

# Insights on the Impacts of Public Agricultural Research and Extension on Agricultural Productivity: Evidence from the United States\*

Nuevas perspectivas sobre el impacto de la investigación agrícola pública y la extensión en la productividad agrícola: evidencia de los Estados Unidos

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## Abstract

*There is broad agreement on the importance of investments in productivity-enhancing agricultural research and extension. Although estimated returns for the US are generally large, recent calculations differ greatly. The objective of this paper is to provide an economic assessment of the recent estimates and a guide to future public investments in this field.*

## Keywords

*agricultural research; agricultural extension; agricultural productivity; returns on investment*

**JEL code:** Q16

## Resumen

*Existe un amplio acuerdo respecto a la importancia de las inversiones en investigación y extensión agrícola para aumentar la productividad. Aunque las ganancias estimadas para los Estados Unidos son generalmente grandes, los cálculos recientes difieren en gran medida. El objetivo de este artículo es proveer una evaluación económica de las estimaciones recientes y una guía para futuras inversiones públicas en ese área.*

## Palabras clave

*investigación agrícola; extensión agrícola; productividad agrícola; rendimiento de la inversión*

**Código JEL:** Q16

## Introduction

In order to feed the growing population of the world, expected to reach 9.6 billion people by 2050—a 29 % increase over 2013—without causing immense environmental damage and human hunger, society must raise agricultural productivity. Two ways, among other things, of achieving this are to invest in public agricultural research and in public extension delivery. The importance of the need for increased investment is widely recognized. In addition, the importance of investing in agricultural research worldwide is cited as a target of Goal 2 in the recently released United Nations Sustainability Development Goals (United Nations, 2015).

Developed countries like the United States have been leaders in science-based agricultural productivity increases for most of the twentieth century. However, after expanding rapidly from 1960-1982, growth in public, productivity-oriented, agricultural research investment in the United States slowed considerably from 1980-1995, and then declined over 1995-1998 by 20 %, before turning around and showing some growth to 2006, to finally decline again during the Great Recession. In contrast, rapidly developing countries, such as Brazil and China, are investing heavily in agricultural research, putting future international competitiveness of US agricultural exports at risk (Fuglie and Wang, 2012). Furthermore, consumers worldwide will be worse off if future investments in public and private agricultural research and extension are not large enough to deliver declining real world food prices in the twenty-first century; but other factors are also important.

Given the established significance of financing agricultural research and extension, those currently engaged in the public agricultural science and agricultural extension policy debates need up-to-date estimates of the expected returns on investment of public funds in both of these activities. However, recent calculations of the rate of return to investments in public agricultural research and extension in the US by Huffman and Evenson (2006), Alston, Andersen, James and Pardey (2011), Andersen and Song (2013) and Jin and Huffman (2016) provide estimates that differ widely. The objective of this paper is to offer an economic assessment of the recent estimates and a guide to future public investments in agricultural research and extension. The paper has following sections on methods, results, and discussion.

## Methods

### Institutions Factors Affecting Choice of Methods

In the US, agricultural research and cooperative extension are separate public programs, each jointly funded primarily by the federal and state governments. Public agricultural research is undertaken mainly by state institutions—state agricultural experiment stations (SAESs) and veterinary medicine colleges/schools, and federal institutions—the U.S. Department of Agriculture-Agricultural Research Service (ARS) and Economic Research Service (ERS). In addition, public agricultural investigation receives a small amount of funding from the private sector and from non-governmental organizations, and public extension receives significant funding from county governments (Huffman and Evenson, 2006).

Although SAESs were established to conduct original research on agriculture, the breadth of the studies undertaken has increased over time to include research to improve the rural home and life, on agricultural marketing and resource conservation, on forestry and wildlife habitat, and on rural development. Hence, the scope of the research agenda of scientists of the SAESs has expanded over time, and by the 1970s, investigation undertaken by SAES scientists was much broader than what could reasonably be expected to impact agricultural productivity. In addition, the extent of research held by the USDA has expanded. For example, in 1940–1941, this institution established four Regional Utilization Laboratories or centers in California, Illinois, Louisiana, and Pennsylvania to undertake research to develop new uses and new and extended markets and outlets for farm commodities and products. Initially, they were independent agencies, but in 1953, the USDA placed these labs under the administration of the ARS (USDA, 2015). In 1972, new federal funding for research on rural development became available to the State Agricultural Experiment Stations. Hence, the breadth of US *agricultural* studies carried out by the public federal agricultural research system has expanded over the past century.

### Critical Measurement Issues

In developing measures of returns to investments in public agricultural research and extension delivery, economists have addressed a variety of issues about data and methods. Four critical issues are: whether to use gross or net measures of public agricultural research and extension; whether to aggregate agricultural research and extension investments together or keep them separate; how to best account for R&D spillover effects and lag lengths; and which metric is best for summarizing returns on investments. These decisions are critical because they affect the size of the estimated benefits and or costs associated with public agricultural research and extension.

### Agricultural Productivity Increasing Investments

Gross measures of public agricultural research and extension use reported aggregates. However, some of the various components of these aggregates make negligible contributions to agricultural productivity. Alston et al. (2011) and Andersen and Song (2013) have chosen to use gross measures of public agricultural research and extension to construct stocks of public agricultural research and extension to explain state agricultural productivity. In contrast, Huffman and Evenson (2006) and Jin and Huffman (2016) net out some types of expenditures that do not have an agricultural productivity focus. To do this, they rely on data collected in the USDA's Current Research Information System (CRIS). It includes expenditures on research by its intramural research agencies, SAESs, state forestry schools and a few other cooperating institutions.

These CRIS collected data contain a description of each new project by the principal investigator—the commodity or resource that is the target of the research, and its problem areas (RPAs). RPAs include goals of research to protect crops, livestock, and forests from insects, diseases, and other hazards, and to produce an adequate supply of farm and forest products at decreasing real production costs. With details available in CRIS, it is possible to quite accurately net out public agricultural research expenditures that clearly do not have a traditional agricultural productivity focus. How much

of a difference does it make? In 1970, 70 % of the US total expenditures on public agricultural research reported to CRIS were on agricultural productivity-oriented research, and 30 % were on all other types. Since then, the share having an agricultural productivity focus has been slowly declining (Huffman and Evenson, 2006).

The federal, state, and county governments fund public agricultural extension in the US, officially labeled Cooperative Extension. It is primarily adult education for immediate decision making of farmers, households, and communities and youth activities (Wang, 2014). Broadly, the goal has been to provide information for better farm, agribusiness and home decision-making.<sup>1</sup> In the 1960s, extension added programs in community development and natural resources. Although Alston et al. (2011) and Andersen and Song (2013) use a gross measure of public agricultural extension in their Total Factor Productivity (TFP) analyses, it seems most likely that only agriculture and natural resource extension contribute significantly to state agricultural productivity. This requires netting out resources allocated to other types of extension activities, such as home economics, community development, and 4-H. How much of a difference is there between the net and gross measures of cooperative extension? Over 1977-1992, only 55 % of the gross measure of extension was accounted for by agricultural and natural resource extension. In addition, in 1977, 30 % was allocated to 4-H, but this share declined to 23 % in 1992 and seemingly leveled off.

### Lags and Timing Weights

It is widely accepted that the impact of public agricultural research on state agricultural productivity has a gestation period where the effect is negligible, then blossoms to full marginal impact and then becomes obsolete. It is also widely accepted that the total length of this lag is long—35-50 years, e.g., Alston et al. (2011) and Huffman and Evenson (2006). Huffman and Evenson (2006) and Jin and Huffman (2016) build on earlier evidence by Huffman (2001) and adopt a short lag for the impacts of agricultural extension on agricultural productivity. One half of it occurs within the year in which the work is undertaken and then, over the next four years, the impact and weights decline to zero as obsolescence occurs. (Huffman and Evenson, 2006, p. 272). Hence, Huffman and Evenson (2006) and Jin and Huffman (2016) create separate agricultural research and extension variables to explain agricultural productivity.

In contrast, Alston et al. (2011) and Andersen and Song (2013) first aggregate public agricultural research and extension expenditures together in each year and then apply a short gestation period followed by a 48-year one, when benefit rises to a peak at about 20 years post investment and then gradually fades away. Although this long lag may be plausible for public agricultural research, the evidence on impacts of agricultural extension, which is mainly information related to current decision making of farmers' decisions, is for a much shorter lag.

<sup>1</sup> The youth activities are comprised of boys and girls clubs, called 4-H clubs, where members undertake practical projects in agriculture, home economics, and related subjects, and they seem unlikely to affect agricultural productivity.

## Spillovers and Spillovers

Public agricultural research undertaken in one state produces discoveries that affect the technology available to agribusinesses and farmers in other states, generating one type of public good (Cornes and Sandler 1996). Spillover areas for US agriculture might be based on grouping states by similarity of agroecological zones, output-mix similarities, or geographical proximity. When areas are physically close to one another, it reduces the physical distance that discoveries and information must travel before they are available to farmers and agribusiness in another area. This diminishes one dimension of the costs of information transfers. For example, findings made by public agricultural research in Iowa on corn production can easily travel to farmers and agribusinesses in adjacent states of Illinois and Minnesota, but are less useful in others much farther away and in different agroclimatic zones such as California, Mississippi, and North Carolina. This is the story behind the choice of spillover areas due to similar geoclimatic regions by Huffman and Evenson (2006) and Jin and Huffman (2016). In contrast, Alston et al. (2011) and Andersen and Song (2013) assume that spillovers are based on similarity of output-mix. The latter index is most commonly used for private R&D spillovers across manufacturing firms, which are quite different from farms aggregated into state units.

Given that extension is primarily information for immediate decision-making, Huffman and Evenson (2006) and Jin and Huffman (2016) do not permit spillover effects to other states. Alston et al. (2011) and Andersen and Song (2013) impose the same spillover structure on public agricultural extension as for public agricultural research.

## Evaluating the Payoff to Public Investments

Social cost-benefit analysis is appropriate for evaluating investments in public agricultural research and extension. In this kind of analysis where comparisons might be made across government funded programs and even internationally, the real (inflation-adjusted) social internal rates of return (IRR) is a better summary statistics than the net present values (NPV) or benefit-cost ratio (PVB/PVC) estimates (Harberger, 1972). The reason is that computing the net present value and the benefit-cost ratio, one must have an estimate of the social opportunity costs of funds—the interest or discount rate—in each year of the investment project. There is no reason to believe that these interest rates are the same in each year of the project (Harberger, 1972; Just, Hueth and Schmitz, 2004). In benefit-cost analysis, the size of the ratio is very sensitive to the choice of the discount rate used to compute present discounted value of the costs and the benefits.

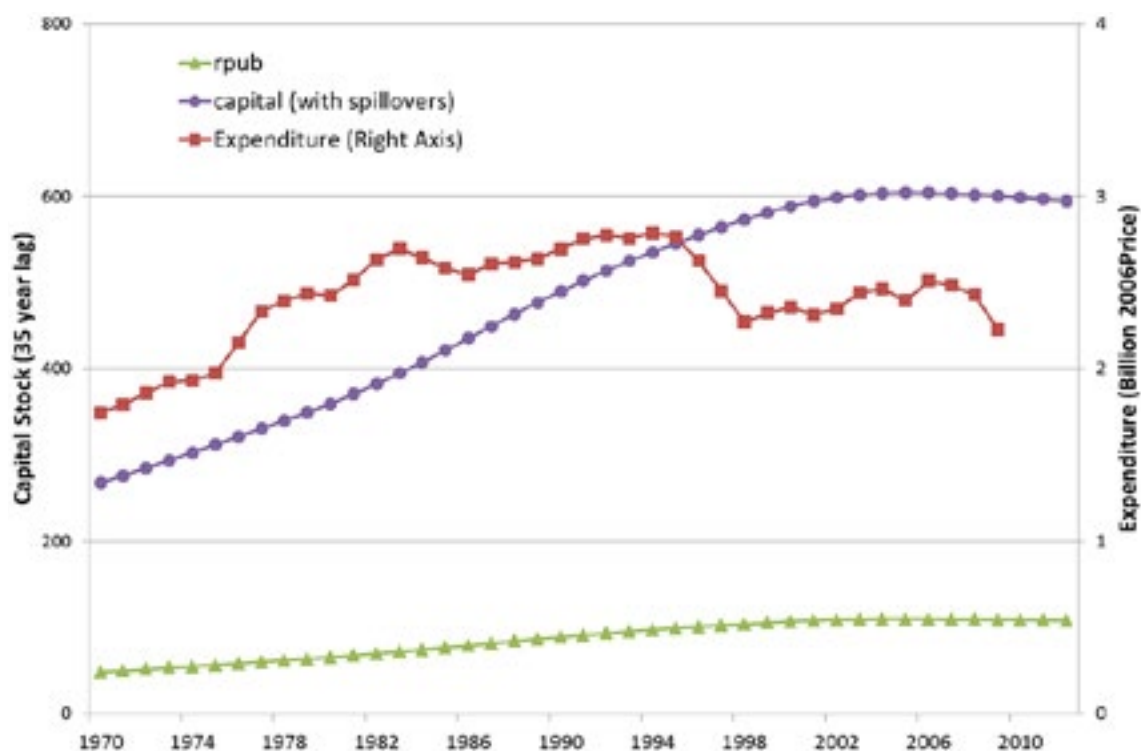
In developing countries where rates of inflation may be high and variable, it becomes difficult to derive defensible measures of nominal discount rates. In addition, Evenson (2001) discusses common problems in interpreting benefit-cost ratios for public agricultural research.

## Results

### Trends in Public Research and Extension Capital

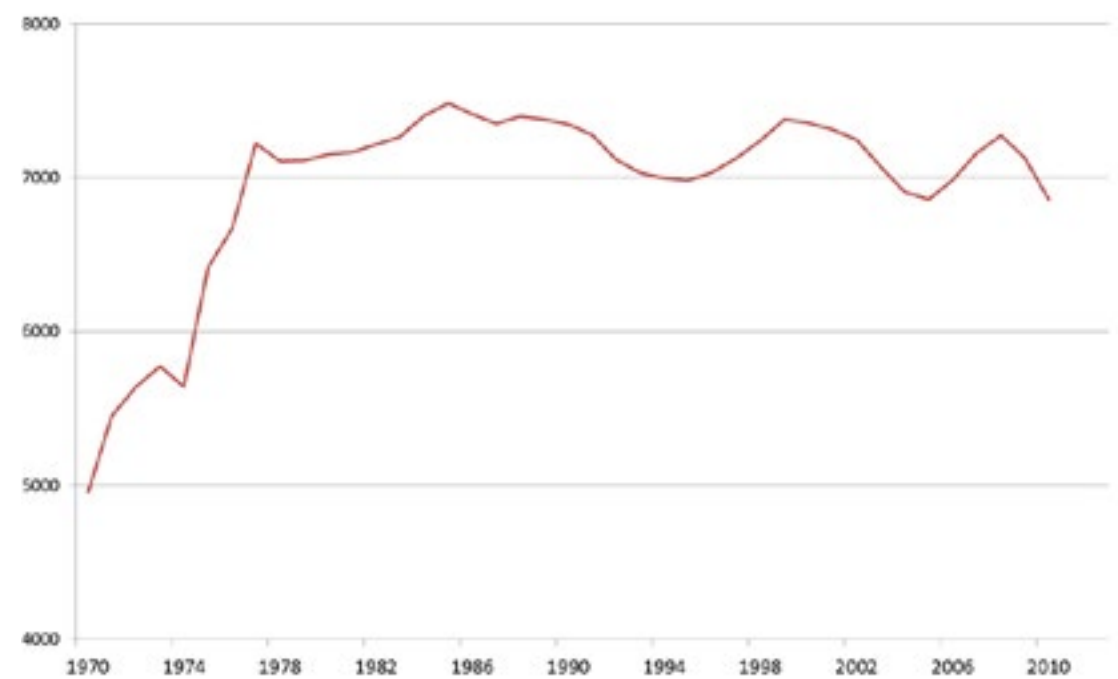
Applying the methods described in Jin and Huffman (2016) and Huffman and Even-son (2006) and summarized above, national aggregate data on productivity-oriented public agricultural research (constant dollar) expenditures and public agricultural research capital from 1970–2011 are displayed in figure 1. The red (solid rectangles) line shows that the total public, productivity-oriented agricultural research, expenditures across the 48 US states increased steadily from 1970 to 1982, took a brief dip over 1982–1986 and then increased up to 1994. The total rises over these 24 years is 44 % or 1.84 % per year. A sharp break in research expenditures occurred from 1994 to 1998, a decline of 20 %. Total public agricultural research expenditures in 2011 were approximately the same as in 1998 (and 1977). The national total of public agricultural research capital after aggregating the within-state component (but ignoring research spillover to other states [green triangles], increased slowly from \$47 billion dollars in 1970 to \$105 billion in 2006, an average rate of increase of 2.2 % per year. After 2006, the US total public agricultural research capital began to decline slowly, being dragged down by the major break in total public agricultural research expenditures a decade earlier. The smooth path for research capital over time relative to research expenditures is due to the long lags used to construct the research capital variable, described in the previous section.

**Figure 1. Total Public Agricultural, Productivity-Oriented Research Expenditures, Research Capital, without and with Spillovers, 48 US States, 1970–2011 (billion 2006 dollars)**



The purple line (figure 1, solid dots) shows US total public agricultural research capital across the 48 states, including each state's spillover components, is about six times larger than each state's own contribution. Hence, if public agricultural research expenditures (capital) in one state increases by 1 dollar, on average it increases US total public agricultural research expenditures (capital) by an additional 5 dollars. These spillover effects are quite important in determining the benefits from investing in public agricultural research at the state level. Given the long research lags for public agricultural research capital and the major break in expenditures in US public agricultural research that occurred in the mid-90s and continuing, US public agricultural research capital will continue to decline well into the twenty-first century.

**Figure 2. Total Public Agricultural Extension Capital, 48 US State, 1970-2011 (full-time equivalent staff-years per 1.000 farms)**



The US total public agricultural extension capital per farm grew very rapidly over 1970-1978, at 4.5 % per year (figure 2). However, over the next 33 years there is no net growth, although there have been short periods when research capital was increasing, for example, 1980-1986, 1996-2000, and 2005-2008. However, each of these short periods of growth was offset by an almost equal later decline. With the total lag length being only five years for public agricultural extension capital (versus 35 for public agricultural research capital), downturns in agricultural extension can fairly quickly be reversed by increased expenditures on agricultural extension per farm.

### Comparing and Evaluating Rates of Return to Investments in Public Research and Extension

The marginal impact of public agricultural R&D capital and agricultural extension capital is estimated using an econometric model for panel data to explain state agri-



**Table 1. Characterization of Real Rates of Return (IRR) to Public Agricultural Research and Extension in the US: Recent Evidence from Econometric Analysis of Total Factor Productivity (TFP)**

Source	Type of analysis	Obs. Units	Time Period Covered	Public Ag Research			Public Ag Extension			Real Social IRR	
				Type	Lag (years)	Time period	Type	Lag (years)	Time period	Ag Research	Ag Extension
Jin and Huffman (2016)	TFP	States	1970-2004	Net	35	1935-2002	Net	4	1966-2004	67 %	> 100%
Andersen and Song (2013)	TFP	US	1949-2002	Gross	50	1900-2002	Gross	50	1900-2002	21 %	Blend*
Alston et al. (2011)	TFP	States	1949-2002	Gross	50	1900-2002	Gross	50	1900-2002	22.7 %	Blend*
Huffman & Evenson (2006)	TFP	States	1970-1999	Net	35	1935-1997	Net	4	1966-1999	49 %	> 100%

\* *Public agricultural research and extension expenditures are aggregated together into one variable before creating the stock or capital variable.*

cultural TFP. Recent evidence on the social IRR to public investments in agricultural research and extension are reported in table 1. The study by Jin and Huffman (2016) provides the most recent evidence covering the period 1970-2004.<sup>2</sup> They find a real IRR for public agricultural research of 67 % and for public agricultural extension of over 100 %. These are large rates of return—for example, relative to a 2-5 % return on stocks and bonds—and relative to those reported by other recent studies of a more or less similar nature for comparable sized public investments. Although productivity-oriented public agricultural research is less diverse than total public agricultural research, it remains a heterogeneous mixture of research across a diverse set of agricultural commodities and major input groups and across basic and applied sciences (Huffman and Evenson, 2006). The high IRR to investments in public agricultural research are due to large geographic spillover effects.

The estimate of the rate of return to investments in public agricultural research by Alston et al. (2011) and Andersen and Song (2013) are significantly lower than those reported by Jin and Huffman (2016). Why is this? They use gross measures of agricultural research and extension, which induce serious measurement errors that bias estimated benefits downward and costs upward. The difference in the IRR estimates for Jin and Huffman (2016) and Huffman and Evenson (2006) are due largely to a revision of the public agricultural research expenditure series in 2010.

## Discussion

How can we identify a productive path forward? Given the long time lags between costs and benefits for public agricultural research, the decline in its capital starting in the mid-90s will be a drag on US agricultural productivity for more than the first quarter of the twenty-first century. While the potential losses from that past decline in US public research investment cannot be recovered, more immediate produc-

<sup>2</sup> The series stops in 2004 since the US Department of Agriculture has been unable to update its input series at the state level because the National Agricultural Statistic Service discontinued their collection of reliable farm labor data for farm operators and unpaid farm family labor in 2004.

tivity gains can be obtained by investing in public agricultural extension. However, the large rates of return from investments in public agricultural research over 1970-2004 suggest society can benefit from investing significantly more over the next quarter century.

The agricultural research discoveries in the US (and other developed countries) are part of the stock of knowledge available to raise agricultural productivity in Argentina and other South American countries. However, the decline in US investments in public agricultural research started in the mid-1990s has reduced the number of agricultural discoveries. This seems likely to reduce the potential of these countries to borrow new agricultural technologies from the US. In addition, successful technology borrowing frequently requires local adaptive research to meet local geoclimatic conditions and to be economically competitive with traditional local technologies. This research has not always been undertaken (Beintema and Stads, 2008). Furthermore, South American countries sometimes obtain access to new agricultural technologies through arrangements with multinational companies, but access to the newest technology requires that these countries provide intellectual property right protection.

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