Appendix: A Critical Assessment of Estimates of Social Returns to Agricultural Research

Some critics have suggested that the estimated social rates of return to agricultural research may be biased upward. In the extreme, some have concluded that after adjusting for upward bias, the rate of return to public agricultural research is comparable to that of other investments in the economy (Pasour and Johnson, 1982; Fox, 1985). We address six specific issues that are potentially serious sources of bias in measured social rates of return to agriculture. These include (1) the research lag; (2) spillovers from the private sector; (3) the added costs to the economy of raising funds for research through taxation, or, in economic terms, the consideration of the “deadweight loss” associated with funding public expenditures through taxes; (4) biases because farm programs create commodity surpluses and may mean that the prices of agricultural products diverge from the economically efficient levels; (5) failure to account for environmental, health, and safety effects of new technology; and (6) failure to account for dislocation and adjustment costs.

Research Lags

The time lag structure of benefits of R&D expenditures is important because the sooner the research benefits are received and the longer they last, the higher the rate of return to research. Econometric estimation of research lags, while artificially truncating lags, usually forces a particular pattern of benefits that can lead to an under- or overestimate of the rate of return (Alston and Pardey, 1996). Studies that have specifically tried to estimate how long research may continue to affect productivity have found persistent effects for at least 30 years (Pardey and Craig, 1989; Schimmelpfennig and Thirtle, 1994).

Analysts have made various assumptions for approximating the complex lag structure of the effects of R&D expenditures on productivity. Overall, evidence and intuition suggest the benefits of research investment are initially small, then rise to a peak, and finally diminish as the innovation becomes obsolete. This structure has been characterized as an inverted U- or inverted V-shaped distribution. The main problem with directly estimating an unconstrained lag structure is that the number of lagged years that can be included is limited by data constraints. Econometric models introduce many independent variables in a data set that extends only 40 or 50 years. The usual approach is to assume that the weights for the lagged years follow a polynomial of a given degree, thus limiting the number of parameters that must be estimated. Constraining the lag structure in this way can introduce bias. Upward bias may be introduced if the polynomial structure overestimates returns in early years. Errors in early years have relatively larger effects on estimated rate of returns than errors in later years, due to discounting.

Alston and Pardey (1996) provide some simulated results that show how variations in the lag between when research is conducted and when benefits accrue can affect the rate of return. In their simulations they control the benefit stream to assure that cumulative benefits are the same across simulations and that benefits always cease after 30 years. The difference among the simulations is that some benefit streams start earlier at a lower rate, while others start later at a higher rate. As a base of comparison, consider their benefit profile that begins 4 years after research was conducted and generates a rate of return of 46 percent. If the benefit stream is delayed by 2 additional years beginning in year 6, the rate of return falls by 10 percentage points to 36 percent. If the benefit stream is delayed 6 years beginning in year 10, the rate of return falls by 20 percentage points to 26 percent. With a limited time series of data it is difficult to judge whether current approaches under- or overestimate returns. We take a conservative approach and adjust our estimates of the rate of return downward by 10 percentage points because many products may not become commercially available for 6 to 8 years after the bulk of research dollars are spent. It is also likely that the lag is longer for basic research than for applied research or extension.

Spillovers

The productivity of the agricultural sector depends on both public agricultural R&D and private agricultural R&D. Private R&D has accounted for more than half of agricultural research expenditures. Studies of the social rate of return to public research may inappropriately include some spillover productivity gains due to private spending. This is a potential problem in both the economic surplus and production function approaches. Until recently, data on private R&D have not been available. Failure to include private expenditures in statistically estimated relationships leads to overestimates of returns to public research to the extent that public and private R&D spending is positively correlated.

Huffman and Evenson (1989) estimated private research by using the number of patents in agricultural technology fields. Other studies assume that private research expenditures are equal to public research expenditures. See for example Griliches (1964, p. 968), Bredahl and Peterson (1976, p. 688), and White and Havlicek (1982, p. 52). Yee’s (1992) estimates of the rates of return to public and private agricultural research explicitly take into account private agricultural research expenditures. He estimates that the social rate of return to U.S. public R&D expenditures falls to 49 percent from 58 percent (after correcting for the omission of private spending).

An incidental result to Yee's (1992) attempt to control for private research expenditures is that he estimated a rate of return to private research of 38 percent. This is very similar to Huffman and Evenson's (1989) estimate of 40 percent rate of return to private agricultural research. Much of the private research in agriculture is conducted by input-producing industries (seeds, chemicals, and farm machinery). Furthermore, Yee's estimates are based on the productive efficiency of the farm sector. Therefore, the 38-percent return reflects mainly those returns not privately captured in the input-producing industries; that is, his estimate reflects returns to this research that has spilled over to farm producers and consumers. The full social return to private research would be higher than 38 percent, as the social return would also include the profits these firms obtain through exercise of their intellectual property rights to obtain monopoly rents. If firms appropriate about half of the returns to their research as suggested for industrial firms overall then the full social return to private research could be nearly 80 percent (Mansfield and others, 1977). Otherwise, if firms are assumed to apply a hurdle rate to research investments of about 20 percent, then the social return to private research may be roughly 58 percent. Both estimates fail to consider the potentially substantial spillovers from research among input-industry firms, namely the ability of one chemical company to build on the research results and findings of another chemical company.

This evidence may also suggest that the private sector has more difficulty in appropriating the returns from agricultural compared with manufacturing industries. Mansfield and others (1977) found that the social rate of return to private research in manufacturing industries to be 50 percent, and the private return to be 25 percent. Yee's estimates suggest a larger share of benefits from private agricultural research spillovers to other firms, farmers, or consumers, compared with Mansfield's estimates for manufacturing. An implication of this hypothesis is that the private sector is more likely to underfund agricultural research than other industries because of the difficulty of appropriating the returns. This evidence is partial justification for the greater involvement of the public sector in agricultural research than in other areas of the economy.

Public and private R&D funding levels are not necessarily independent, as represented in Yee's (1992) study. Possible interrelationships may be positive or negative. Public R&D expenditures may stimulate private R&D expenditures by increasing the technological opportunities from which private firms develop profitable commercial products. Alternatively, public R&D may crowd out private R&D expenditures by acting as a substitute for private R&D. The empirical work of Pray, Neumeyer, and Upadhyaya (1988) finds that public investment in research increases the amount of private investment in research. Thus, a $1 increase in public research results in more than a $1 increase in total research. Public research in basic and pre-technology research increases technological opportunities for applied private research and development. Thus, public research promotes private research by increasing the competitive pressure in an industry. Companies that fail to invest in new technology risk being left behind by their competitors. To the extent that public R&D stimulates private R&D in this way, the returns to public R&D would be underestimated.

Geographical spillovers are particularly important in estimating returns to smaller geographical units, such as individual States. White and Havlicek (1979) found that failure to take into account the geographical spillovers from U.S. regional agricultural research inflated the estimated rate of return to research and extension in the Southern region by more than 25 percent. Evenson (1989) reported substantial spillovers of research benefits between States, with larger spillovers for livestock than for crops. This may explain higher returns to livestock than crop research as found by Bredahl and Peterson (1976) and Norton (1981). States are likely to be most interested in funding research where the benefits accrue to farmers in the State and thus may be more likely to fund crop research. This would drive down the marginal rate of return to crop research. Because the benefits of livestock research spill over widely, State funding for it may be comparably lower. This would drive up the marginal rate of return to livestock research.

U.S. agricultural productivity may similarly benefit from spillovers of technology developed by foreign R&D expenditures. Thirtle and others (1994) incorporate spillovers between the EC countries and from the United States in examining the returns to agricultural R&D for the EC countries. They find that spillovers between European research systems and from the United States may be more important than the direct effects of the national agricultural research systems. The authors conclude that failure to take into account spillovers may bias upward the rate of return to R&D in EC countries. These estimates suggest that an individual country could reduce some spending money on research and take advantage of the research of other countries. This result shows that the public good nature of research is not contained by national borders. If countries act purely in their own self interest, it could lead to global underfunding of agricultural research.

Tax Collection and Deadweight Losses

The economic inefficiencies created by tax collection, termed "deadweight losses" by economists, increase the economic cost of publicly conducted research. For example, a tax on wages reduces labor supplied, and a tax on capital reduces capital investment. Deadweight losses refer to the value of foregone production resulting from imposition of taxes in an economy. Fox (1985) mentions this possibility, which seems to have gone unnoticed previously in the agricultural research literature. Ballard, Shoven, and Whalley (1985) estimated 17-56 cents of deadweight loss per dollar of tax collected in the United States. More recent work aimed at reconciling major differences in the literature concluded that deadweight losses fall between 7 and 25 cents per tax dollar (Ballard and Fullerton, 1992).

Appendix table 1 extends the work of Yee (1992) to incorporate the deadweight loss of taxation for a range of deadweight loss estimates. Extra tax collection costs reduce the effective rate of return on a dollar of public expenditure from 49 percent to between 40 and 46 percent given a range of deadweight loss estimates. Fox (1985) showed a much higher penalty but assumed that the benefits of research are constant through time. The reason Yee's estimates show a smaller penalty is that he directly estimates a lag structure of benefits. The lag structure is crucial to estimating the deadweight loss penalty. To illustrate this, consider three cases: (1) a one-time return occurs in year 1; (2) returns flow at a constant rate indefinitely into the future; and (3) returns start out low and grow at a constant rate over time. In each case, assume that $1 is invested and earns a 50-percent return before being adjusted for deadweight loss of $0.30 per dollar. In the first case, $r = [B/C(1+\tau)] - 1$ where τ is the deadweight loss. The rate of return is 50 percent with no deadweight loss if B = $1.50. The rate of return falls to 15 percent if the deadweight loss is 0.30. In the second case, $r = B/[C(1+\tau)]$. Assuming no deadweight loss, the rate of return is 50 percent if B is $0.50 but falls to 38 percent if the deadweight loss is 0.30. Finally, in the case where returns begin at a low rate and grow constantly over time, $r = [B/C(1+\tau)] + g$ where g is the growth rate. The rate of return is 50 percent if there is no deadweight loss and B starts at 0.20 and grows at 30 percent per year. With a deadweight loss of 0.30, the adjusted rate of return falls only to 45 percent. As these examples illustrate, the deadweight loss adjustment is very large if returns are heavily weighted to the near term but much smaller if the returns are more heavily weighted to the future.

Appendix table 1—Adjusting the social rate of return to public research for deadweight losses and spillovers from private R&D

Social rates of return	Annual return
	Percent
Estimated without private R&D	58
Estimated with private R&D	49
Estimated with deadweight losses of:	
17 cents/dollar	46
30 cents/dollar	43
56 cents/dollar	40

Source: Data compiled by Economic Research Service. Public rates of return with and without private R&D are from Yee (1992). Rates adjusted for deadweight loss include private R&D. They were calculated from equation 1 in the text by adding the additional deadweight losses to the cost of public research, C_t, and then solving for r. The specific lag structure of returns was that estimated by Yee (1992).

The relatively small deadweight loss penalties based on the Yee (1992) study are due to a pattern of benefits that is very low in initial years but grows rapidly. In contrast, Fox (1985) adjusted the rate of return from 37 percent to 26 percent for a deadweight loss of $0.30 per dollar of tax collected. Critical to the Fox estimate is that he assumes a constant flow of benefits over time that begins in year zero. If benefits are more realistically assumed to begin 1 or 2 years after the research investment, the adjusted rate of return is 28 percent (1-year delay) and 30 percent (2-year delay).

This feature of the deadweight loss adjustment would likely affect the size of the adjustment among research components, such as basic research, applied research, and extension. The benefits of extension would likely be weighted more heavily toward the near-term, and extension advice may become obsolete relatively quickly as the available technology set, commodity and input prices, and other factors change. Thus, the deadweight loss adjustment for extension would likely be larger. In contrast, the benefits to basic research likely begin relatively small and may grow over time as applications of the basic research result are refined and broadened. Thus, the adjustment for basic research would likely be smaller.

Commodity Programs and Agricultural Surpluses

Government intervention in farm commodity markets is widespread and diverse. Taken at face value, the Federal Government programs that generate surplus stocks and remove acreage from production may be in serious conflict with funding of research and development to increase yields. Alston and Pardey (1996) show, however, that even in cases of surplus production, research that reduces the cost of production can still be beneficial to the economy because production occurs at lower cost and using fewer inputs. Surpluses and budget outlays due to commodity program interventions affect how the benefits of research are distributed between farmers, taxpayers, and consumers but have less effect on the overall net benefit of research.

Farm programs may also distort the incentives to develop and adopt new technology (Alston, Edwards, and Freebairn, 1988). Offutt and Shoemaker (1990) estimated that various farm programs that have removed land from production have encouraged land-saving and manufactured input-using (chemicals, seeds, etc.) technical change in the United States. Thus, there is empirical evidence that commodity programs affect the types of technologies developed and adopted.

Several studies have considered the economic effects of government interventions in commodity markets on the benefits from research (Oehmke, 1988; Alston, Edwards, and Freebairn, 1988; Murphy, Furtan, and Schmitz, 1993; Chambers and Lopez, 1993; Alston and Pardey, 1996). Oehmke (1988) specifically explores how one might adjust the rate of return to research to reflect government interventions. Under his approach he finds that the adjustments can be large enough to make substantial positive rates of return negative. His approach is extreme and likely flawed but raises several questions. In particular, how and whether to account for farm programs in rate-of-return studies depends on some political economy issues that are not easily resolved through appeal to standard economic methodologies.

Most of the economic analyses of farm programs and rates of return to research implicitly make gross and unrealistic assumptions about the political economy of farm programs. There is a standard political economy story behind these analyses: the parameters of the programs are set in the naive belief that productive efficiency will not improve despite decades of evidence to the contrary. Furthermore, when productive efficiency does improve, farm program parameters remain indefinitely unchanged. The result is a significant incentive for farmers to expand production (because costs have fallen compared with commodity target prices). With prices fixed by the program, demand does not increase and the government is faced with ever-accumulating surplus stocks. Further, some analyses assume these stocks are essentially thrown away and thus all government expenditures on farm programs are a pure economic loss. A final important consideration is that many analyses assume that increases in production in the country where the research is conducted affect the world commodity prices. The assumptions used to adjust research benefits for the presence of commodity programs are both unrealistic and extreme.

Explicitly reconsidering the political economy of farm programs might lead to a more realistic scenario as follows: farm programs serve to redistribute income to farmers, particularly in periods of declining prices. An auxiliary effect is that surplus stocks of commodities are used for school lunch programs, distributed to the poor both domestically and abroad through international food aid assistance, or are simply put back in the market during periods of shortages. Farm programs are designed to give considerable flexibility to the Secretary of Agriculture (Secretary) to set target prices, loan rates, and percentage of cropland set aside through the Acreage Reduction Program. By reviewing these program variables yearly, the Secretary exercises control over budget outlays and surplus stock accumulations within the limits of the program's broad dimensions. These various government interventions create distortions as do all government interventions aimed at affecting income distribution. Given the many considerations that go into any political decision, Congress and the Administration have implicitly negotiated what they believe to be a fair amount of redistribution among consumers of different income levels, farmers, and taxpayers. The Secretary's job is to manage program variables to keep budget outlays and other program dimensions in line with the political consensus.

Two factors can result in changes in the rules governing farm programs when they are rewritten: changing views of the appropriate size of outlays and amount of fair redistribution, and changes by the Secretary to manage the program along the wishes of elected officials. In this view of the political economy of farm programs, certain changing conditions are anticipated, specifically: weather, the general economy, export demand and import supply, and productive efficiency arising from technical improvements. Since the specific nature of the changes cannot be predicted ahead of time, flexibility is built into the system to adjust to these changes as they occur. Among these various factors, improvements in productive efficiency are probably the most constant over time. If it were the only factor that was changing, the Secretary could easily adjust program dimensions to avoid unwanted surplus stocks and excessive program outlays. As Alston and Pardey (1996) conclude, if there are pre-existing distortions, the social benefits of research are affected only if R&D worsens the pre-existing distortion. Under this more realistic farm policy scenario, there is little or no reason to expect that improvements in productive efficiency would generate unwanted changes in surpluses or budget outlays. Thus, there is little reason to expect that whatever distortions caused by the programs were worsened or improved by technical change.

In fact, if the above scenario is at all accurate, using the farm program-adjusted rate of return to guide the level or allocation of research would put research spending at odds with the implicit goals of farm programs. Put another way, changing research spending to avoid commodity surpluses or program outlays would be an attempt to reform farm programs through research policy. Such an approach would be neither effective nor economically efficient, since farm programs could respond far faster to meet political goals than could research spending because of the long lead times between funding and technology adoption. The result of such an attempt would seriously misallocate and underfund research spending without having any effect on commodity program budget outlays or surplus stocks.

In summary, research likely has small or negligible effects on the preexisting economic distortions caused by farm programs. Viewing farm programs as largely redistributing the gains from technology is more accurate. A more realistic consideration of farm programs leads to the conclusion that adjusting the rates of return to research for commodity program inefficiencies may lead to misguided decisions on research funding and allocation.

Environmental and Health Effects

The net environmental and health effects of new technology may be negative or positive. Without quantification of these effects, concluding whether estimated rates of return are too high or too low is not possible. For example, the introduction of new agricultural fertilizers and pesticides, largely developed by the private sector, and their increased use, has led to a number of environmental and health concerns. However, yield improvements and reduced crop losses from pests likely reduced the demand for land and consequently its price and the incentive to convert land to cropland. The Conservation Reserve Program, which aims to remove highly erodible land from production, would have had to offer higher rental rates to compete in land rental markets, thus increasing the cost of conservation. Thus, the social rate-of-return adjustment to private sector investments in agricultural chemicals depends on two valuations: (1) the health and environment effects of more chemicals in the environment versus (2) less extensive land use and the lower conservation program costs. The rate of return could be positive or negative. Reilly and Phipps (1988) identify the complexity of linkages between technology and the environment. They note that when taken together, generalizations are not very meaningful because some types of technological advances are benign while others are environmentally damaging. Capalbo and Antle (1989) point out that very little effort has been directed at the measurement of social costs caused by environmental damage and human health risk. They advocate a cross-disciplinary effort and outline a framework for cross-disciplinary research for the measurement and valuation of pollution externalities. Public interest in environmental effects of agriculture and new laws regulating these effects have created significant incentives for public and private researchers to seek environment-saving technology.

Adjustments to social rates of return to research for environmental, health, and safety effects would provide a better accounting of past returns. However, the conclusions to be drawn for future research funding and allocations from adjusted historical rates of return are unclear. The implications of adjusting historical rates of return are unclear because, over time, whether and how environmental effects are regulated have changed. Agricultural chemical research, while principally funded by the private sector, provides a useful illustration of the problems in adjusting historical rates of return for environmental considerations. When many early agricultural chemicals were first introduced, only their immediate health effects were considered. Long-term health effects (for example, carcinogenicity) and broader environmental effects were unknown and, thus, not regulated. In retrospect, one could evaluate the environmental costs of these chemicals and adjust the social rates of return to these private investments downward. New technologies must, however, face a process of product approval and use regulation reflecting what we now know about the potential for broader environmental and health effects. Much of the current private research on agricultural chemicals is aimed at finding new chemicals that are less environmentally damaging and pose fewer health risks. Other private-sector research and much public research is aimed at other approaches for pest control, such as the development of biopesticides and pest-resistant crops.

Consider the implications of adjusting downward the past rate of return to chemical research. The implication would be to reallocate research away from chemical research toward other types of research. Nevertheless, such a reallocation could mean that progress on developing new chemicals that were less environmentally damaging was slowed. In other words, an adjustment in the rate of return meant to speed improvements in the environment could actually have the opposite effect. Such a perverse result could occur because the rate of return on research that occurred 15 or more years ago is only a rough indicator for today's research decisions. For environmental effects, by the time we become aware of the unexpected environmental cost of past research such that we could adjust rates of return, society is likely to have already taken steps to ensure that these environmental costs are reflected in product approval and use regulations.[18] Technologies being developed today may have environmental costs that we do not currently foresee. Because we cannot foresee them, we cannot adjust for them. We do not know whether those areas of research that created environmentally harmful technologies in the past will also be the source of future environmental problems.

An induced-innovation model can be broadened so that applied research responds to the price and regulatory signals provided by the economy and society. If this model uses a public focus assuring that the price and regulatory signals correctly reflect society's valuation of environmental problems, this model represents a more effective and decentralized approach for assuring that research is consistent with environmental goals. This is better than attempting to direct a top-down reallocation based on historic rate-of-return estimates. Competition and the need to introduce marketable products that allow farmers to produce efficiently while meeting environmental requirements provides the incentives for private firms to direct research toward environmental problems reflected in environmental regulation. How the public sector responds to market and regulatory signals is less clear because public research is not directly driven by competitive market forces.

Dislocation and Adjustment Costs

The fact that the introduction of new technology causes dislocation and adjustment has been recognized since some earliest economic thinking on technical change. Schumpeter (1947) used the term "creative destruction" to describe technical change. Economic efficiency is enforced through competition. These incentives operate to reward successful innovators and to penalize less effective innovators (or those who are slow to adopt successful innovations). While the cause of economic efficiency is served by this process and members of society are on average better off, focusing only on the average outcome conceals a range that includes both winners and losers from technological change.

Most concerns regarding dislocation and adjustment have focused on the possibility of job losses resulting from innovations. Smaller and poorer farmers who are slow to adopt new technologies may also face economic losses because of innovation leading to declines in market prices. Schmitz and Seckler (1970) is a rare study that attempted to include the social costs of displaced farmworkers when calculating the rate of return. This study looked historically at the mechanical tomato harvester because of the concern that its introduction had significantly reduced the need for migrant laborers. The largest case in point is the huge rural-to-urban migration that has taken place in the United States and in other industrialized countries. Whether labor-saving technology forced people from the farm or whether they were drawn from the farm by the expectation of higher wages remains an unsettled topic. However, studying the effect of prices and technology on U.S. farm size between 1930 and 1970, Kislev and Peterson (1982) found that the rise in the ratio of nonfarm wages to farm machinery costs could explain statistically nearly all of the growth in average farm size during this period. They concluded that the adoption of large-scale farm machinery was largely in response to, rather than the cause of, the declining number of workers in U.S. agriculture. Workers left agriculture because nonfarm jobs offered better opportunities.

Attempts to limit innovation may eventually force an industry to undergo an even larger adjustment. The U.S. automobile manufacturing sector was able to maintain high wages and employment for many years but ultimately was then forced to adjust in response to foreign competition. Efforts to subsidize directly or provide adjustment assistance to those hurt by new technology can easily become an incentive to avoid adjustment rather than transitory assistance to make an adjustment. Concerns about the distributive effects of new technology may be better served through maintenance of a broad social safety net rather than specific adjustment assistance and damage compensations. In this way, human costs of adjustment can be limited while reducing the disincentives to improve the productive efficiency of the economy.

[18] There is a long lag between when the health and environmental effects are recognized and when their effects are finally controlled. Even after it is partially controlled, uncertainty in evidence complicates assessing whether the level of control fully internalizes negative effects into private decisions about research. Uncertainty further complicates determining whether regulations under- or over-control product development and use. The example in the text is meant to be illustrative.