

Persistence Pays

NATURAL RESOURCE MANAGEMENT AND POLICY

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EDITORIAL STATEMENT

There is a growing awareness of the role that natural resources such as water, land, forests and environmental amenities play in our lives. There are many competing uses for natural resources, and society is challenged to manage them to improve social well being. Furthermore, there may be dire consequences to natural resources mismanagement. Renewable resources such as water, land and the environment are linked, and decisions made with regard to one may affect the others. Policy and management of natural resources now require an interdisciplinary approach including natural and social sciences to correctly address our societal preferences.

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Persistence Pays

U.S. Agricultural Productivity Growth
and the Benefits from Public R&D Spending

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This book was many years in the making. In different ways and at different times along the way we received advice, inspiration, and encouragement from many friends and colleagues. We owe a particular intellectual debt and personal thanks to Zvi Griliches (1930–1999), Bruce Gardner (1942–2008) and Vernon Ruttan (1924–2008). This book is dedicated to their memory.

Advance Praise for *Persistence Pays*

Persistence Pays is a definitive source book on the economics of agricultural R&D in the United States. The topical coverage is impressively comprehensive, ranging from discussion of the historical development of U.S. agriculture and U.S. agricultural research policy, through a quantification of the patterns of production and input use, to econometric models of R&D and productivity and their implications. The treatment of particular themes is careful and instructive. The authors provide new, detailed, state-level data on both agricultural R&D investments and productivity, along with a critical survey and review of relevant measures, methods, and models, before presenting brand-new econometric results. These new results refine and extend past work in the area, reinforcing many of the past findings about the high social returns to agricultural research and the persistent patterns of underinvestment. The book has significant technical content that will be primarily of interest to other economists both in the classroom and in research applications, but it is also readily accessible to research administrators and policy makers, well beyond the United States, who wish to understand the links between public research policy, agriculture, and the economy.

—Jock R. Anderson. Emeritus Professor of Agricultural Economics at the University of New England, Armidale, Australia, and Adviser, Agriculture and Rural Development, World Bank, Washington, DC.

This is a sophisticated book on a critically important subject. Many people have talked about the importance of public R&D in propelling the growth in American agricultural productivity but there has been scant hard evidence on the issue. Alston, Andersen, James, and Pardey rectify this deficiency with a brilliant book that represents a major contribution to our understanding of technological change—this is the new gold standard in the field. Their achievement is multidimensional—they carefully construct new state-level data series on the quantity and quality of agricultural inputs and outputs, they offer a wealth of information on the institutions and functioning of the public agricultural research system, and they employ well-conceived models and state-of-the-art econometrics to tease out the effects of R&D expenditures on productivity growth. In the process they provide entirely new insights into myriad issues such as the extent of research spillovers, the nature of the lags in R&D investments, and the extent of the policy failures since the 1970s giving rise to a slowdown in farm productivity in the past 10–20 years.

—Alan L. Olmstead. Distinguished Research Professor, Department of Economics, University of California, Davis and co-author of *Creating Abundance: Biological Innovation and American Agricultural Development*, Cambridge University Press, 2008

This book presents new solid empirical evidence about the past, current and required future role of research and innovations to prepare U.S. agriculture to meet future domestic and international food demand in a sustainable manner. The economic rates of return are high and spillovers across states are large. The authors make a strong and well-supported case for expanding federal funding for agricultural research. Global food demand is likely to double over the next 50 years. Given the long time lag between research investments and productivity gains, documented in this book, and the recent global food crisis, expanded investments are long overdue. Policy-makers, advisors and analysts should pay attention to the findings reported in this book and take appropriate action now to stop the current trend of decreasing rates of productivity growth.

—Per Pinstrup-Andersen. H. E. Babcock Professor of Food, Nutrition and Public Policy, J. Thomas Clark Professor of Entrepreneurship, and Professor of Applied Economics at Cornell University; and Professor of Agricultural Economics at Copenhagen University. World Food Prize Laureate, 2001

Foreword by Norman Borlaug

The invention of agriculture heralded the dawn of civilization. Through the domestication of plant and animal species, and subsequent productivity improvements which began with irrigation, humankind has moved from a hand-to-mouth existence to one in which surplus food supplies permitted the establishment of permanent settlements and urban societies which, in turn, engendered culture, science, and technology. The rise and fall of ancient civilizations in the Middle East and Meso-America were closely tied to successes and failures in agriculture. It behooves us to remember that this axiom remains valid today. Indeed, without abundant and stable food supplies we cannot hope to achieve and sustain global peace and prosperity.

The United States today is the world's second-largest producer of agricultural products and the world's largest agricultural exporter. The success story of American agriculture is not accidental, nor is it exclusively due to natural resource endowments. Rather, it is the result of investments in agricultural education, research, and extension; mechanization and transport; fertilizers; irrigation; energy; credit; stimulatory agricultural policies; and lastly, but certainly not least, extremely productive farmers and ranchers.

The success of American agriculture owes much to the agricultural institutions and policies first established nearly one century and a half ago. In 1862 President Lincoln signed into law three bills that played a vital role in raising the U.S. to its preeminent position: The Homestead Act, which made relatively large (at the time) tracts of land on the frontier available to persons who committed themselves to living on the property and developing it; a law establishing the U.S. Department of Agriculture; and the Morrill Act, which established publicly supported land-grant colleges of agriculture and mechanical arts in every state. These laws later were supplemented in 1887 by the Hatch Act, which provided for the establishment of agricultural experiment stations, as well as closer collaboration between the agricultural colleges and USDA, by the Smith-Lever Act in 1914, which established the cooperative extension service, charged with introducing new technology to farm and ranch families; and by the Smith-Hughes Action in 1917, which established vocational agriculture programs in high schools.

The significance of these institutional developments cannot be over-emphasized. They truly revolutionized agricultural production in the United States, and had many positive spillover effects around the world. Indeed, few industries have been as productive and innovative as agriculture during much of the 20th Century. The quantity, quality, and availability of food have increased many-fold, and real food prices have steadily declined. Today, less than 1 percent of the U.S. population is directly engaged in primary agricultural production, yet American farmers are able to provide consumers with an abundant, high-quality and safe food supply at a low cost while still maintaining a strong position in world markets.

American farmers and ranchers not only have been able to increase agricultural production many-fold through the application of science and technology, I contend that they have also been able to achieve these production feats in ways that have helped conserve the environment, not destroy it. For example, had the U.S. agricultural technology of 1940—when relatively little chemical fertilizer and agricultural chemicals were used—still persisted today we would have needed an additional 675 million acres of agricultural lands—of the same quality—to equal the 2006–07 output of roughly 800 million tons for the 17 main food and fiber crops produced in the United States.

Put another way, thanks to the agricultural productivity increases made possible through research and new technology development since 1990, an area greater than all the land in the 26 states east of the Mississippi River, has been spared for other uses. Imagine the environmental disaster that would have occurred if hundreds of millions of environmentally fragile acres, not suited to farming, had been ploughed up and brought into production. Think of the soil erosion, loss of forests and grasslands, and biodiversity, and extinction of wildlife species that would have ensued!

During the past two decades, U.S. public agricultural research funding, in real terms, has stagnated, as has support to international agricultural research. U.S. private sector agricultural research funding has followed a similar pattern. If these trends continue, we risk losing the broad continuum of agricultural research, from the more basic to the more applied and practical, needed to keep agriculture moving forward.

In an earlier day, public sector institutions—mainly the U.S. Land Grant Universities and the USDA's Agricultural Research Service, were concerned with this full gamut. But with the advent of hybrids and modern varieties, and crop protection chemicals, private companies became more and more involved in applied research activities in which the marketplace will enable them to capture a return on their investments. As the scope and quantity of private sector agricultural research has expanded, publicly funded research has tended to shift away from farm productivity oriented R&D, with longer payback periods to society,

and where the private sector cannot easily capture directly the benefits from the investments.

Private sector research, which tends to be more narrow and short term, and public sector research, which can be broader and longer term, complement each other, and should not be seen as competitive. It is important to maintain a healthy balance between the two and strong and growing support for both.

Science-based agriculture is really a 20th Century invention. Until the 19th Century, crop improvement was in the hands of farmers and food production and was largely increased by expanding the cultivated land areas. Improvements in farm machinery expanded the size of a farm that could be cultivated by one family. Machinery also made possible better seedbed preparation, conservation and utilization of moisture, and improved planting practices and weed control, resulting in modest increases in yield per hectare.

By the mid-1930s, much of the scientific knowledge needed for high-yield agriculture was available in the United States. However, its utilization was delayed due to the Great Economic Depression. It was not until WWII brought a great demand for food that the new research findings began to be applied widely. In no crop has this modernization process been more evident than in maize (corn). In 1940, U.S. farmers produced 56 million tons of maize on roughly 31 million hectares, with an average yield of 1.8 tons per hectare. In 2007, U.S. farmers produced 331 million tons of maize on roughly 35 million hectares, with an average yield of 9.5 tons per hectare. This more than five-fold yield increase—which continues to grow—is the impact of modern seed-fertilizer-weed-pest control technology!

Most agricultural increases over the next several decades will have to come from lands already in production through yield improvements. Fortunately, productivity improvements in crop management can be made all along the line—in plant breeding, crop management, tillage, water use, fertilization, weed and pest control, and harvesting.

By 2050, we will likely need to double current crop production again. This cannot be done unless farmers across the world have access to high-yielding crop production methods and new biotechnological breakthroughs that can increase the crop yields, dependability, and nutritional quality.

To meet projected food, feed, and fiber demands will require breakthroughs in both conventional and transgenic breeding to raise the maximum genetic yield potential of the major food crop species. Without increased investments in agricultural research and technology development it is unlikely that we will achieve adequate growth in agricultural production, and certainly not in environmentally sustainable ways.

While we must continue to push the frontiers of science forward, we also must be mindful of the need to protect the gains already made. Agriculture is a

continuing struggle against mutating pathogens and insects. A clear example is the new race of stem rust that has emerged in East Africa, which is capable of devastating most of the world's commercial bread wheat varieties.

I commend the authors of this path-breaking book. It is an extraordinarily comprehensive analytical review of the benefits from public research and development spending on U.S. agricultural productivity growth. The story looking back is of remarkable returns to investment. The story going forward is one of faltering agricultural productivity gains, almost surely due to a slowdown in the growth of farm productivity oriented agricultural R&D in America. Unless these disturbing trends change, the future adequacy of U.S. and global food supplies is in jeopardy.

July 4, 2009

Norman E. Borlaug (1914–2009)
Founder, the World Food Prize
1970 Nobel Peace Prize Laureate

Acknowledgments

The series of projects that evolved into this book began at least fifteen years ago, possibly twenty. It had its initial genesis in the IR-6 regional research project, led by W. Burt Sunquist, funded by the USDA. Over time the group of participants evolved along with the focus, which was initially U.S. agriculture in aggregate. Barbara Craig and W. Burt Sundquist participated in early elements of that work which helped set the scene for the work in the past decade. The data for the analysis has also been revised and updated several times including two major revisions to incorporate results from censuses in 1996 and 2002, and a number of other revisions. The current form of the project, with its current participants and use of state-level data ending in 2002, took shape in the early 2000s as we faced up to yet one more major revision of the data to bring it up to 2002 (and at the time of writing we are engaged in further updating to 2007). In the course of a project of such long duration we have benefited from discussions with many colleagues in formal and informal settings, we have been supported by funding from a variety of sources, we have received help with data and other resources, and we have employed a large number of research assistants. We are grateful for all of this help and we do our best here to remember and acknowledge all of those who contributed significantly, one way or another, to the elements of the work that ended up in this book.

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The work here is inspired by and seeks to build on prior work by Zvi Griliches, Vernon Ruttan, and Robert Evenson, in particular, among a long list of others. As well as drawing on their written work, we have benefited from their comments and advice about how to improve the work. In the context of presentations of elements of the ongoing work at various conferences and seminars, and in less-formal settings, we have also benefited from discussions with many other colleagues including (in alphabetical order): Jock Anderson, Kym Anderson, John Antle, Walt Armbruster, Eldon Ball, Nicole Ballenger, Ron Bewley, Mary Bohman, John Brennan, Steven Buccola, Derek Byerlee, Jim Chalfant, Jean-Paul Chavas, Tom Cox, Jeff Davis, Dana Dalrymple, John Dillon, Robert Dixon, Ruben Echeverría, Geoff Edwards, Shenggen Fan, Brian Fisher, John Freebairn, Lilyan Fulginiti, Keith Fuglie, Murray Fulton, George Frisvold, Bruce Gardner, Dinos Giannakas, Richard Gray, Terry Hurley, Wally Huffman, Frank Jarrett, Richard Just, Nicholas Kalaitzandonakes, Bruce Kefford, John Kerin, Yoav Kislev, Bonwoo Koo, Frikkie Liebenberg, Bob Lindner, Alan Lloyd, Michele Marra, Will Martin, Alex McCalla, Ian McLean, Catherine Morrison-Paul, John Mullen, Bob Myers, George Norton, John O'Connor, Chris O'Donnell, Alan Olmstead, Richard Perrin, Willis Peterson, Roley Piggott, Prabhu Pingali, Carl Pray, Per Pinstrup-Andersen, Gordon Rausser, Paul Rhode, Bob Richardson, Rick Roush, Scott Rozelle, Jim Ryan, David Schimmelpfennig, Andy Schmitz, Ed Schuh, Grant Scobie, Robbin Shoemaker, Vince Smith, Daniel Sumner, Michael Taylor, Colin Thirtle, Wally Thurman, Kien Tran, Greg Traxler, Alistair Watson, Mike

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We undertook to develop camera-ready copy in-house at InSTePP. This would not have been feasible without Amy Praught. Amy took hundreds of pages of manuscript, including dozens of complex figures and tables, and turned them into (slightly fewer) hundreds of book pages, with attention to placement of items, format, fonts, and so on, all of which is meant not to be noticed by the reader. This work requires creativity and precision, which in turn requires painstaking care. Amy combines these qualities with patience and good humor. We also thank our Springer editor, Jon Gurstelle, for his gracious guidance as we brought this work to fruition.

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PART I

Context

Introduction

Agricultural science policy in the United States has profoundly affected the growth and development of agriculture worldwide, not just in the United States. Over the past 150 years, and especially over the second half of the 20th Century, public investments in agricultural R&D in the United States grew faster than the value of agricultural production. Public spending on agricultural science grew similarly in other more-developed countries, and collectively these efforts, along with private spending, spurred agricultural productivity growth in rich and poor nations alike.

The value of this investment is seldom fully appreciated. The resulting productivity improvements have released labor and other resources for alternative uses—in 1900, 29.2 million Americans (39 percent of the population) were directly engaged in farming compared with just 2.9 million (1.1 percent) today—while making food and fiber more abundant and cheaper. The benefits are not confined to Americans. U.S. agricultural science has contributed with others to growth in agricultural productivity in many other countries as well as the United States. The world's population more than doubled from around 3 billion in 1961 to 6.54 billion in 2006 (U.S. Census Bureau 2009). Over the same period, production of important grain crops (including maize, wheat and rice) almost trebled, such that global per capita grain production was 18 percent higher in 2006. This increase in production came largely from unprecedented increases in yields.¹ Notwithstanding the persistence of chronic hunger for hundreds of millions of people around the world, the absence of a Malthusian nightmare is in significant measure attributable to historically unprecedented improvements in agricultural productivity achieved largely through technological change enabled by investments in agricultural R&D.

1 Pardey et al. (2007, p. 12) noted that “Since 1961, around 78 percent of the increase in [global cereal] production has come from increases in yields, except in Africa where about 60 percent of the gains have come from expanding the area of cultivation.”

Over the past 20 years or so, several patterns have emerged suggesting that public policymakers around the world may have begun to take continuing agricultural productivity growth for granted, to have decided that it is no longer an important priority, or to have determined that it has become the responsibility of the private sector. With a few notable exceptions, the rate of growth in public agricultural research investments has slowed worldwide (Pardey et al. 2006), and research resources have been progressively diverted away from farm productivity enhancement, with an increased focus on newer, seemingly more-pressing issues related to human health, the environment, food safety, and so on.² Agricultural science takes a long time to generate benefits, many of which are broadly distributed and not easy to observe directly. In a world where people, and particularly policymakers, seem increasingly impatient (and, perhaps, short-sighted) and demanding immediate outcomes, it is easy to understand why investing in agricultural science has lost some of its political appeal.

Perhaps reflecting the past redirection of research resources, in the 1990s some early warning signs of a slowdown of agricultural productivity growth became visible in the United States (and also in some other countries, including Australia, Canada and the United Kingdom).³ If such a slowdown were to be sustained and widespread, the long-term consequences for the world's poor could be tragic. As in the case of other global public goods such as the mitigation of air and water pollution, the full social costs of today's agricultural R&D policies could take many years to become apparent but the effects will last for decades and might be difficult to reverse.

More recently, the global commodity market boom of 2006–2008 has drawn attention to agricultural productivity and resource scarcity, but perhaps in a way that may not lead to the right agricultural R&D policy solution. The boom in grain prices—associated with high oil prices, exacerbated by the U.S. government's biofuels policy—may have reminded people in rich and poor countries alike that resources for producing agricultural commodities are scarce and agricultural productivity is valuable. But the discussion of the Research Title of the U.S. Farm Bill in late 2007 and early 2008 did not promise a significant reinforcement of the national investment in farm productivity enhancement. Instead, the emphasis has shifted to biofuels research.

This book is predicated on the notions that (a) public investments in agricultural science by the U.S. government have been important for the United States and the world, (b) notwithstanding a significant body of prior scholarly work by economists and others, the payoffs to investment in agricultural research are still poorly understood and little appreciated, and (c) providing information

2 See Pardey, Alston and Piggott (2006) for more discussion of these trends.

3 For instance, see Thirtle et al. (2004), Kokic, Davidson and Boero Rodriguez (2006), Veeman, Unterschultz and Stewart (2007), Zhao et al. (2008) and Alston, Babcock and Pardey (2009).

about these issues can facilitate better decisions by policymakers about agricultural research investments for the future. To achieve this purpose we have sought to provide a clear, contemporary, convincing and empirically comprehensive assessment of the links between public investments in agricultural science in the United States and agricultural productivity, and the value of the productivity gains relative to the costs of the research that allowed them.

The focus here is on the role of public agricultural R&D, including both state and federal investments. We aim to shed new light on the role of spatial spillovers among states in moderating incentives of individual state governments to invest in public agricultural R&D, and the implications both for the generally observed tendency towards an underinvestment in agricultural R&D and for appropriate roles to be undertaken by the federal government to correct the underinvestment problem or to modify the incentives of the states.⁴ With this aim in view, we measure the impacts of federal and state-government investments in agricultural research and extension (1900–2002) on productivity and estimated rates of return using state-specific data on U.S. agricultural productivity (1949–2002). We pay particular attention to the specification of the research lag structure (i.e., the temporal aspects of the relationship between knowledge stocks and productivity) and interstate spillovers (i.e., the spatial aspects), and the roles of these and other aspects of the model specification in influencing the findings.

To complete Part I of the book, which sets the scene for the chapters that follow, Chapter 2 presents an overview of the changing structure of farms and farming and the patterns of agricultural input, output and productivity growth in the United States for the past 150 years. This long-run perspective provides context for the more detailed and original data we present in Chapters 3, 4, and 5, respectively concerning agricultural input, output, and productivity patterns over the period 1949–2002 across the 48 contiguous U.S. states. These three chapters comprise Part II of the book. The emphasis is on describing and interpreting the broad trends, although important details of the data and methods used to construct these indexes, and the underlying trends in disaggregated inputs and outputs, are also presented. These indexes reveal important differences among states in the shifting pattern of input use and production over time, but with a consistent pattern among the states indicating a pronounced and widespread slowdown in the rate of productivity growth in the most recent period of our data, which ends in 2002. The productivity slowdown may reflect past shifts in public support for agricultural R&D, and raises concerns about the prospects for coming years.

4 See Ruttan (1980 and 1982) and Pasour and Johnson (1982) for an exchange on the veracity of the underinvestment hypothesis. Much of the Pasour and Johnson critique centers on the accuracy of the evidence of high measured rates of return to agricultural research. Alston et al. (2000a and 2000b) provide a comprehensive cataloging of the literature and undertake a formal meta-analysis of the sources of variation in the measured rates of return. See also Chapters 8 and 9 of this volume.