Private Sector in Agricultural Research and Development World-Wide." Global Food Security 10.
- Fuglie, Keith O, Paul W Heisey, John L King, Kelly Day-Rubenstein, David Schimmelpfennig, and Sun Ling Wang. 2011. "Research Investments and Market Structure in the Food Processing, Agricultural Input, and Biofuel Industries Worldwide." Washington DC.
- Heisey, Paul W, and Keith O Fuglie. 2018. "Agricultural Research Investment and Policy Reform in High-Income Countries." Washington DC.
- Makoni, Munyaradzi. 2020. "In COVID-19–Hit Africa, Agricultural Research Feels the Pinch." The Scientist, August 2020.
- Nagarajan, Latha, Anwar Naseem, and Carl E. Pray. 2018. "Transformation of the Agricultural Input Industry and Private R&D in India." In 22nd ICABR Conference. Washington DC: ICABR.
- Nordling, Linda. 2020. "Science Faces 'Survival' Crisis in Wake of Covid-19 Funding Cuts." Research Professionals News. 2020.
- Oikeh, S. 2020. TELA Maize Project, AATF. Nairobi. Available at: https://www.aatf-africa.org/aatf_projects/tela-maize/.
- Pray, Carl E., and Keith O. Fuglie. 2015. "Agricultural Research by the Private Sector." Annual Review of Resource Economics.
- Pray, Carl, Latha Nagarajan, Anwar Naseem, and Jock R. Anderson. 2020. "Policies to Encourage Private Agribusiness to Contribute to Innovation and Agricultural Productivity in Developing Countries." Background Paper Prepared for Keith Fuglie, Madhur Gautam, Aparajita Goyal and William F. Maloney (2020). Harvesting Prosperity : Technology and Productivity Growth in Agriculture. Washington DC.
- Resnick, Danielle. 2020. "IFPRI's COVID-19 Policy Response Portal: Identifying Trends and Implications for Food Systems." In COVID-19 and Global Food Security, edited by Johan Swinnen and John McDermott. Washington DC: IFPRI.
- Schreinemachers, Pepijn, Kanokwan Chodchoey, Steven Layne, and Weeranuch Mhadlhoo. 2020. "Asia-Pacific Seed Trade Slowly Emerges from COVID-19 Lockdowns." 2020.
- UNIDO Investment and Technology Promotion Office (ITPO) Germany. 2020. "The Impact of COVID-19 on Agricultural and Food-Processing Industries , with Special Focus on Asian and African Markets."
- Woodhill, Jim. 2020. "Responding to the Impact of COVID-19 on Rural People and Food Systems." Working Paper. Foresight4Food.
- World Bank. 1981. "Agricultural Research: Sector Policy Paper." Washington, DC.
- World Bank. 2012. "Agricultural Innovation Systems: An Investment Sourcebook." Agriculture and Rural Development. Washington DC.
- Xinhua. 2020. "India's Agriculture Booms during COVID-19." Xinhuanet, August 4, 2020.