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Measuring Agriculture Research and Development Return on Investment: Relevance for Florida[1]

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Abstract

This publication describes why science and research are critical inputs for the future success of agriculture. It provides an overview of challenges to evaluating outcomes of research investments and some common approaches to measuring returns. The authors summarize emerging federal science and research priorities significant for Florida agriculture. This EDIS publication is intended as a helpful reference for Florida producers, taxpayers, and state government agencies. It is part of a series that examines federal policies relevant to specialty crops.

Introduction

Research and development (R&D) is a driver for enhancing agricultural productivity and improving public health, food safety, and environmental quality. The motivations for increasing investments in agricultural research include improving global food security and maintaining the competitiveness of US agriculture. Uncertainties and challenges from frequent adverse weather events, international trade, and shifting government policies heighten the importance of R&D for Florida agriculture.

The Shifting Landscape of Agriculture Research

Public sector R&D investments have long been a foundation for US agricultural competitiveness. The Morrill Acts of 1862 and 1890 established land grant colleges and universities, while the Hatch Act established state agricultural experiment stations. The Florida Agricultural Experiment Station oversees the research mission of the University of Florida Institute of Food and Agricultural Science (UF/IFAS). The United States Department of Agriculture (USDA) Cooperative Extension Service was created by Congress in the Smith-Lever Act of 1914, at a time when 30 percent to 40 percent of Americans worked in farming and half of the US population lived in rural communities (Kile 1948). Extension agents were embedded within land grant university systems and in local rural communities, translating research results for farmers and rural residents (Garst and McCawley 2015). UF/IFAS, together with Florida A&M University, administers the Florida Cooperative Extension Service with agents located in all 67 counties of the state.

In 2019, approximately two-thirds of public agricultural R&D in the United States was supported by the federal government with state and non-government sources providing the other third (Nelson and Fuglie 2022). However,

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support for public research from all sources has been declining with an increase in the share of agricultural R&D being conducted by the private sector (Pardey et al. 2016; Heisey and Fuglie 2018). As shown in Figure 1, US public agricultural R&D spending has generally decreased since the early 2000s, and in 2020 it approached the same level of spending seen in 1970. Between 2003 and 2014, investment in private agricultural and food R&D almost doubled in inflation-adjusted terms, while public R&D fell by around 30%, as seen in Figure 2 (Nelson and Fuglie 2022). Private R&D spending on agricultural inputs had already exceeded the total public agricultural R&D by 2010 (Fuglie, Njuki, and Wang 2022).

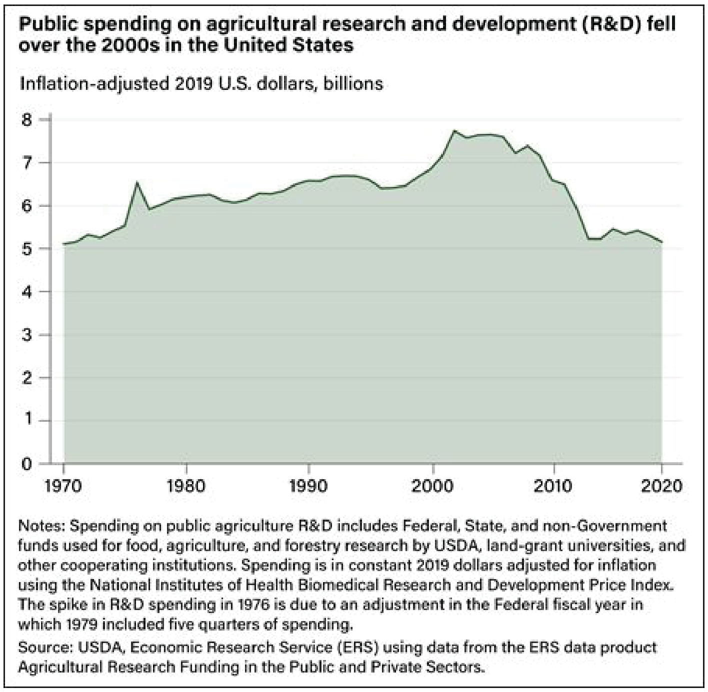

Figure 1. Trends in public spending on agricultural R&D between 1970 and 2020.
Credits: U. S. Department of Agriculture (reprinted in Nelson and Fuglie 2022)

While public and private research in agriculture can be complementary, privately supported research is often not widely accessible. Only the largest or best-financed firms have resources to support their own private R&D, limiting access by smaller firms. A rise in public R&D investment can lead to increases in private R&D by creating technological opportunities for the private sector to commercialize. Thus, increases in agricultural R&D by the private sector are likely to be an imperfect substitute for public R&D (Heisey and Fuglie 2018). Intellectual property from publicly sponsored research is generally more open with fewer constraints for protection of trade secrets and patent rights (King, Toole, and Fuglie 2012).

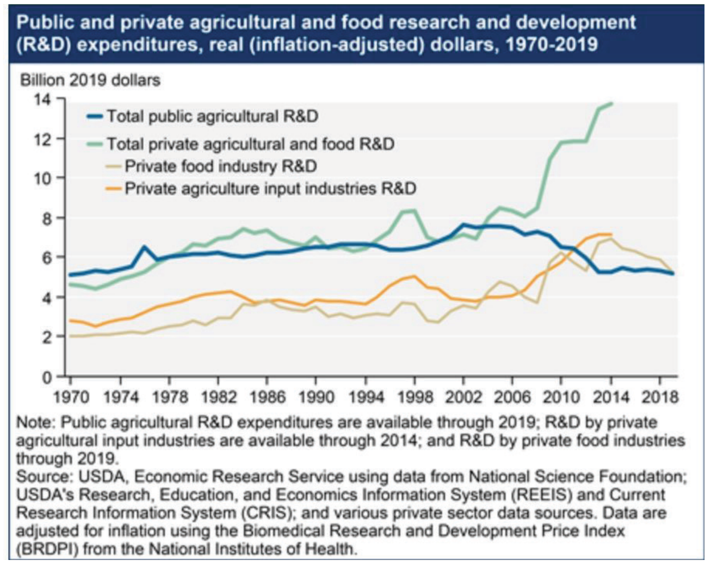

Figure 2. Trends in private and public spending on agricultural R&D between 1970 and 2018.
Credits: U. S. Department of Agriculture (reprinted in Nelson and Fuglie 2022)

Challenges for Measuring R&D Returns

The openness and broad availability of innovations generated from publicly supported R&D create challenges for measuring returns on these public investments and often make it difficult to convey the value. A common measure of investment value is Rate of Return on Investment (ROI), which describes the monetary benefit generated from an investment relative to the initial investment itself. Two types of ROI are (1) private and (2) social. Private ROI is calculated based on the income received by an individual or private firm resulting from their own investments, such as money invested in the stock market, or a new product or service launched. ROI must be carefully interpreted as a measure of impact from public R&D spending. Social ROI is calculated by adding public economic benefits to other groups in society (for example, to consumers) and private returns on investment (King, Toole, and Fuglie 2012). Social ROI is particularly relevant when a complex system is impacted by an investment and spill-over or additional benefits are widespread. Private ROI (market returns) are more easily measured and are much lower than their social returns (Pray and Fuglie 2015).

For publicly funded investments in agricultural R&D, social ROI includes returns to the investors as well as returns to farmers, who benefit from an increase in production efficiency, and to consumers, who benefit from more abundant and less expensive food, fiber, or other agricultural products (Fuglie and Heisey 2007). Social returns can also include benefits to the environment, rural communities, and students that receive education or training. A systems approach allows R&D to address how the component parts of agricultural supply chains impact each other and address how changes in one part impact the whole (Ahlborg et al. 2019; Ambulkar et al. 2022). The need for an integrated systems approach to investment in agriculture innovation and decision-making was emphasized in a Dec. 6, 2022 Senate Agriculture Committee hearing on Farm Bill research needs (https://www.agriculture.senate.gov/hearings/farm-bill-2023-research-programs) and at a Farm Bill listening session in Newberry, Florida, on April 24, 2023 (https://www.youtube.com/watch?v=rqJ345ltFo4).

Including social returns creates challenges for measuring returns to public R&D investments, and, thus, social returns are often overlooked or underestimated. Research, education, and Extension have broad reach with benefits that are realized directly by some recipients but continue to accrue over time through the advancement of science and knowledge. Maximizing the benefits from R&D requires looking ahead (Rhemann 2017; Martins et al. 2019; Kristoffersen et al., 2020) as science and research solutions require time to develop and deliver. The research lag is the time period from when research starts to when benefits are realized. Benefits also decay over time as new challenges and new solutions emerge. The depreciation of knowledge associated with a project is research-specific (Nin-Pratt and Magalhaes 2018), which is especially true if R&D changes have system-wide implications. The stream of benefits and expenditures from a particular project are often widespread in terms of time, geography, and the agricultural system, making them very difficult to track and measure. Spillover effects occur over years or decades, or across geographical boundaries when "research done in one state, region, or country contributes to new knowledge or technology that is used in another geographic area" (Fuglie and Heisey 2007), or when changes in one sector impact other sectors of the economy.

Estimating the Rate of Return on Investment

The three most common methods used to calculate the ROI for agricultural R&D include the benefit-cost ratio, the internal rate of return, and the modified internal rate of return. Originally developed for the financial sector to measure market (not social) returns, each method has pros and cons for use with R&D (Table 1). The three methods can be used for an assessment of outcomes from past investments (retrospective) or they can be used in combination with forecasts of expected future costs and returns to evaluate potential for future investments (prospective).

Since ROI calculations are based on values spread over different time periods, a discount rate is necessary. The discount rate is the annual interest rate that is used to estimate the present value of future cash flows. Future values are reduced, or discounted, and a higher discount rate indicates less significant future values (Li and Pizer 2021).

Benefit Cost Ratio

The benefit cost ratio (BCR) is calculated by dividing the present value of benefits associated with the investment by the present value of the associated costs while assuming a discount rate for future values.

$$BCR = \frac{\Sigma \text{Present Value of Future Benefits}}{\Sigma \text{Present Value of Future Costs}}$$

Equation 1.

The BCR has the advantage of being simple to interpret because it indicates the investment return in monetary terms. If the calculated ratio is greater than one, the benefits of the project outweigh the costs, meaning the investment is generally worthwhile, but if the ratio is less than one, the project is too costly or did not reap enough benefits. The majority of retrospective assessments regarding agricultural R&D have been greater than one, meaning that most agricultural investments have increased technological efficiency and productivity, providing benefits that are greater than the costs (Briones et al. 2005; Alston et al. 2011; Alston, Pardy, and Rao 2020; Rao, Hurley, and Pardey 2020).

Internal Rate of Return

The internal rate of return (IRR) is an alternate method that calculates the discount rate that makes the difference between the discounted value of future cash inflows and future cash outflows, or the net present value (NPV), equal to zero.

$$NPV = \sum_{n=0}^{N} \frac{CF}{(1+IRR)^n} = 0$$

Equation 2.

where CF = cash flows in time period n

In this method, the calculated discount rate is the measure of ROI, interpreted as the expected annual growth rate of investment returns above costs. A higher internal rate of return means the investment is advantageous and generates more net benefits. Despite IRR being used more frequently to evaluate rate of return in studies assessing returns to agricultural R&D (Alston, Pardey, and Rao 2020), the method still has challenges. Calculating internal rate of return is better suited for situations where those that pay the costs reap the benefits, but in the case of public agricultural research, the government invests money and the benefits accrue primarily to farmers and consumers (Alston et al. 2011).

Modified Internal Rate of Return

The modified internal rate of return (MIRR) uses a different approach to calculate the discount rate so that the investment equals the future value of cash flows and the net present value equals zero over "n" time periods (Kierulff 2008).

$$\text{MIRR} = \sqrt[n]{\frac{\textit{Future value of cash flows}}{\textit{Present value of cash flows}}} - 1$$

Equation 3.

The MIRR allows for the reinvestment rate of positive cash flows to be adjusted. For example, if an investment results in a positive cash flow, then a negative one, and then another positive one, the modified internal rate of return allows the negative cash flows to be cancelled out by the positive ones. The higher the modified internal rate of return, the more desirable the investment. The resulting measure of rate of return can be treated as an annualized percentage with an interpretation similar to that of a financial product return, such as a mutual fund or a mortgage. In retrospective assessments, modified internal rates of return are lower than the internal rate of return where these adjustments are not accounted for (Alston et al. 2011; Rao, Hurley, and Pardey 2019).

Looking Forward

The rate of technology development and adoption must accelerate to keep up with changing needs. Public sector R&D investments have long been a foundation for US agricultural competitiveness. At the same time, production and supply chain challenges during the recent COVID-19 pandemic highlighted the importance of social factors and public investment for US industries and consumers (Hobbs 2020; USDA 2022; Peterson et al. 2023) but public resources are limited.

Major public R&D funding organizations typically develop a set of priorities to signal areas that fill critical gaps, address social ROI, and complement efforts in the private sector. Thus, prioritizing agricultural R&D with the highest economic potential and broadest reach is critical. Given the inherent lag between research and commercial applications, prioritization often takes a futurist approach. Public R&D often fills a critical need in risky and basic research in particular, where positive outcomes may not be realized for many years or decades. The private sector typically doesn't address these topics of risky or basic research due to length of time before profits accrue. Market ROI may be low in the near-term, but significant opportunities exist for social ROI.

USDA Science and Research Strategy

A recent example of national priority setting for public agriculture research is the *USDA Science and Research Strategy, 2023–2026: Cultivating Scientific Innovation* released by USDA in May 2023. This document resulted from a cross-Department effort to identify "opportunities to shape the future of US agriculture and forestry to ensure they are prosperous and profitable for the many and the most, instead of just the few" (USDA 2023 p5). These priorities provide insight for how emerging R&D might shape future opportunities for Florida agriculture. Initiatives in documents such as the UF/IFAS Pathway to Creating Engagement Through Innovation and Excellence shape a vision for how broad national priorities can be adapted to critical state issues (UF/IFAS n.d.). The USDA's *Science and Research Strategy* includes the five key science priority areas and their supporting objectives quoted below to address societal challenges and to capture opportunities to make significant advances in food, agriculture, and natural resource sectors.

1. Accelerating Innovative Technologies and Practices

- Establish a transformative innovation culture.
- Rapid assessment and communication of production risks, consumer demand, health needs, and market trends.
- Automate or eliminate repetitive tasks and transition workers to high-quality jobs of the future.
- Develop novel selectable plant and animal traits and customized management practices.
- Create technologies suitable for use across diverse scales, systems, types, and locations of farms.

2. Driving Climate-Smart Solutions

- Bolster quantification and measurement systems.
- Improve the technical greenhouse gas mitigation potential of agriculture and forestry sectors.

- Position the agricultural sector to be resilient in the face of climate change.
- Develop and expand availability and application of science-based, climate-informed decision-making tools and practices.
- Support sustainable markets for agriculture and forest bioproducts.

3. Bolstering Nutrition Security and Health

- Improve understanding of factors influencing food and nutrition security for all populations.
- Develop an understandable picture of linkages between nutrition security and health.
- Increase data and analytics for predicting, developing, and disseminating appropriate intervention or management strategies.
- Develop and deploy innovations to reduce pathogen occurrence in food systems through increased support for risk-based analysis.
- Support decisions related to dietary guidance, food safety, agriculture, economics, and federal nutrition assistance with new evidence-based food systems.

4. Cultivating Resilient Ecosystems

- Determine the DNA sequences of plant and animal genomes to improve sustainability.
- Promote and advance microbiome research for soil, plant, and animal health.
- Restore and improve resiliency of agroecosystems and aquatic ecosystems.
- Develop capabilities that identify, combat, respond to, and eradicate plant and animal infectious diseases.
- Identify and enable the adoption of practices to improve biodiversity, air quality, water quality and retention, carbon sequestration, and pollinator populations.

5. Translating Research into Action

- Improve communication and awareness of scientific progress and related policy issues.
- Support the equitable development of a workforce with the knowledge, skills, and abilities to drive agricultural research forward.
- Ensure the collection, delivery, storage, interoperability, and protection of high-quality data and results.
- Enable risk-based and scientifically sound decision making and policymaking.

Summary

Agricultural R&D is a critical driver of productivity gains and competitiveness for Florida agriculture. With the decline in overall support for R&D and the shift towards private investment, access to science and technology advancements can be more limited. Research lags and spillover benefits make estimating returns to public investments difficult and commonly used ROI measures tend to focus on market or private returns. Often overlooked and underestimated, social ROI is particularly relevant when a complex system such as agriculture research is impacted by public investments and spill-over or additional benefits are widespread. While public and private research in agriculture can be complementary, privately supported research is often not widely accessible. Thus, prioritization for publicly funded research is even more critical. National science priorities provide insight for how emerging R&D might shape opportunities for Florida agriculture as we move forward.

Table 1. Comparing methods for measuring rates of return.

	Pros	Cons
Benefit Cost Ratio Ratio of the present value of benefits over the present value of costs while using a discount rate for future values	• Indicator of value for money	• Sensitive to the discount rate • Cannot be interpreted as a percentage
Internal Rate of Return The discount rate that makes the net present value of all cash flows equal to zero	• Lack of assumption regarding the discount rate • Commonly used	• Assumes that beneficiaries can reinvest their benefits at the same high rate of return • The investment cost is discounted over time at the same high rate of return • Relies on predictions for future cash flows
Modified Internal Rate of Return The discount rate that makes the investment equal the future value of cash flows	• Can be interpreted as an annualized percentage rate of return	• The estimated reinvestment rate can be subjective

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