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Public Funding for Research into Specialty Crops

1. Introduction

Government involvement in agricultural R&D is justified if the benefits exceed the costs. Does the private sector neglect socially profitable investments? So-called market failures in R&D can result if inventors are unable to fully appropriate the returns to their inventions—if "free-riders" can adopt new technology and benefit from it without having to contribute to the costs of research. In agriculture, in particular, it seems likely that, absent government intervention, the private sector will invest too little in certain types of R&D, and there is a strong in-principle case for government to intervene either to improve private incentives or, more directly, to fund or undertake research.

In the United States, both state and federal governments are extensively involved in agricultural R&D. Perhaps the most obvious, and arguably the main form of involvement is the government production of agricultural science—in government labs or in public Universities—using general government revenues. This intervention is justified both in principle and by the evidence that the rates of return to public agricultural research have been very high, even with very extensive government intervention to correct the private-sector under-investment in agricultural R&D (e.g., see Alston et al. 2000). This suggests that the government intervention to date has been inadequate; that the United States could have profitably spent much more on agricultural R&D.

These observations apply to differing extents to different elements of U.S. agricultural R&D in aggregate in terms of fields of science, locations of production, or commodity orientation of research. This paper considers public funding for R&D directed to specialty crops. Specific questions to be addressed include whether R&D for specialty crops has been under-funded, both in absolute terms and relative to other crops and agriculture more generally. First, evidence is presented on past funding patterns and on rates of return; second, implications of that evidence in the context of specialty crops production are discussed.

2. Trends in U.S. Public Agricultural R&D[1]

In the United States, agricultural research is funded by the federal government through a variety of mechanisms. Historically the United States Department of Agriculture (USDA) has been the primary federal government agency channeling funds to the State Agricultural Experiment Stations (SAESs), but that is now changing.[2] In 1970, the USDA disbursed almost 70 percent of the federal funds flowing to the SAESs, but by 2004 that had declined to less than 50 percent, with more than half the federal funds now being disbursed by a wide range of federal agencies, including the National Science Foundation (NSF), the National Institutes of Health (NIH), the Department of Energy (DOE), Department of Defense (DOD), the U.S. Agency for International Development (USAID) and others. The USDA conducts intramural research, mainly through the Agricultural Research Service (ARS) in addition to distributing federal funds to the SAESs through a combination of formula funds, grants, and contracts.

Long-Term Trends

In 1889, shortly after the Hatch Act was passed, federal and state spending appropriations totaled $1.12 million. Over a century later, in 2004 the public agricultural R&D enterprise had grown to almost $4.2 billion, an annual rate of growth of 7.7 percent in nominal terms and 4.1

[1] This section draws on a forthcoming report by Alston, Anderson, James, and Pardey (2007).

[2] While farm acts authorize certain amounts of USDA funds to be used for particular programs, actual expenditures are set annually by agricultural appropriations acts. In the Research Title, appropriated amounts have often differed substantially from those authorized. Several grant programs authorized in earlier Research Titles were not appropriated the funds that were expected. In recent years, Congress has also tended to fund more grants specified by members of Congress than the broader grant programs requested by the Administration.

percent in real (i.e., inflation adjusted) terms.[3] Intramural USDA and SAES research accounted for roughly equal shares of public research spending until the late 1930s, after which the SAES share grew to 73 percent of total public spending on agricultural R&D by 2004 (Figure 1).

[Figure 1: *U.S. Public-Sector Agricultural R&D Spending by Performing Agencies*]

Of the funds spent in the SAESs in 2004, 41 percent came from federal sources, 39 percent from state government, and 20 percent from industry, income earned from sales, royalties, and various other sources. The share of SAES funds coming from federal sources has been increasing recently, and the composition of those funds has changed too, with an increase in competitive grants and a decline in formula funds (Figure 2). The public provision of extension services in the United States is essentially a state or local activity. Consequently funds from within-state sources accounted for 74 percent of the total funds for extension with federal funds accounting for the remaining 26 percent in 2004 (Figure 3).

[Figure 2: *SAES Research Expenditures by Source of Funds*]
[Figure 3: *Extension Expenditures by Source of Funds*]

The more recent patterns are of particular interest. Combined spending on all SAES and USDA intramural research grew rapidly during the 1960s and 1970s, averaging an increase of 2.83 percent per year in real terms over this period. Since then the growth has generally slowed, and become quite erratic. Total spending on public agricultural R&D grew by just 0.51 percent per year during the 1980s, and by 1.18 percent per year from 1990 to 2004 (but by only 0.45 percent per year during the 1990s followed by 2.65 percent annually from 2000 to 2004).[4] Federal support for intramural research conducted by the USDA has stagnated, but this has been

[3] To convert research spending from nominal values to real terms reflecting the purchasing power of the spending, in this report we divide nominal spending by an index of the unit costs of agricultural research, a price index for agricultural R&D, documented by Pardey and Andersen (2007). If we wanted to reflect the opportunity cost of that spending we might alternatively deflate by a general price index such as the price deflator for GDP.

[4] Similarly, real extension spending grew by 2.3 percent annually during the 1960s and 1970s, slowing to a rate of increase of just 0.26 percent per year during the 1980s and then contracting by 0.35 percent per year from 1990 to 2003 (with the rate of decline accelerating from 0.31 percent per year in the 1990s to 0.45 percent annually during the 2000-2003 period).

offset by increased federal support for SAES research. Support for extension has also stagnated in real terms, especially federal government support. In this paper we focus on public spending on agricultural research, without specific reference to extension although many of the same points would apply to extension. In addition, unless specific reference is made to private research spending, it is being set aside from the discussion for now.[5] Of interest is the extent of public support for research into specialty crops and how that has fared in the context of the generally evolving patterns of federal and state government support for agricultural R&D.

3. Funding for R&D on Specialty Crops

As shown above, aggregate public spending on agricultural R&D can be broken down between intramural USDA spending and SAES spending (some of which is financed from federal funds), state by state. The USDA also compiles information and reports spending on commodity-oriented research. The Current Research Information System (CRIS) database contains detailed information of this type, which can be used to examine the pattern of support for research, including the allocation among agricultural commodities and various types of other, non-commodity research. These commodity-specific spending figures, like the aggregate spending figures, can also be broken down into intramural USDA spending and SAES spending (some of which is financed from federal funds), state by state. In what follows we focus on national aggregate figures, rather than state-by-state figures, and examine patterns over time for spending on research into crops versus livestock and other research, and then within crops, between specialty crops and all other crops.

[5] In the United States, private agricultural research spending more than doubled in real terms from 1970 to 2000, and private research spending now exceeds public research spending (according to unpublished and updated data originally published in Klotz, Fuglie and Pray 1995). This growth has been associated with improvements in intellectual property rights (especially pertaining to plant varieties), and modern biotechnology, among other things.

Commodity Orientation of U.S. Public Agricultural Research Spending

The focus here is on public support for R&D on specialty crops. The Specialty Crop Competitiveness Act of 2004 (PL 108-465) defines specialty crops as: fruits and vegetables, tree nuts, dried fruits, and nursery crops, including floriculture. The proposed legislation, HR 6193 "Equitable Agriculture Today for a Healthy America Act" (sometimes referred to as the "Specialty Crop Farm Bill") maintains the definition from the 2004 Competitiveness Act.[6] This category includes a long list of crops. Table 1 lists a selection of these and other crops and shows crop-by-crop figures for (a) U.S. planted (or harvested) acreage in 2004, (b) the value of U.S. production in 2004, (c) total public spending on research for these crops in 2004, (d) the share of that spending undertaken by SAESs (versus the USDA on intramural research), (e) public spending on research as a percentage of the gross value of U.S. production in 2004, and (f) public spending on research per acre in 2004.

[Table 1: *Specialty Crops Acreage, Production, Value, and Research Expenditures in 2004*]

Specialty crop commodities vary substantially in terms of the size of the industry and the size of the corresponding public agricultural research budget, both in absolute terms and relative to the size of the industry. In this section we examine these patterns in depth. Before doing that, to provide some context, we consider the allocation of the total public agricultural research budget among different types of research. Figure 4 and Table 2 show the allocation of total U.S. public agricultural R&D spending (including both USDA intramural and SAES expenditure) over time between commodity-specific and other (i.e., non-commodity specific) research. Table 2 also allocates the research directed towards specific commodities between crops versus

[6] A subset of specialty crops are designated as "Mediterranean" crops, which have been defined by the Cal-Med consortium as including olives and olive oil; tree nuts; grapes and wine; raisins; vegetables—processed and fresh; citrus—processed and fresh; and stone fruits. The Mediterranean crop definition does not include nursery and floriculture, which are included in specialty crops, and it is unclear whether processed fruits and vegetables are included in the specialty crop definition contained in the 2004 Competitiveness Act and HR 6193.

livestock research; among the major categories within crops (i.e., grains and oilseeds, pasture and forage, other crop, and specialty crops); and then among the main categories of specialty crops (i.e., fruits and nuts, vegetables, and ornamentals). The top half of Table 2 includes the real (year 2000) dollar values of the expenditures (i.e., nominal values deflated by an index of agricultural research costs) while the bottom half of the table includes those expenditures expressed as shares of different sub-totals.

[Figure 4: *Allocation of U.S. Public Agricultural R&D Spending, 1975 and 2004*]
[Table 2: *Allocation of U.S. Public Agricultural R&D Spending, 1975 to 2004*]

The shares of spending have been fairly constant over time, with no significant discernible trend among the main categories. More substantial changes have been made in the allocations within major categories (e.g., consider beef cattle versus other livestock). Specialty crops research has been a fairly constant share of expenditure on crop-specific research (about 35 percent) which has held a fairly constant but slightly declining share of total research, drifting down from 37.8 percent in 1970, to 35.0 percent in 1980 and 34.6 percent in 2004.[7] Combining these two effects, the specialty crops share of total public agricultural research spending was fairly stable, between 14 and 16 percent over the 25 years 1980 through 2004. In turn, the allocation of specialty crops research among major categories was also fairly stable over the 25 year period, with roughly equal shares going to fruit and nuts and to vegetables (13 to 16 percent each out of the 35 percent spent on crops research) and a smaller share going to ornamentals (about 5 to 6 percent of the 35 percent).

[7] Crop-related research accounted for 41 percent of all public-sector agricultural R&D in 2004, several percentage points below the share of crop-related R&D in total R&D observed several decades earlier. Substantial amounts of agricultural R&D not specifically reported as crop-related R&D nonetheless have implications for crop production generally or a particular crop.

Congruence of U.S. Research Spending and Value of Production

Further insights can be gleaned by considering the commodity-by-commodity congruence between research funding and the value of production. In 2004, the aggregate *commodity-specific* (i.e., crop and livestock) research spending of $2,509 million (including $668 million of USDA intramural spending) represented 1.06 percent of the gross value of agricultural sales, compared with an overall agricultural research intensity (i.e., including all commodity and non-commodity specific research) of 1.53 percent. This compares with an overall intensity of 0.72 percent in 1975.

In Table 1 there are no readily discernible differences in agricultural research intensity ratios between specialty and field crops. One third (or 3 of 9 commodity areas) of the field crops reported in Table 1 had intensities higher than 1.5 percent, and roughly the same share of specialty crops (9 of 23) had intensities higher than 1.5 percent. However, a multitude of minor specialty crops have been omitted from this table.

Figure 5 presents a more comprehensive picture of the evolution of agricultural research intensity ratios for broad commodity categories since 1970. Including all relevant commodities, there has been little change around an essentially flat trend line for the intensity of public investment in specialty crops research. In contrast the intensity of investment in grains research (and hence all crop research) increased over time. Likewise, the intensity of investment of livestock research has risen as well. Notably, however, specialty crops had a higher intensity of public research investment than (mainly grain) crops subject to price supports under various U.S. farm programs from 1970 to about the late 1990s (Figure 5).[8] In the late 1990s and early 2000s, the intensity of R&D investment in program crops exceeded that for specialty crops, but by 2004

[8] "Program crops" include corn, soybeans, upland cotton, wheat, rice, feed grains (barley, oats, and grain sorghum) peanuts, oilseeds, lentils, chickpeas, and dry edible beans. Grain crops include barley, buckwheat, cowpeas, rice, millet, corn, wheat, sorghum, oats, rye and other small grains

the gap had narrowed such that program and specialty crops had much the same intensity of R&D investment. The total research intensity ratio expresses all public agricultural R&D—i.e., including research targeted to specific commodities plus all non-commodity R&D—relative to the total value of agricultural sales. This ratio rose steadily from 0.82 percent in 1970 to 1.53 percent in 2004, about 45 percent higher than the corresponding 2004 intensity of investment in commodity specific R&D (Figure 5, Panel b). This pattern is consistent with the finding (see Table 2) that a sizable, and of late growing, share of public agricultural R&D does not target specific commodities. The U.S. public agricultural research agenda has increasingly focused on concerns such as food safety, food security, and the environmental implications of agriculture that have little if any impact on enhancing or even maintaining farm-level productivity.[9]

[Figure 5: *Agricultural Research Intensities, 1970-2004*]

Figure 6 provides more commodity-specific detail on the pattern of agricultural output and the amount and intensity of public research spending for 2004. The figures for total spending over time on crop-specific research were broken down between SAES and USDA intramural research spending, and the agricultural research intensities were computed by dividing the total crop-specific research spending and its SAES and USDA intramural elements by the gross value of sales. To understand all of these patterns is a large assignment towards which we can only make partial progress here.

[Figure 6: *Commodity Specific Output, Research Spending, and Research Intensity in 2004*]

Comparing the right and left hand panels of Figure 6, there is an apparent but loose concordance between the value of crop sales and the amount of public R&D spending—higher-valued crops garner greater R&D spending. However, the amount of R&D spending does not rise uniformly with the value of crop sales. In Figure 6, the most valuable crop categories

[9] See Alston and Pardey (2007) for more discussion and details on this aspect of the changing U.S. agricultural R&D agenda.

(specifically corn, soybeans, and ornamentals and nursery) have especially low intensities of R&D spending compared with almost all of the lower-valued crop categories in this figure. Turning back to Table 1, we also see that large-acreage field crops have comparatively low public research spending per acre (and especially corn, wheat and soybeans, where less than two dollars per acre is spent on publicly performed R&D) while, for the smaller-acreage specialty crops, research spending per acre often exceeds 20 dollars, and in quite a few cases more than 40 dollars. These spending patterns suggest there may be economies of scale and size in research—solving a production problem for one acre solves it for all similar acres for any given crop.[10]

The site specificity of many crop production problems means that the location matters as well as the amount of acres. Crop acreage in a given location is likely to experience the same or similar production constraints as acres for the same crop in a physically different but agroecologically similar location. Moreover, crops that are grown in close proximity are usually (but not always) more likely to share similar agroecological attributes than if they were grown in distant locations. Figure 7 plots the cumulative distribution of R&D spending and the value of agricultural sales across the 48 contiguous U.S. states. Specialty crop output is concentrated in fewer states than crops generally, and certainly compared with all agricultural output. For example, the top five specialty crops producing states account for 65 percent of the U.S. total value of specialty crops marketings but the top five agricultural states account for only 35 percent of the value of agricultural sales.

[Figure 7: Spatial Distribution of Agricultural Sales Values and SAES Research Spending, 2004]

[10] Ruttan (1983) observed that research intensities were comparatively high for a number of smaller crops and questioned whether this allocation of research resources made economic sense.

4. The Economics of Specialty Crops R&D

This section presents theoretical arguments about the role for government in specialty crops R&D, versus other agricultural R&D, that may help explain the patterns of research investments. These arguments are supported with evidence from the literature on rates of return to different types of agricultural research and some analysis of patterns of crop-specific productivity growth and price patterns.

Economic Arguments

In the absence of other information, a first approach to allocating agricultural research resources is to use a congruence rule, as discussed by Alston, Norton, and Pardey (1995, pp. 488-490). Specifically, allocating public commodity-specific agricultural research resources strictly in proportion to the value of production (or sales) would lead to equal agricultural research intensities across all industries. Comparing specialty crops in aggregate with other crops, the agricultural research intensity for specialty crops is comparable now but has fallen in relative terms over time. Agricultural research intensities for specialty crops are comparatively low once we account for the fact that the research intensity tends to be inversely related with industry size, and the value of production of individual specialty crops is generally low.

The fact that actual agricultural research intensities are not congruent might reflect a number of factors at work. One possible interpretation is that research resources have been misallocated relative to maximizing the national social returns; that too little has been spent on specialty crops research either because of government failure owing to incomplete information, or as a reflection of the politics of research funding processes in which other commodity interests have been more influential. An alternative interpretation is that a lower public agricultural research intensity is warranted because the payoff to research on specialty crops could be expected to be comparatively low. For instance, differences in determinants of research benefits, including the size of the industry to which research results will be applicable, and differences in research costs, together mean that some industries have higher net research payoffs justifying higher rates of investment, everything else equal. This latter possibility is the focus of much of this section in which we consider theoretical arguments about the determinants of the likely payoff to public research investments, and some empirical evidence.

We do not propose to go deeply into the political economy of research funding. However, we do note that specialty crops have some features that seem likely to have influenced the agricultural research intensities regardless of the relative payoffs to different types of research. First, producers of specialty crops may have comparatively low political influence compared with producers of some of the larger crops owing to (a) the small individual importance of each specialty crop, (b) low relative importance of specialty crops collectively in the economics and politics of the states where they are grown, and (c) the diverse interests among different specialty crops. In addition, production of individual specialty crops tends to be comparatively concentrated geographically (with many of the crops produced mostly if not entirely in one state or only a few states); thus they have limited interstate research spillover potential, which reduces the justification for federal government involvement. Finally, specialty crops agricultural research intensities may be comparatively low simply as a reflection of the effects of inertia in research spending patterns during a period when the denominator (the value of production or sales) in the agricultural research intensity ratio has been growing relatively quickly for specialty crops compared with other commodities.[11] These and other political factors

[11] The rate of growth in the intensity of specialty crop research from 1975 to 2004 of 0.7 percent per year represents an annual 5.41 percent increase in nominal spending on specialty crops research and an annual 6.04 percent increase in the value of sales. This compares with a 6.37 percent increase per year in investments in public research in all other crops whose value of sales grew by 2.08 percent per year.

should be borne in mind along with the determinants of the costs and benefits that are considered next.

Some simple economic arguments do not favor (public) investments in specialty crops research. As shown by Alston, Norton, and Pardey (1995), the gross annual research benefits (*GARB*) to society from a given research-induced productivity gain are roughly proportional to the value of production (V): for a 100 k percent improvement in productivity, $GARB \approx kV$. In addition, the benefits accruing to private researchers from certain types of (appropriable) innovations increase with increases in the acreage of production to which they will apply. Thus, other factors equal, we would expect to find a comparatively low social and private payoff to R&D on individual specialty crops owing to the comparatively small size of production in terms of both area grown and value of production. In addition, a number of specialty crops face market conditions that are different from those for the stereotypical agricultural commodity (an annual, comparatively non-perishable crop that is internationally traded and for which demand facing the United States is fairly elastic, such that changes in U.S. production would have small effects on prices) and which mean research benefits are lower for producers and the nation. In the case of a crop like almonds, for instance, California faces a comparatively inelastic demand, which means that a significant share of research benefits go to consumers, a large share of whom are not in California or the United States. Thus, for a given total benefit, the benefits to producers, the state, and the nation are smaller. In addition, the perennial crop nature of almonds means that new technologies embodied in trees or certain other capital inputs can only be adopted at the time of new planting or replanting, and this influences the distribution of benefits and the incentives of producers to spend resources on developing new technologies.[12]

[12] Alston (2002b) discusses some general issues related to the implications of mis-matching of distributions of research benefits and costs for incentives, and refers specifically to this type of intertemporal mis-matching.

On the cost side, too, the conditions might not favor certain specialty crops research. Achieving a given research-induced productivity gain is likely to be more expensive for perennial crops (a large proportion of the fruit and tree nut categories within specialty crops are perennial) compared with annual crops (like vegetables and field crops generally) both because the individual experimental units are larger and more expensive and because research takes longer; and possibly for other reasons related to the biology of the plants and related scientific opportunities. In addition, there are some fixed cost components to the innovation process—including costs of compliance with regulatory processes that are onerous for pesticides and other chemical innovations and even more so for biotech crop varieties.[13] These factors mean that private research investors are less likely to find it profitable to invest in developing proprietary technologies for smaller-scale industries in general. Consequently, smaller-scale commodities are tending to become technological orphans both because of the effects of the size of the market (especially when we allow for buyer resistance to products certain types of technologies) and because of the overhead costs of R&D and regulatory compliance, both of which tend to favor research targeted towards the larger-scale commodities. Alston (2004) also makes the point, which is also relevant here, that the same factors that discourage private investment make the same investment less attractive to society as well, such that the lack of private investment does not necessarily mean that the government should invest to compensate.

These factors combined may mean that, everything else equal, we might anticipate relatively low private and social rates of return to research into specialty crops, and especially perennial crops, which could help justify a comparatively low public agricultural research intensity. But everything else is not equal, and a number of other factors could have contributed to a greater market failure and underinvestment in specialty crops research compared with

[13] Kalaitzandonakes, Alston, and Bradford (2006) estimated that the costs of complying with U.S. regulations for a new biotech crop variety range between $6 million and $16 million, which is very large relative to the potential value of such technology in many of the smaller specialty crop industries.

agricultural R&D more generally. If so, everything else equal, perhaps the government should invest relatively more in specialty crops R&D to compensate or should intervene in other ways to encourage more specialty crops research.

Sources of Market Failure

Why might there be a greater market failure in specialty crops research than in other commodity-specific research? First, the basic economic arguments made above—concerning effects of scale and size of the market, and so on—might mean that the incentives for private agricultural research investments related to specialty crops, and especially perennial crops, may be even more attenuated than those related to larger scale field crops like grains, oilseeds, or cotton. Whether this is so may depend on other determinants of incentives for research investments, especially the relevant intellectual property protection and other factors that determine the extent to which the returns to invention can be appropriated, including the degree to which the industry is concentrated in the production or marketing of the commodity in question.[14] Second, other forms of market failure, other than those related to research per se, may be important for specialty crops and may mean that the social payoff to research is higher than may be indicated otherwise. Potential sources of such distortions include aspects of production (including positive and negative environmental externalities associated with landscape amenities, and pollution of air and groundwater associated with the use of agricultural chemicals and irrigation), and aspects of consumption (including negative externalities through

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[14] Data on concentration ratios in the food industry may be relevant. A number of specialty crops industries have cooperatives that handle a significant share of production and some have marketing orders that are authorized to conduct marketing activities and to raise funds for industry collective goods, including agricultural research (e.g., see Carman and Alston 2005). A substantial amount of the intellectual property rights concerning plants in the United States pertain to specialty rather than field crops. Summing the total number of U.S. rights granted in the form of plant patents, varietal related utility patents, and plant variety protection certificates, Koo et al. (2007) report that only 22 percent of those rights related to cereal and oilseed crops. Specialty crops account for 71 percent of the total, with ornamental plants alone accounting for half of all the rights granted.

the healthcare and health insurance system associated with diseases and illness that may be reduced by consumption of specialty crops).

Among these possible reasons, consumption externalities are the most credible given the scale of human health problems in the United States related to diet and nutrition and the related social costs, the distortions in incentives inherent in the health care system in the presence of insurance, and the potential for specialty crops to contribute to more-healthy diets and thereby to reduce both the private and social costs of diet-related illness. The available time-series data indicate that over the period 1949-2004 farm and wholesale prices of fruits and vegetables did not fall as fast as the corresponding prices for agricultural commodities more generally and that, therefore, relative prices have moved against a healthier diet. This may have contributed to the current so-called epidemic of obesity. Of more potential relevance is the suggestion that the allocation of a greater proportion of the available research funds towards specialty crops could enhance productivity growth in, and a relative price decline for, specialty crops resulting in favorable effects on Americans' diets and significant social payoff through human health impacts.[15] The direction of these effects is clear but the quantitative importance is a matter for further research.

Rates of Return to Specialty Crops R&D

Previous studies have found a high private rate of return to agricultural research in general, and an even higher social rate of return. These findings support the argument that government intervention has been inadequate; that (even with the substantial government intervention) the observation of high rates of return means that even more money could have

[15] Alston, Sumner, and Vosti (2006) and Alston, Vosti, Sumner, and Kish (2007) documented and discussed these relative price trends, the role of government policy, and the possible implications for obesity. They concluded that other factors were relatively important contributors to the rise of obesity, but that an increased emphasis of R&D on specialty crops might help slow that growth. See, also, Cutler, Glaeser, and Shapiro (2003); Philipson and Posner (2003); Ladwalla, Philipson, and Battacharya (2005); and Gelbach, Klick, and Stratmann (2007).

been invested profitably in agricultural R&D. Similar arguments can be made with respect to particular types of agricultural R&D. A rate of return above the social opportunity cost of funds indicates an underinvestment in some absolute sense. A high rate of return on research into, say, specialty crops relative to other types of agricultural research would indicate a relative underinvestment: that it would have been profitable to have spent a larger share of the given total on specialty crops. Against that background, what does the evidence in the literature say about the private and social returns to research on specialty crops compared with the social opportunity cost of funds and compared with investments in other types of agricultural R&D?

Alston et al. (2000) reviewed the extant evidence on the rates of return to agricultural research. They compiled a total of 289 studies of returns to agricultural R&D (including extension), which provided 1,821 separate estimates of rates of return. For the present purpose we selected a subset of those estimates comprising (a) all estimates of rates of return to research related to specialty crops, separated into potatoes and other specialty crops, and (b) for comparison, estimates of rates of return to U.S. research on other (i.e., non-specialty) crops. We included estimates of returns to research done in other countries as well as U.S. research for specialty crops, but not for the other types of crop research. To narrow the basis for comparison, we excluded estimates of returns to extension. Table 3 reports some summary statistics on these selected estimates after we excluded as outliers all estimates of rates of return greater than 100 percent per annum, which were more prevalent for crops research than for specialty crops research. Appendix Table A1 contains more complete information on the studies in question.

[Table 3: *Rates of Return to Specialty Crops and Other Crops Research*]

It can be seen in Table 3 that the range of estimates of rates of return to specialty crops research falls generally within the range of estimates for crops research generally. As reported by Alston et al. (2000) in their meta-analysis, the signal-to-noise ratio is low such that it is difficult to identify statistically significant differences among estimates of rates of return to research according to particular characteristics of the research being evaluated—such as the nature of the commodity to which it applies. That general observation appears to apply to the comparison of returns to research on specialty crops versus other types of research. Further, the studies of research on specialty crops tended to focus on a small number of commodities (such as potatoes or certain tropical products) to the extent that the results may not be representative of the past returns to research on specialty crops in the United States, most of which were not represented in the studies cited. Thus, whilst there is no evidence from estimates of research benefits to indicate that specialty crops research has been less profitable than other types of agricultural research, nor is there any evidence from the same set of estimates to support a claim that specialty crops research was significantly more profitable and therefore inappropriately neglected.

Importantly, however, these estimates did not include any allowance for human health benefits from increased consumption of fruit and vegetables resulting from research-induced reductions in prices of fruit and vegetables. This dimension of potential benefits from research into specialty crops could be large, if research-induced price changes could be expected to contribute significantly to improved dietary quality and lower rates of obesity, and if so the rates of return may have been seriously understated.[16] Further, this factor changes the argument for public policy since some of the benefits would be associated with reductions in externalities in

[16] Work has begun in this area and results to date support the view that consumption and measures of obesity such as the "body mass index" are affected by relative prices of "healthy" and "unhealthy" foods—e.g., see Cutler, Glaeser, and Shapiro (2003); Philipson and Posner (2003); Ladwalla, Philipson, and Battacharya (2005); and Gelbach, Klick, and Stratmann (2007). Further work is needed to establish and quantify the links from R&D to relative prices, from price-induced changes in consumption and obesity to health outcomes, and from there to dollar values of social costs (e.g., as done by Gray and Malla 1998, 2001). A key point is that only very small changes in health outcomes will generate very large benefits relative to national expenditures on agricultural research. Results from Cash, Sunding, and Zilberman (2005) would support the conjecture that comparatively small research- (or subsidy-) induced changes in relative prices and consumption of fruit and vegetables would generate large net benefits through health impacts.

the health care system that would be ignored by the private sector in choosing research investments.

Prices and Productivity Growth for Specialty Crops

An examination of past changes in prices and production of specialty crops compared with other crops may yield some insight about the relative growth of supply and demand, and thus, indirectly, about the relative contributions of productivity growth among the different sectors. As shown in Figure 8, specialty crops have grown in importance relative to other crops and livestock; the specialty crops share of agricultural output value grew from 8.7 percent in 1949 to more than 21.3 percent in 2004.[17] Within specialty crops, the value shares of both ornamentals and fruits and nuts grew a little faster than the value share of vegetables.

[Figure 8: *Value of Specialty Crops as a Share of U.S. Agricultural Production*]

Part of the reason for the increase in value share has been the change in relative prices. Panel a, Figure 9, shows the nominal prices for the main product categories. The prices of specialty crops have grown both absolutely and relative to field crops and livestock products, which have had fairly static nominal prices for the 20 years prior to 2004 in spite of general cost inflation.[18] Panel b, Figure 9 shows the same price series deflated by an index of prices received by farmers and in Panel c specialty crops prices are deflated by the implicit price deflator for gross domestic product (representing prices generally in the economy). Figure 10 shows the corresponding (Panel c) average annual rate of change in deflated output prices for the 1950-2004 period. Prices received by farmers for all crop categories trend down relative to prices paid by consumers for all goods and services. The increase in consumption could be accounted for by

[17] Specialty crops grew from 17.7 percent of the total value of crop production in 1949 to 41.2 percent in 2004.

[18] As discussed by Alston, Sumner, and Vosti (2006), and Alston, Vosti, Sumner, and Kish (2007), some of these price increases for specialty crops might reflect premia for changes in quality, variety, or seasonal availability, which might not have been fully addressed in the indexing procedure. This possibility is a subject for continuing research, and is set aside for the time being.

the lower real price or growth in demand, or a combination of the two. The increase in production in spite of lower real producer prices indicates that productivity must have increased.

[Figure 9: *Prices of Specialty Crops—Nominal and Real Values, 1949-2004*]
[Figure 10: *Real Movement in Prices of Specialty Crops, 1949-2004 annual averages*]

A first impulse may be to assume that, since prices have fallen faster for other products (i.e., field crops and livestock), the rate of productivity growth must have been comparatively slow for specialty crops, suggestive of a comparative underinvestment in productivity-enhancing research for specialty crops. However, such an interpretation may not be justified. More specific interpretations are possible if we have more information. Specifically, if we know the elasticity of supply, we can partition changes in production into those associated with changes in prices and those associated with changes in the quantity supplied; and if we know the price elasticity of demand, we can partition changes in consumption into those associated with changes in prices and those associated with changes in quantities demanded. Here, we are mainly interested in the supply side. The indexes of prices and quantity for the different categories of output grew at different rates over the period 1949 through 2004, as summarized in Table 4. The indexes all started at 100 in 1949. By 2004 the quantity indexes had reached 212 for livestock (i.e., the index grew by 112 percent), 278 for field crops, 262 for vegetables, 283 for fruits and nuts, and 742 for nursery and greenhouse marketing. In contrast, the corresponding price indexes were 307 for livestock, 190 for field crops, 489 for vegetables, 519 for fruits and nuts, and 534 for nursery and greenhouse marketing. Dividing by the GDP deflator, which had grown from 1.0 in 1949 to 6.69 in 2004, the corresponding real price indexes were 45.9 for livestock, 28.4 for field crops, 73.1 for vegetables, 77.5 for fruits and nuts, and 79.8 for nursery and greenhouse marketing. Suppose, for the sake of argument, that the relevant elasticity of supply is $\varepsilon = 1.0$ (a value of $\varepsilon = X$ means that a 1 percent increase in price would call forth an X percent increase in production). A real price index of 45.9 for livestock in 2004 indicates a price decrease of 55.1 percent since 1949, which given ε = 1.0, ceteris paribus, would imply a 55.1 percent decrease in quantity supplied. Subtracting the price-induced change in quantity supplied (– 55.1 percent) from the overall observed growth in quantity (112 percent) implies an increase in livestock supply of 167.1 percent (i.e., 112 – (– 55.1) = 167.1 percent). Table 4 reports the corresponding computations for each category of production using an elasticity of supply of either ε = 1.0 or ε = 0.5.

[Table 4: *Growth in Production and Prices for Agricultural Products, 1949–2004*]

Considering the estimates made using an elasticity of ε = 1.0, the computed growth rates of supply of vegetables as well as fruits and nuts fall in between those of livestock and field crops. Only greenhouse and nursery is outside the typical range for livestock and other crops. When we use an elasticity of ε = 0.5 instead, the differences in the computed growth rates of supply are reduced. In either case, with the exception of nursery and greenhouse, which has been growing much faster but from a very small base, supply of specialty crops has been growing at a rate similar to that for the supply of U.S. agricultural products generally. Thus there is not a prima facie case to suggest that specialty crops have been technological orphans. Of course, we have not identified the source of the growth in supply, and it might be mostly from capital investment in fruit and nuts, and mostly from new technology in field crops, but whether that is so remains a matter of speculation for now.[19]

Collective Action as a Correction for Incentive Problems

A case can be made that an increase in the rate of investment in specialty crops research would be profitable for both the industry and society more generally (whether from the viewpoint of the nation or the state of California that produces many of the specialty crops

[19] Data on yields per acre, or other partial productivity measures, and acreage planted to the different crops may provide some further insight into the sources of growth. This is a subject for continuing research.

considered here). And, to the extent that inter-industry spillovers of technology or health-care externalities are important sources of benefits, a further case can be made for contributions by the state or federal governments to reinforce investments that the industry finds profitable to make. Industry advocates have suggested that the annual public investment should be a billion dollars, roughly twice the current amount. However, a substantially increased commitment of federal or state government funds to specialty crops research must come at the expense of other government priorities, and may be hard to secure on an enduring basis, if at all.[20] In its proposal for the 2007 Farm Bill, the USDA proposed an additional $100 million per year for specialty crops research, and even this amount may be hard to secure.[21]

An alternative approach, combining collective action by industry with support from government, may be more effective as a way of securing a long-term commitment of funding support, and may be a fairer and economically more efficient way to finance an increase in specialty crops research funding. Specifically, rather than intervene directly, the government could establish institutions whereby the industry itself could raise research funds using commodity levies supported by matching government grants.[22] In Australia, this approach has proven very successful as a way of locking in government support for commodity-oriented agricultural research, and has allowed substantial growth in total funding, to the point where the Research and Development Corporations (RDCs) now drive the total agricultural research activity in Australia.

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[20] The gross evidence presented here does not clearly support shifting the balance of existing research resources towards specialty crops. A shift of that magnitude would not go un-noticed by the others interested in the allocation of public agricultural research resources. On the other hand, half a billion dollars is much smaller as a share of spending on farm commodity programs and the like, with recent annual spending in the range of $20 billion, more than 10 times the federal commitment to agricultural research.

[21] Details on the USDA 2007 Farm Bill Proposals can be found on the USDA Economic Research Service web site, at http://www.ers.usda.gov/Features/FarmBill2007/ (accessed May 20, 2007).

[22] These policies are discussed in detail by Alston and Pardey (1996) and Alston Pardey and Smith (1999), and more recently by Alston (2002) and Alston, Freebairn and James (2003, 2004).

As documented by Carman and Alston (2005), California specialty crops producers are quite willing to tax themselves to finance industry collective goods such as standards, inspection, research, and commodity advertising and promotion, even without the additional incentive provided by matching government grants. As shown in Table 5, in 2002 54.8 percent of California agricultural production was subject to a mandated marketing program; the percentage was much higher for fruits and nuts (73.5 percent), but somewhat lower for vegetables (43.1 percent). As shown in Table 6, these programs spent over $200 million in 2002. Of that total perhaps one quarter was spent on programs for livestock and field crops, which leaves $150 million for specialty crops; but very little of that money was spent on agricultural research, in the range of one-tenth of the total.

[Table 5: *California Commodities Covered by Marketing Programs, 2002*]
[Table 6: *Expenditure by California Marketing Programs, 2002*]

Rather than simply press for an increased amount of funding for specialty crops research to be provided in the conventional fashion—to be diverted from alternative allocations on other research or from other parts of the farm bill—it might be more effective to develop a proposal for joint public-private funding of a substantial increase in specialty crops research using the Australian RDC model as a template, but perhaps in the context of the legal framework under which marketing orders and like institutions are created in the United States.

5. Conclusion

Specialty crops have become increasingly important relative to other categories of agricultural production in the United States over the past 50 years, especially during the past 25 years. The growth in the value of production of specialty crops has not been matched by commensurate growth in public agricultural research spending. The specialty crops share of spending on crops research (or on all agricultural research) has remained approximately constant during a period when the specialty crops share of the value of production has increased significantly. In addition, the agricultural research intensity ratio for specialty crops—expressing research spending as a share of the corresponding value of output—changed little over the past several decades, while agricultural research intensities were rising generally. Thus, the relative intensity for specialty crops has fallen. By 2004, the R&D investment intensities for specialty and program crops were roughly equal, though for many years there was substantially more intensive R&D investment in specialty crops than in crops research generally (or program crops in particular). However, this overall picture masks a great deal of variation among crops within the category specialty crops.

Everything else equal, and in the absence of better information, research funding could be based on a congruence rule. Such a rule would dictate equal research intensities among all agricultural commodities, and to achieve this outcome would require increasing the share of spending allocated to some specialty crops (and lowering it for some others). Such a congruence rule may not be appropriate for specialty crops. Research on some specialty crops may have a relatively low private or social payoff because the acreage and value of production of individual commodities are relatively small, which limits the potential for taking advantage of economies of scale in research and in adoption of the results from research unless there are substantial economies of scope among specialty crops research projects. On the other hand, for similar reasons, the extent of market failure from private sector neglect of research opportunity may mean that there is a comparatively high social rate of return to public investment in research on specialty crops. There is limited direct evidence available to support either of these conjectures.

In 2004, a little over half a billion dollars was spent on research directly related to specialty crops, which amounted to almost 14 percent of total public agricultural research spending and a little over 20 percent of spending for public research on crops and livestock.

These recent broad allocations have been approximately consistent with a broad congruence rule. In addition, relative growth rates of supply (or perhaps productivity) have been comparable between specialty crops and the rest of agriculture—with the exception of the very rapidly growing greenhouse and nursery products—, a pattern that is not obviously inconsistent with a balance existing in the allocation of research resources. Finally, the available evidence is consistent with a view that research on specialty crops has yielded rates of return comparable to research on other crops, though these results relate mainly to research on comparatively large-scale commodities, such as potatoes. Taken together, these observations do not provide support for a major shift in the allocation of public agricultural research resources towards specialty crops.

An additional argument can be made that research on some specialty crops may have a larger social rate of return if it makes fruit and vegetables cheaper and therefore contributes to encouraging Americans to eat healthier diets. This effect alone is not sufficient to justify a policy shift. There must also be a market distortion in health care that entails a negative externality (a social cost not borne by private individuals) that would be reduced as a result of specialty-crops research. Direct evidence on that issue is not available either, but the social costs of the health care system are sufficiently large that only a small improvement caused by research-induced dietary change would be sufficient to justify sizable increases in agricultural research spending (e.g., see Gray and Malla 1998, 2001). One might argue, however, that, if agricultural science is to be used as an instrument of public health policy in this way, the funding ought to be provided by other arms of the government, such as the NIH, rather than by the USDA or as an earmarked component of Title 7 of the U.S. Farm Bill.

The U.S. government could act in a number of ways to enhance specialty crops research. One option would be simply to redirect funding that would otherwise be spent on other types of agricultural research or on farm commodity programs. Alternatively, the government could seek to encourage collective action to be undertaken by commodity groups. Specialty crops producers are very actively engaged in check-off-funded programs, but they spend the lion's share of the funds they raise on commodity promotion programs. These promotion programs have been subject to controversy and litigation. The Australian government offers matching grants for levy-funded research and this policy has facilitated a very significant growth in commodity-specific research managed by producers with joint funding by industry and government. State governments could also develop programs of this type to enhance funding support for specialty crops research or, indeed, any type of commodity specific research that has a natural funding base.

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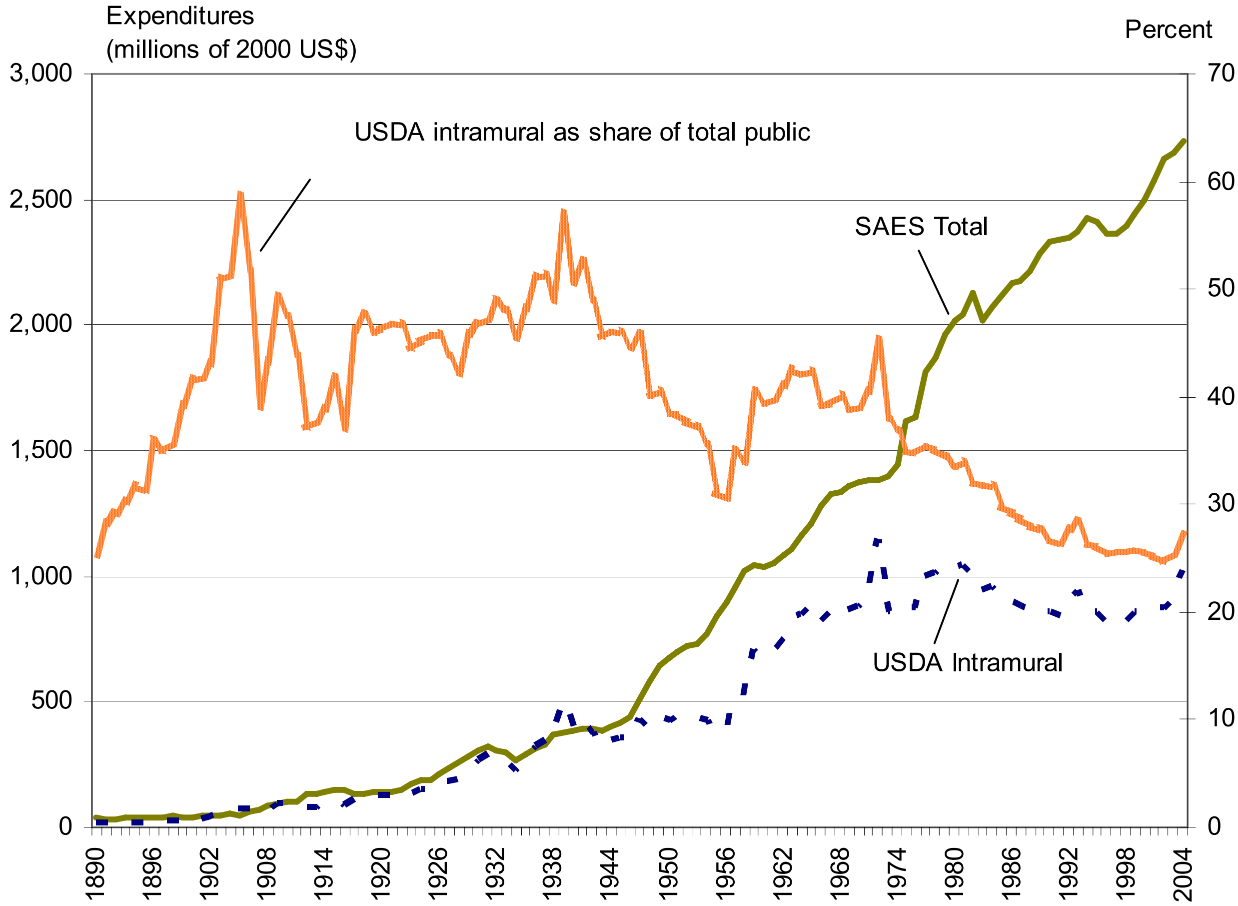
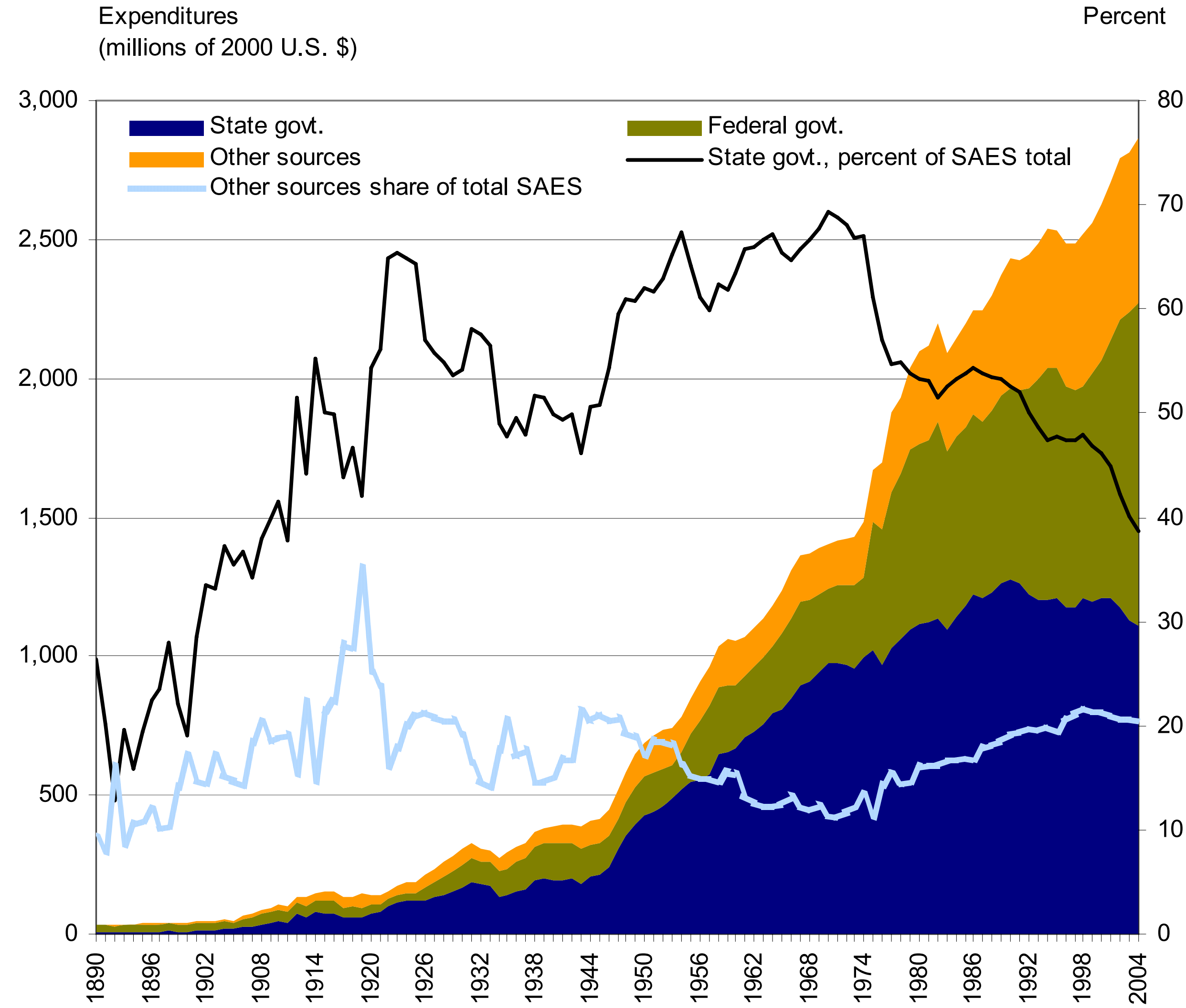
Figure 1: ***U.S. Public Sector Agricultural R&D Spending by Performing Sector***



Source: SAES series extracted from CRIS data tapes and USDA's *Inventory of Agricultural Research* publications. USDA Intramural series developed from unpublished USDA budget reports.

Note: Nominal research expenditure data were deflated by a U.S. agricultural research price index reported in Pardey and Andersen (2007). SAES Total includes 48 contiguous states, excluding Alaska and Hawaii which totaled $27.36 million in 2004 (or $24.5 million in 2000 prices)—just 0.85 percent of the 50 state total. These data are inclusive of all but the forestry R&D performed by the SAESs and the USDA.

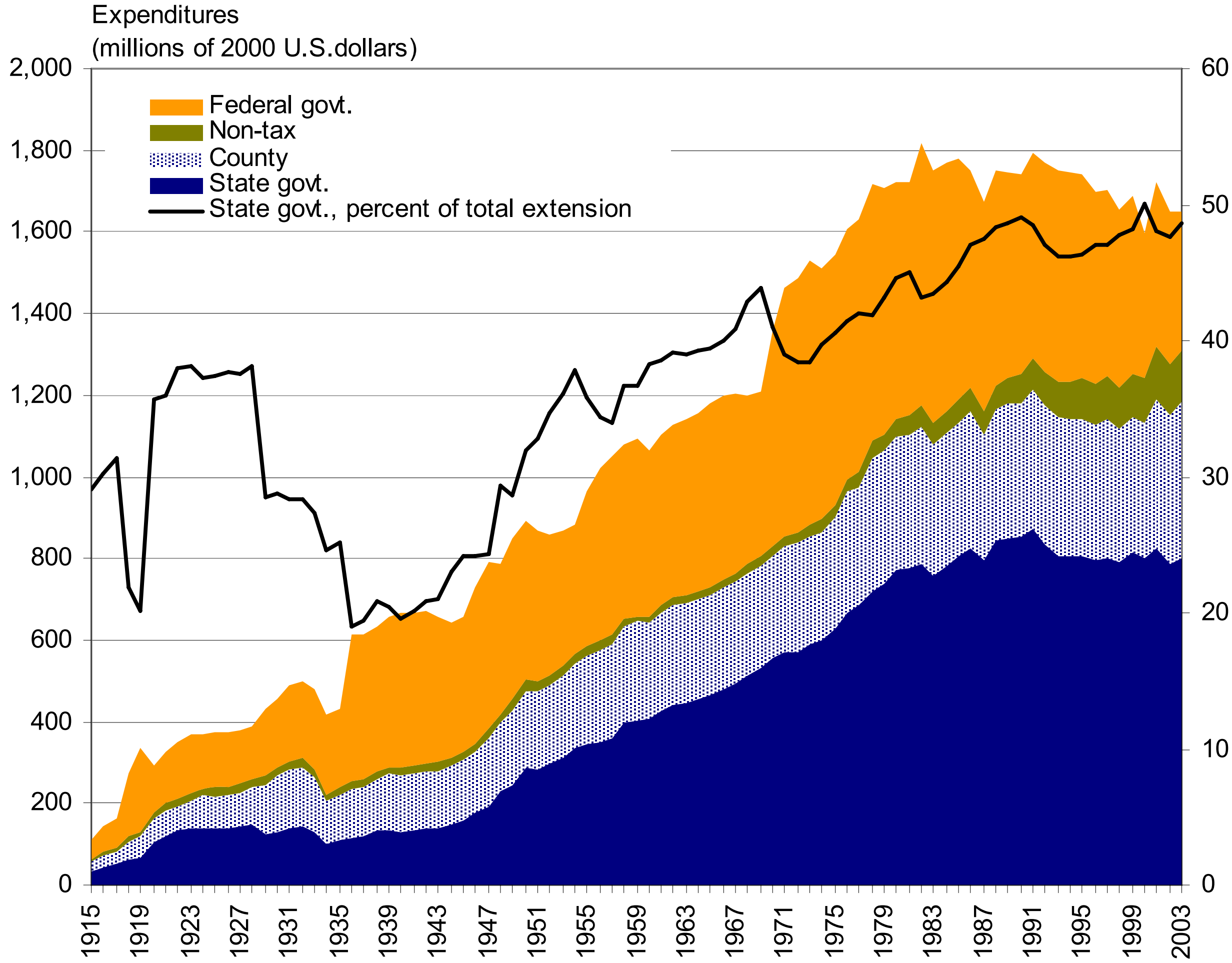
Figure 2: ***SAES Research Expenditures by Source of Funds***



Source: SAES series extracted from CRIS data tapes and USDA's *Inventory of Agricultural Research* publications. USDA Intramural series developed from unpublished USDA budget reports. See Pardey and Andersen (2007) for details.

Note: Nominal research expenditure data were deflated by a U.S. agricultural research price index reported in Pardey and Andersen (2007). The data included here refer to the source of funds for all the R&D performed by the SAESs.

Figure 3: ***Extension Expenditures by Source of Funds***



Source: See Pardey and Andersen (2007) for details.

Note: Nominal extension expenditure data were deflated by a U.S. agricultural research price index reported in Pardey and Andersen (2007).

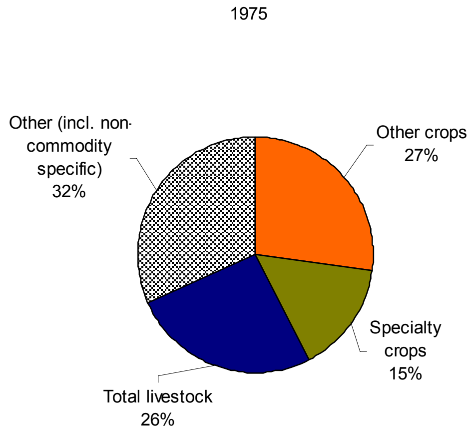
Table 1: ***Specialty Crops Acreage, Production, Value, and Research Expenditures in 2004***

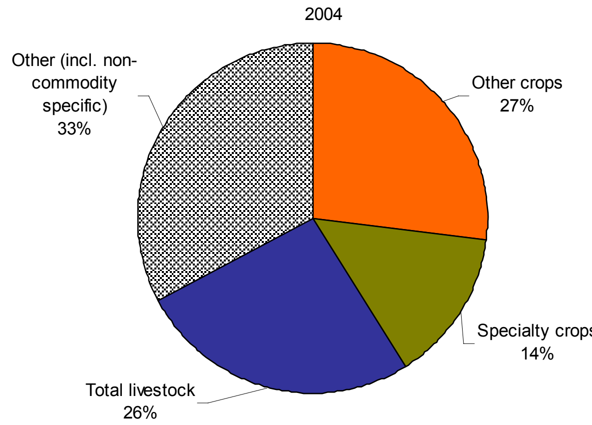
	U.S. Planted Acreage	Total Value of Sales	Total Public R&D	SAES Share of Total R&D	R&D Spending as a Share of Value of Sales	R&D Spending per Acre
	1000 acres	*1000 US$*	*1000 US$*	-------- *Percent* --------		*US$/ac*
Specialty crops						
Vegetables						
Tomato (fresh and processed)	770	2,156,518	33,782	75.9	1.57	43.89
Potato	1,193	2,384,178	43,854	59.6	1.84	36.75
Greens and leafy vegetables	319	2,223,078	12,652	67.2	0.57	39.71
Carrot	117	111,560	3,157	69.0	2.83	27.04
Peppers	57	518,344	7,260	65.1	1.40	127.14
Onion, garlic, leek, shallot		1,134,280	5,227	82.1	0.46	
Beans	1,354	438,794	9,632	85.6	2.20	7.11
Mushrooms		606,373	2,167	94.0	0.36	
Fruits and nuts						
Grapes (fresh, dried and wine)	933	3,003,553	34,527	62.1	1.15	37.00
Apples	386	1,766,698	29,712	64.5	1.68	76.88
Pears	64	286,286	5,450	41.3	1.90	84.95
Peaches	146	461,624	10,648	59.7	2.31	73.16
Cherries	115	507,074	4,918	68.8	0.97	42.68
Other stone fruits		323,387	12,736	65.4	3.94	
Oranges	761	1,714,499	9,051	40.1	0.53	11.89
Lemons	60	304,558	1,692	43.9	0.56	28.29
Strawberries	52	1,460,362	12,477	61.8	0.85	241.80
Other berries		904,145	11,904	67.1	1.32	
Almonds	550	2,189,005	2,705	45.6	0.12	4.92
Walnuts	217	451,750	2,259	59.5	0.50	10.41
Ornamentals and Nursery						
Trees and shrubs		499,323	23,125	66.6	4.63	
Potted plants			6,189	75.9		
Cut flowers, foliage and greens		5,215,192	2,989	92.1	0.06	
Other ornamentals and nursery		9,995,965	53,001	91.0	0.53	
Other Crops						
Grains, oilseeds, and sugar						
Corn	80,929	21,199,263	121,584	57.8	0.57	1.50
Wheat	59,674	7,123,970	102,665	62.5	1.44	1.72
Rice	3,347	1,768,284	46,050	73.7	2.60	13.76
Barley	4,527	597,959	20,138	58.2	3.37	4.45
Sorghum	7,486	818,000	20,239	63.4	2.47	2.70
Sugar beets	1,346	1,106,878	11,533	33.6	1.04	8.57
Sugar cane		864,479	12,948	45.3	1.50	
Soybeans	75,208	16,441,344	103,790	67.5	0.63	1.38
Other grain and oilseeds	6,981	6,940,046	87,498	65.0	1.26	12.53
Total Crops		**113,684,233**	**1,488,877**	**68.2**	**1.31**	

Source: U.S. planted acreage downloaded from NASS (www.nass.usda.gov); Value of sales (cash receipts) U.S. Production: USDA-ERS farm cash receipts data downloaded from http://www.ers.usda.gov/data/FarmIncome/;Total Public R&D: authors' computation based on CRIS data tapes.

Note: Total R&D is total commodity-specific agricultural R&D undertaken by SAES and USDA, exclusive of research on forestry, rangeland, recreation and wildlife, game birds and animals, pets, laboratory animals, aquaculture and fisheries, horses, ponies, and mules. Other stone fruits include apricots, prunes, nectarines, and so on.

Figure 4: ***Allocation of Public Agricultural Research Expenditures, 1975 and 2004***





Total: $2.19 billion, 2000 prices

Total: $3.25 billion, 2000 prices

Source: Extracted from CRIS data tapes.

Note: Public agricultural research includes SAES and intramural USDA agricultural R&D spending, exclusive of research on forestry, rangeland, recreation and wildlife, game birds and animals, pets, laboratory animals, aquaculture and fisheries, horses, ponies, and mules.

Table 2: ***Allocation of U.S. Public Agricultural R&D, 1975–2004***

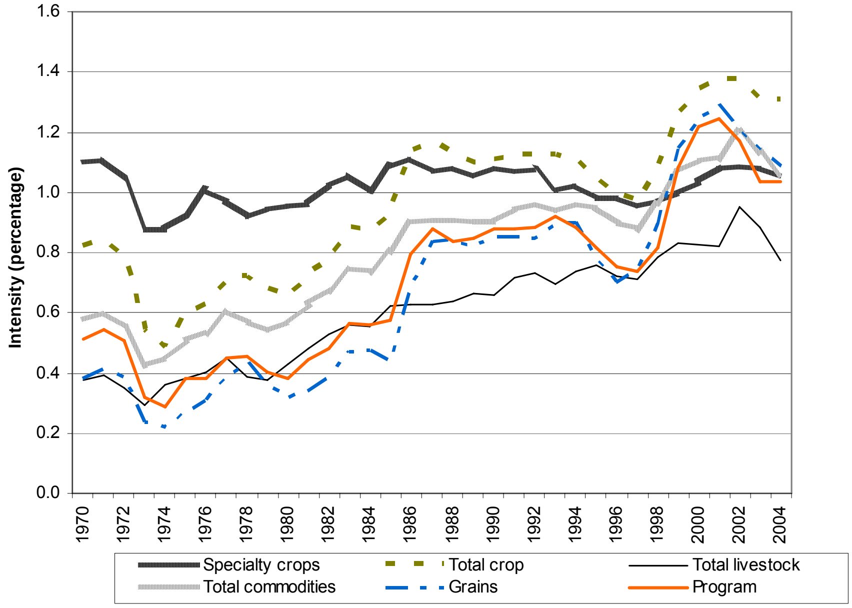
	1975	1980	1990	2000	2004
			(million dollars, 2000 prices)		
Expenditures					
Crops total	934.3	1,178.5	1,220.6	1,229.1	1,333.6
Specialty crops	336.8	412.5	434.1	434.3	461.6
Other (non specialty crops)	597.5	766.0	786.4	794.9	871.9
Livestock total	567.3	731.4	806.9	815.7	850.4
Other total (includes non-commodity)	691.5	724.0	771.0	834.4	1,064.7
All Research	*2,193.1*	*2,633.9*	*2,798.4*	*2,879.2*	*3,248.8*
Crops					
Grains and oilseeds	275.5	365.4	412.4	426.9	451.3
Pasture and forage	77.2	110.9	95.2	73.7	73.2
Other crop	244.8	289.8	278.8	294.3	347.5
Specialty crops	336.8	412.5	434.1	434.3	461.6
Vegetables	131.5	168.1	195.3	193.9	197.8
Fruits and nuts	148.0	172.9	172.1	170.5	187.5
Ornamentals	57.3	71.4	66.7	69.9	76.4
Livestock					
Beef Cattle	180.6	247.6	224.2	181.2	195.3
Dairy Cattle	142.7	168.8	175.7	162.2	155.5
Poultry	98.7	103.9	116.5	113.4	121.1
Swine	75.2	99.7	116.6	120.4	97.0
Other livestock	70.2	111.4	173.9	238.5	281.4
			(percentage)		
Expenditure Shares					
Crops total	42.6	44.7	43.6	42.7	41.0
Specialty crops	15.4	15.7	15.5	15.1	14.2
Other (non specialty crops)	27.2	29.1	28.1	27.6	26.8
Livestock total	25.9	27.8	28.8	28.3	26.2
Other total (includes non-commodity)	31.5	27.5	27.6	29.0	32.8
All Research	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Share of crop total					
Grains and oilseeds	29.5	31.0	33.8	34.7	33.8
Pasture and forage	8.3	9.4	7.8	6.0	5.5
Other crop	26.2	24.6	22.8	23.9	26.1
Specialty crops	36.0	35.0	35.6	35.3	34.6
Vegetables	14.1	14.3	16.0	15.8	14.8
Fruits and nuts	15.8	14.7	14.1	13.9	14.1
Ornamentals	6.1	6.1	5.5	5.7	5.7
Share of livestock total					
Beef Cattle	31.8	33.9	27.8	22.2	23.0
Dairy Cattle	25.1	23.1	21.8	19.9	18.3
Poultry	17.4	14.2	14.4	13.9	14.2
Swine	13.3	13.6	14.4	14.8	11.4
Other livestock	12.4	15.2	21.5	29.2	33.1

Source: Extracted by authors from CRIS data tapes.

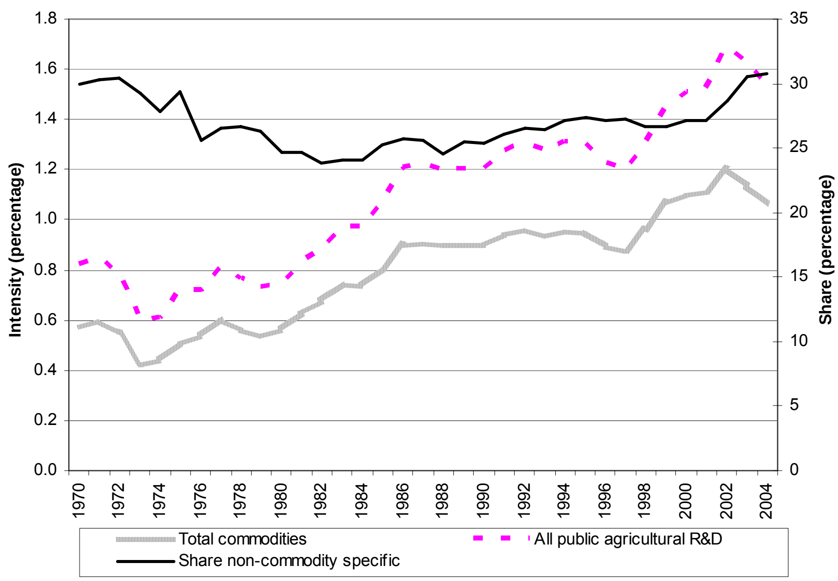
Note: Nominal research expenditure data were deflated by a U.S. agricultural research price index reported in Pardey and Andersen (2007). Public agricultural research includes all SAES and intramural USDA spending, exclusive of research on forestry, rangeland, recreation and wildlife, game birds and animals, pets, laboratory animals, aquaculture and fisheries, horses, ponies, and mules. “Other total” includes food (not readily associated with specific plant and animal products), economic and other social science research basic R&D, and environmental and resource-related research not directly attributable to a particular commodity.

Figure 5: *Agricultural Research Intensity Ratios, 1970-2004*

Panel a: Commodity-specific intensity ratios



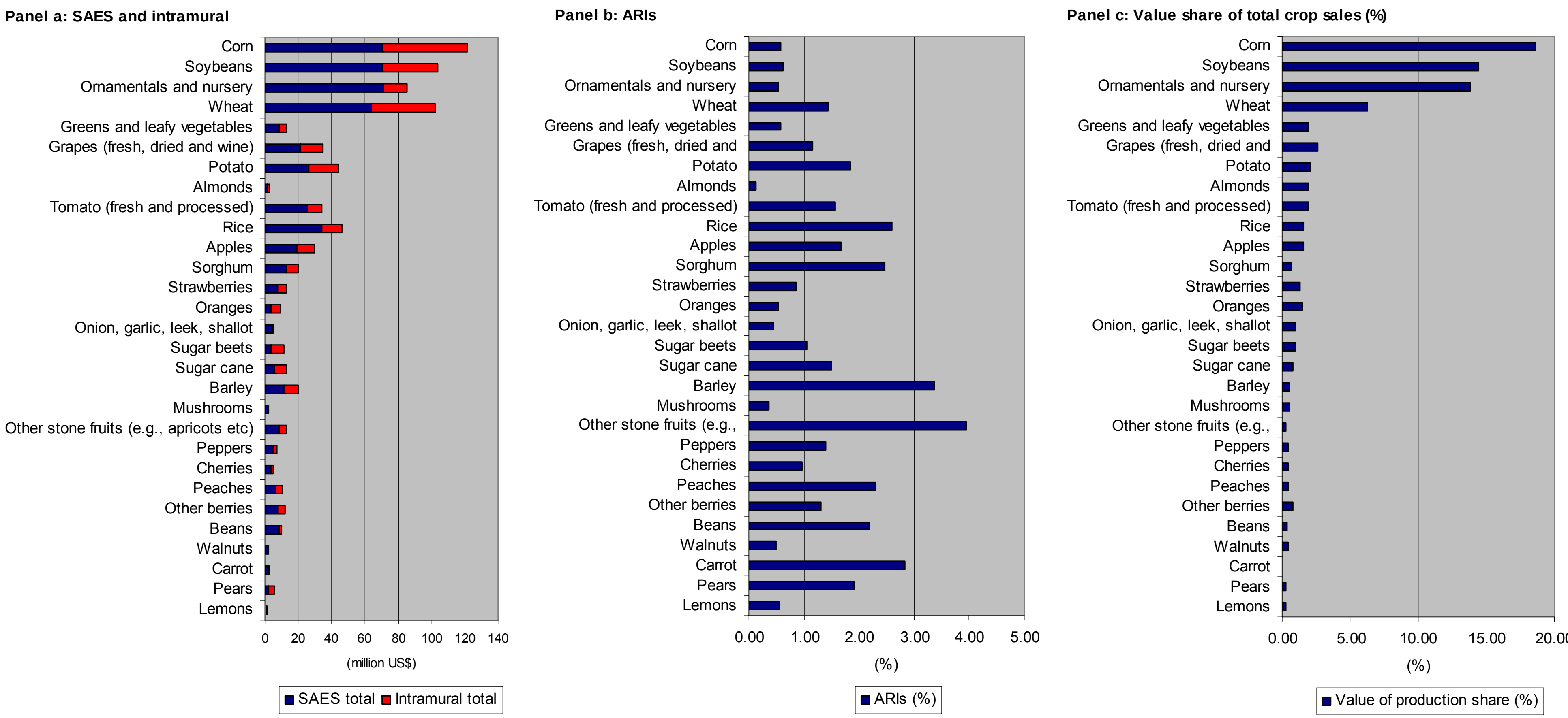
Panel b: Overall intensity ratios



Source: See Figure 1 for details on R&D series. Details on the cash receipts series are in Alston, Andersen, James, and Pardey (2007).

Note: Here each agricultural research intensity ratio is the ratio of public agricultural research spending to the corresponding value of cash receipts. Public agricultural research includes all SAES and intramural USDA spending, exclusive of research on forestry, rangeland, recreation and wildlife, game birds and animals, pets, laboratory animals, aquaculture and fisheries, horses, ponies, and mules. Panel a includes only public research identified as commodity-specific R&D. The "Total crop" series includes all research related to a specific crop or to multiple crops, and similarly so for the "Total Livestock" series. "Total commodities" research is the sum of total crops and total livestock research. Panel b repeats the "Total commodities" series from Panel a and by way of comparison also includes the intensity of non-commodity specific R&D performed by the public sector (expressed relative to the value of cash receipts) plus the ratio of *all* public agricultural R&D (total commodity plus non-commodity R&D) spending and the value of cash receipts. Cash receipts exclude sales of forestry, aquaculture and fisheries products. Ostensibly, farm gate (or first point of sale) prices and quantities marketed by farms are used to form the cash receipts series.

Figure 6: ***Research Spending versus Value of Sales, Various Commodities, 2004***

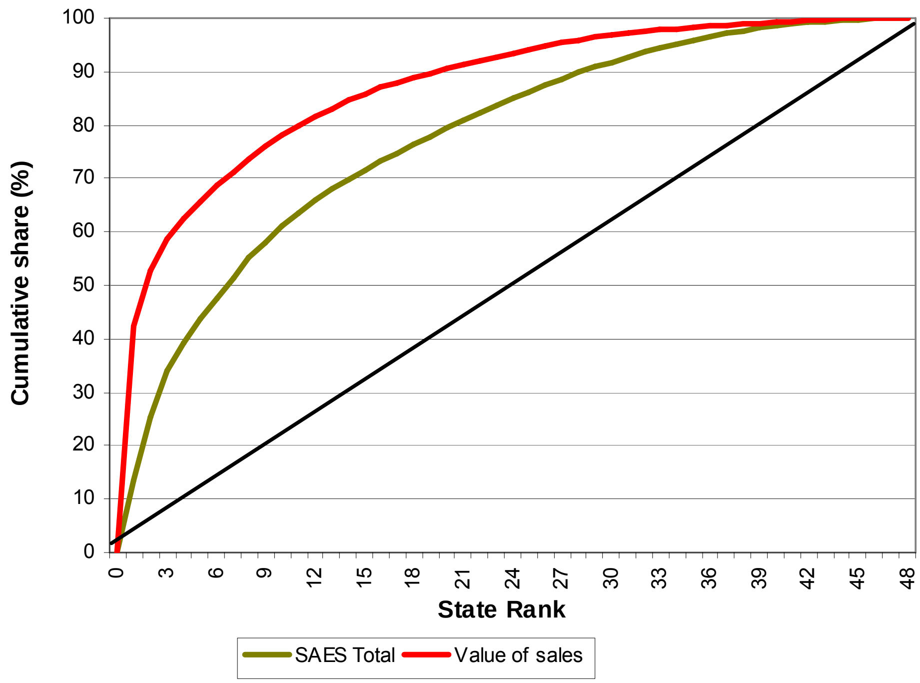


Source: See Figure 1 for details of R&D data. Value shares of crop sales drawn from USDA-ERS farm cash receipts data downloaded from http://www.ers.usda.gov/data/FarmIncome/.

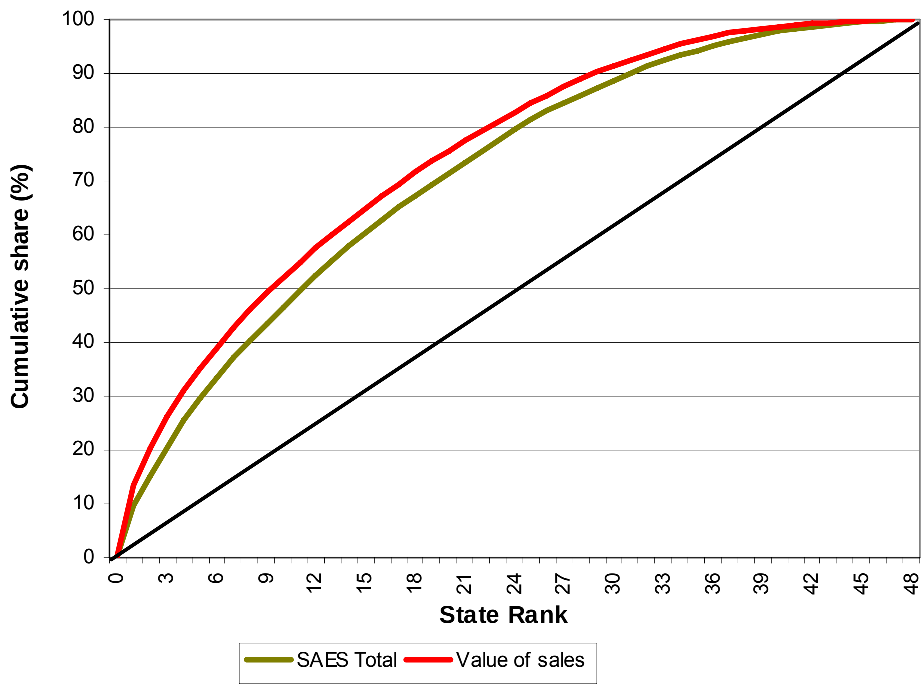
Note: Public agricultural research includes all SAES and intramural USDA spending as defined in the notes to Table 2.

Figure 7: Spatial Distribution of Agricultural Sales Values and SAES Research Spending, 2004

Panel a: Specialty Crops



Panel b: Total (all agricultural output)



Source: See Figure 6 for details.

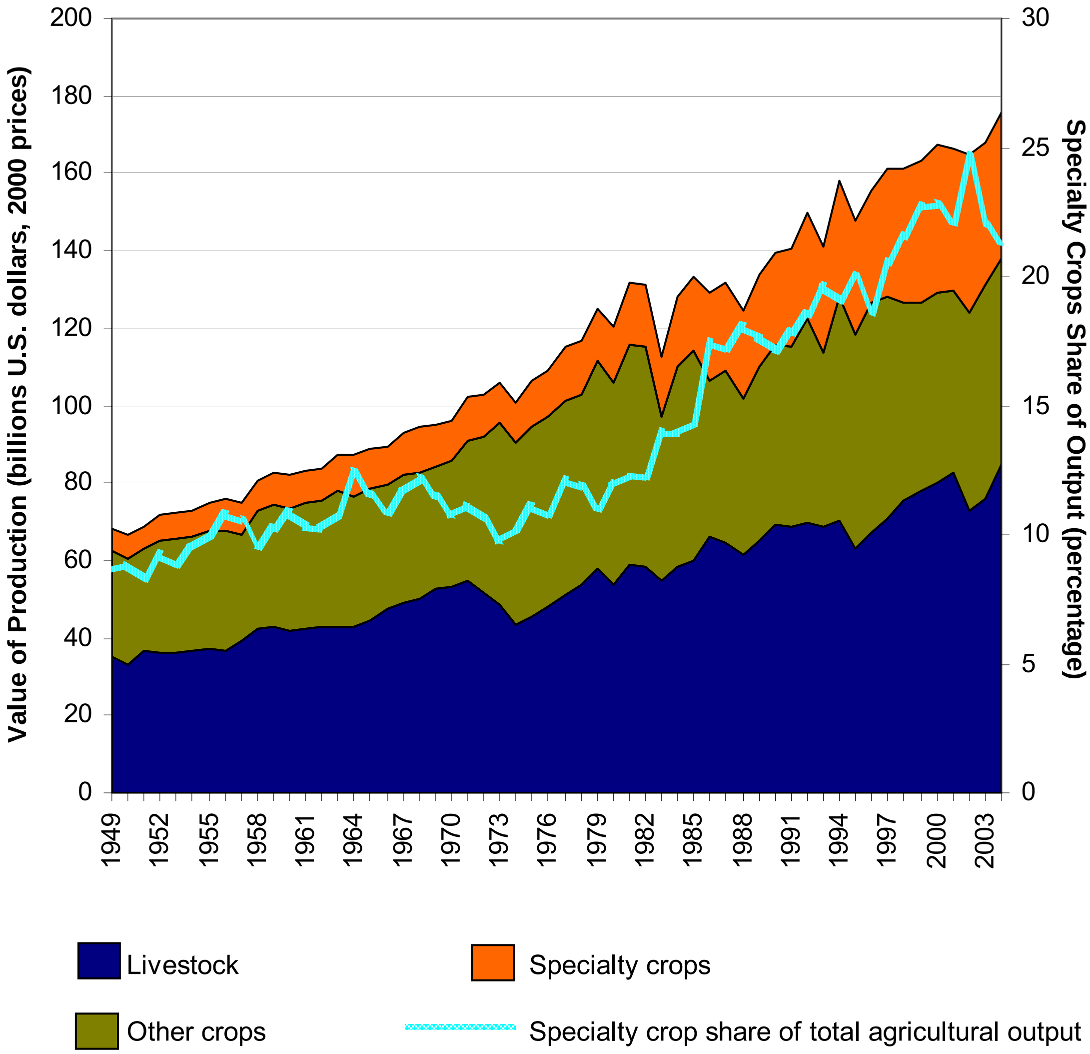
Note: SAES and intramural USDA agricultural R&D spending is exclusive of research on forestry, rangeland, recreation and wildlife, game birds and animals, pets, laboratory animals, aquaculture and fisheries, horses, ponies, and mules.

Table 3: *Rates of Return to Specialty Crops and Other Crops Research*

Crop	Total number of studies	Observations		Rate of return		
		Total Number	U.S. Share	minimum	maximum	average
	count		*percent*	*percent per annum*		
Potato	11	21	47.6	1.05	100.0	44.8
Other specialty crops	8	33	48.5	1.4	92.8	30.7
All specialty crops	19	54	48.1	1.05	100.0	36.2
Corn	20	62	8.1	-6.9	96.9	40.0
Wheat	32	103	24.3	11.1	97.0	47.9
Rice	31	15	6.5	11.44	99.6	54.8
All crops	111	520	18.3	-7.4	100.0	44.5

Source: Extracted from data reported in Alston et al. (2000).

Figure 8: ***Value of Specialty Crops versus Other Agricultural Production***



Source: Details on value of production series are in Alston, Andersen, James, and Pardey (2007).

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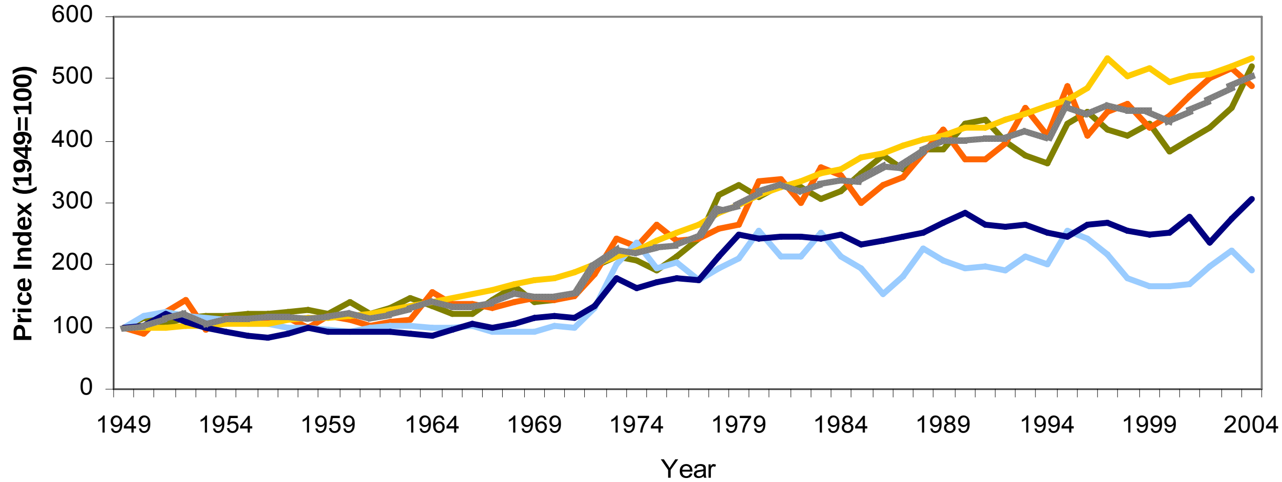
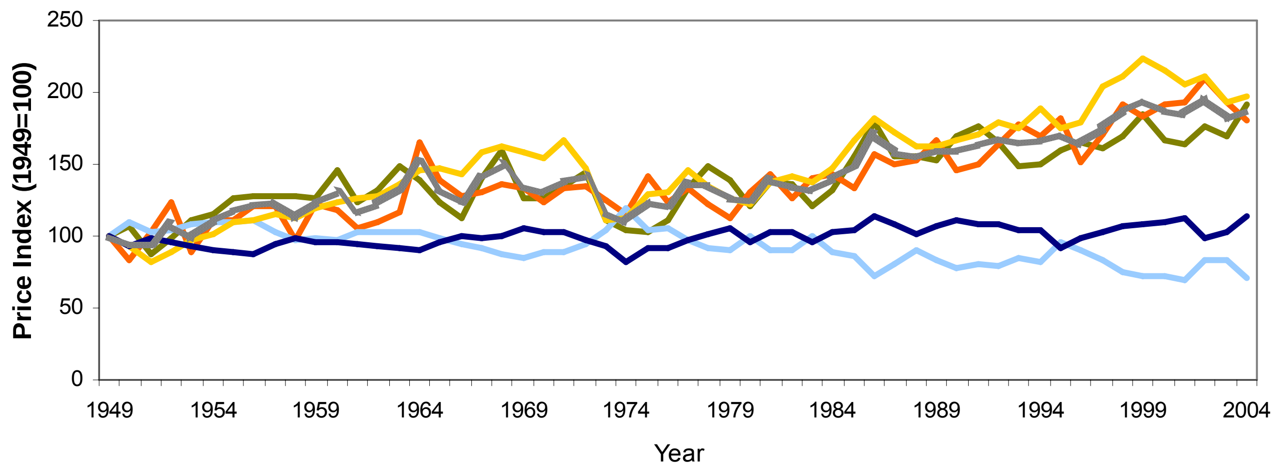
Figure 9: *Prices of Specialty Crops—Nominal and Real Values, 1949-2004*

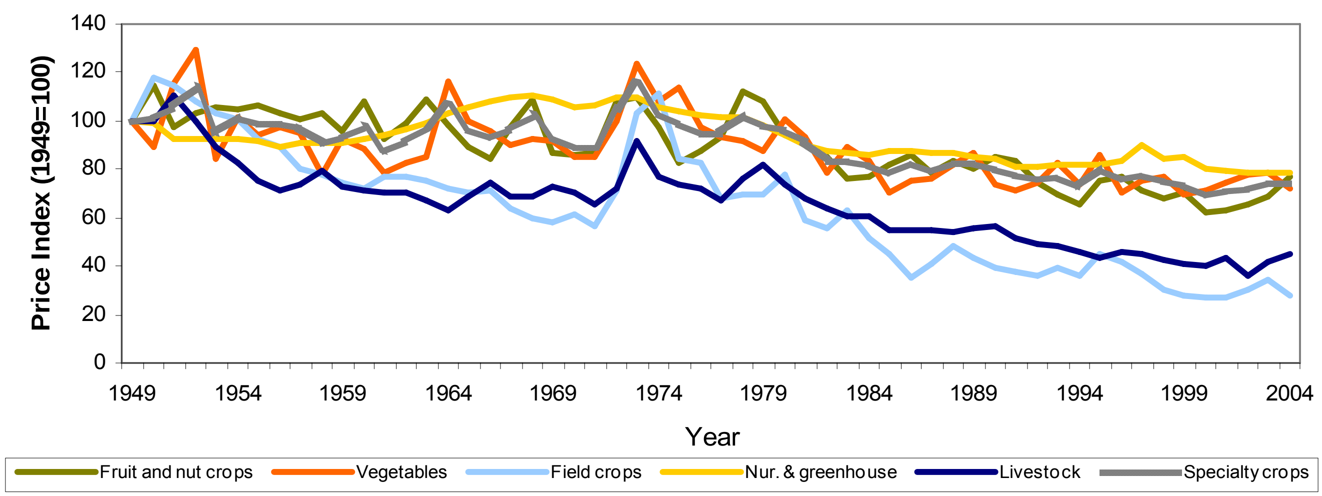
Panel a: Nominal Prices



Panel b: Real Prices Deflated Using Output Price Index

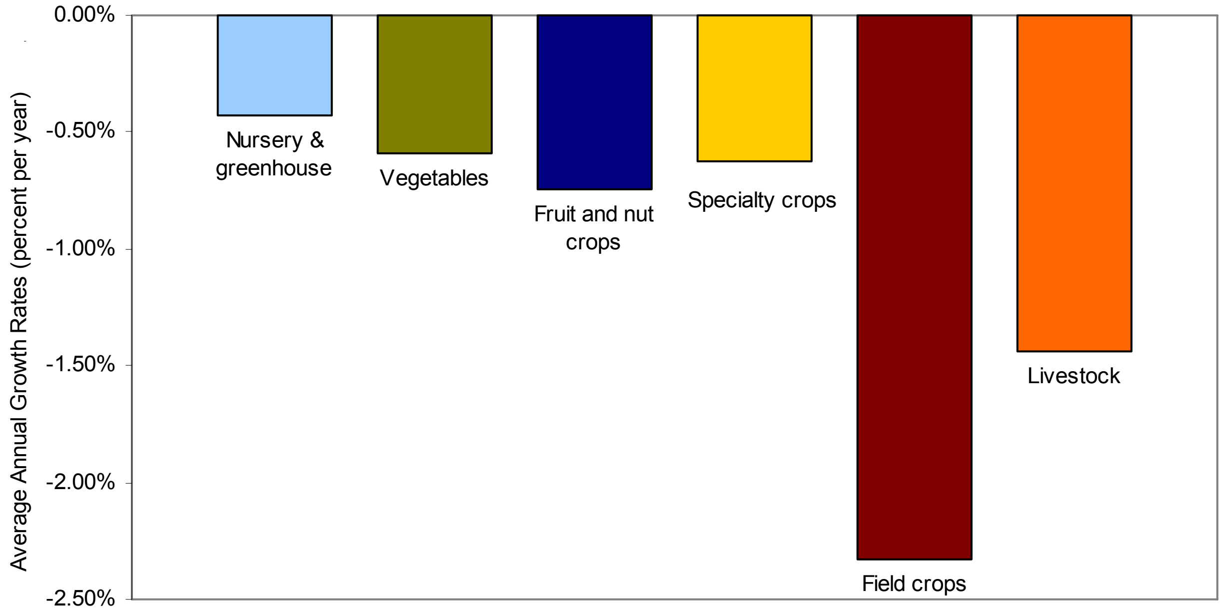


Panel c: Real Prices Deflated Using Implicit GDP Index



Source: Details on price series are in Alston, Andersen, James, and Pardey (2007).

Figure 10: ***Real Movements in Prices of Specialty Crops, 1950-2004***



Note: Nominal prices were deflated using the GDP implicit price deflator.

Table 4. *Growth in Production and Prices for Agricultural Products, 1949–2002*

Commodity Category	Percentage Changes between 1949 and 2004 in				
				Supply Growth	
	Production	Nominal Price	Real Price	ε = 1.0	ε = 0.5
Livestock	112	207	–55.1	167.1	139.6
Field Crops	178	90	–72.4	250.4	214.2
Vegetables	162	489	–27.9	189.9	176.0
Fruits and Nuts	183	419	–22.5	205.5	194.3
Greenhouse and Nursery	642	534	–20.2	662.2	652.1

Source: Developed by authors.

Table 5. ***California Commodities Covered by Marketing Programs, 2002***

Commodity Category	Value of Production		Share of Total California Value of Agricultural Production
	Total	Commodities Under Marketing Programs	
	$1,000		*percent*
Field Crops	3,827.8	795.1	20.8
Fruits and Nuts	9,705.3	7,139.7	73.5
Vegetables	6,701.6	2,888.1	43.1
Animal Products	7,090.7	5,586.2	78.8
Nursery & Floral	3,310.1	365.9	11.1
Total	*30,635.5*	*16,775.1*	*54.8*

Source: Carman and Alston (2005).

Note: Fishery and Forestry are excluded.

Table 6. ***Expenditure by California Marketing Programs, 2002***

Commodity Program	Administration	Advertising and Promotion	Research	Total	Shares	
	(1)	(2)	(3)	(4)	({1 + 2} / 4)	(3/4)
		thousands of dollars budgeted			*percent*	
Federal Marketing Orders						
Almonds	3,466.1	13,963.1	1,850.3	20,358.3	85.6	9.1
Dates	123.7	101.7	0	225.4	100	0
Grapes-California Desert	80.2	0	100.0	180.2	44.5	55.5
Kiwifruit	67.6	0	0	67.6	100	0
Nectarines	1,771.4	2,263.1	138.9	4,173.4	96.7	3.3
Olives	347.1	633.5	250.0	1,230.6	79.7	20.3
Peaches-Fresh	1,736.0	2,211.3	138.9	4,086.3	96.6	3.4
Pistachio						
Potatoes, Oregon-California						
Prunes-Dried	324.3	0	0	324.3	100	0
Raisins	1,986.5	0	0	4,621.3	43.0	0
Walnuts	710.6	1,470.0	1,045.0	3,225.6	67.6	32.4
Sub-Total	10,613.6	20,642.6	3,523.2	38,493.1	81.2	9.2
State Marketing Orders						
Alfalfa Seed	24.1	0	34.1	58.2	41.4	58.6
Artichoke Promotion	0	0	0	0		
Cantaloupe	68.4	0	33.5	258.0	26.5	13.0
Carrot (fresh)	77.7	75.0	370.5	523.2	29.2	70.8
Celery	63.1	0	205.4	268.5	23.5	76.5
Cherry	223.2	1,452.7	165.0	1,840.9	91.0	9.0
Citrus	602.3	0	2,796.0	3,398.3	17.7	82.3
Dry Bean	186.9	194.0	177.7	558.6	68.2	31.8
Figs (Dried)	514.7	256.3	28.0	798.9	96.5	3.5
Garlic and Onion Dehydrator	254.2	0	0	469.0	54.2	0
Iceberg Lettuce Research	256.4	0	784.6	1,040.9	24.6	75.4
Melon Research	73.5	0	201.6	275.1	26.7	73.3
Manufacturing Milk	94.0	301.0	0	395.0	100	0
Market Milk	1,884.0	34,542.0	1,900.0	38,326.0	95.0	5.0
Milk (Fluid)	711.7	19,881.2	0.0	20,592.8	100	0
Peach (Cling)	151.8	1,825.3	355.0	2,332.1	84.8	15.2
Pear	122.3	1,749.5	176.3	2,048.1	91.4	8.6
Plum Order	546.7	2,179.9	99.6	3,763.6	72.4	2.6
Dried Plum	683.1	5,185.0	446.0	6,314.1	92.9	7.1
Potato Research	50.4	0	100.5	150.9	33.4	66.6
Raisin	1,294.8	4,460.7	725.0	6,480.5	88.8	11.2
Rice Research	194.9	0	2,177.3	2,372.2	8.2	91.8
Strawberry (Processing)	449.4	0	0	931.4	48.2	0
Tomato (Processing)	200.1	0	37.0	3,673.5	5.4	1.0
Wild Rice	23.6	40.0	1.0	64.6	98.5	1.5
Sub-Total	8,751.3	72,182.5	10,813.9	96,934.5	83.5	11.2

Commodity Program	Administration	Advertising and Promotion	Research	Total	Shares	
	(1)	(2)	(3)	(4)	({1 + 2} / 4)	(3/4)
		thousands of dollars budgeted			*percent*	
State Commodity Commissions						
Apple Commission	247.1	401.4	13.6	662.1	97.9	2.1
Asparagus Commission	175.7	529.1	111.5	816.2	86.3	13.7
Avocado Commission	2,245.0	9,762.5	1,615.6	13,623.1	88.1	11.9
Date Commission	28.6	0	90.0	118.6	24.1	75.9
Cut Flower Commission	267.3	999.0	117.9	1,384.2	91.5	8.5
Forest Products Commission	197.0	1,334.7	30.0	1,561.7	98.1	1.9
Grape Commission-Table	900.0	12,100.0	1,000.0	14,000.0	92.9	7.1
Grape Rootstock Commission	61.4	0	251.0	312.4	19.7	80.3
Kiwifruit Commission	123.2	224.0	14.9	362.1	95.9	4.1
Pepper Commission	54.1	0	145.0	199.1	27.2	72.8
Pistachio Commission	2,295.7	6,138.7	563.3	8,997.7	93.7	6.3
Rice Commission	1,088.6	1,879.2	26.0	3,023.7	98.1	0.9
Sea Urchin Commission						
Sheep Commission	78.3	172.5	45.2	296.0	84.7	15.3
Strawberry Commission (Fresh)	1,324.6	4,839.4	1,576.9	7,740.9	79.6	20.4
Tomato Commission	499.9	1,095.0	318.7	1,913.6	83.3	16.7
Walnut Commission	711.6	7,115.8	625.0	8,452.4	92.6	7.4
Wheat Commission	368.0	195.0	176.6	739.6	76.1	23.9
Lake County Winegrape Com.	46.1	125.8	56.8	228.7	75.2	24.8
Lodi-Woodbridge Winegrape Com.	197.1	546.7	120.1	863.9	86.1	13.9
Sub-Total	10,909.1	47,458.8	6,898.1	65,296.0	89.4	10.6
Councils						
Beef Council	661.3	966.2	0	1,627.5	100	0
Dairy Council	1,282.1	4,591.4	0	5,873.5	100	0
Salmon Council	55.7	124.9	0	180.6	100	0
Sub-Total	1,999.1	5,682.4	0	7,681.5	100	0
Grand Total	**32,326.7**	**145,966.4**	**21,235.2**	**208,498.6**	**85.5**	**10.2**

Source: Carman and Alston (2005).

Table A1. *Rates of Return to Research on Specialty Crops and Other Crops*

Year published[a]	First author	Subregion	Commodity	Number of observations	Minimum value	Maximum value
Specialty Crop				*(count)*	*(percentage)*	
1978	Araji A.	U.S. State	Fruit, nut	6	5.70	48.69
1978	Araji A.	U.S. State	Fruit, nut	6	1.40	35.12
1981	Araji A.	All United States	Fruit, nut	11	11.88	102.50
1981	Araji A.	All United States	Fruit, nut	8	2.10	35.24
*1986	Stranahan J.	U.S. State	Fruit, nut	1	57.40	57.40
1991	Norton G.	All United States	Fruit, nut	1	33.00	33.00
*1990a	Doeleman J.	Australia, Asia/Pacific	Fruit, nut	3	32.00	130.00
1994	Davis J.	Australia, Asia/Pacific	Fruit, nut	3	34.00	48.00
*1981	Moricochi L.	Brazil	Fruit, nut	2	24.69	27.61
*1988	Scobie G.	Honduras	Fruit, nut	6	16.20	92.80
*1988	Scobie G.	Honduras	Fruit, nut	2	22.60	28.10
*1989	Norton G.	Eastern Caribbean	Fruit, nut	3	21.00	28.00
*1990	Tobin J.	Australia	Fruit, nut	6	210.00	1736.00
*1992	Johnston B.	Australia	Fruit, Nut	2	28.30	28.60
*1992	Johnston B.	Australia	Fruit, nut	2	87.20	87.30
1994	Davis J.	Australia	Fruit, nut	3	21.00	38.00
1994a	Evenson R.	Indonesia	Fruit, nut	3	>100	
1994a	Evenson R.	Indonesia	Fruit, nut	1	80.00	80.00
1978	Araji A.	U.S. State	Potato	2	104.43	104.81
1978	Araji A.	U.S. State	Potato	2	69.36	70.63
1981	Araji A.	All United States	Potato	2	39.82	44.90
1981	Araji A.	All United States	Potato	3	1.05	10.06
*1995	Araji A.	All United States	Potato	1	79.02	79.02
*1995	Araji A.	U.S. State	Potato	6	41.26	153.71
*1990	Horton D.	Tunisia	Potato	1	80.00	80.00
*1997	Chilver A.	Egypt	Potato	1	28.00	28.00
*1995	Fuglie K.	West Asia, North Afr., Latin Amer./Carib.	Potato	3	45.00	74.00
*1996	Chilver A.	India, Peru	Potato	1	22.00	22.00
*1971	Barletta N.	Mexico	Potato	1	69.00	69.00
*1987	Norton G.	Peru	Potato	4	22.00	42.00
*1994	Cap E.	Argentina	Potato	1	68.99	68.99
*1994	Penna J.	Argentina	Potato	3	52.60	61.23
*1996	Alvarez P.	Dominican Republic	Potato	1	27.00	27.00
*1996	Ortiz O.	Peru	Potato	1	30.00	30.00
*1996	Fonseca C.	Peru	Potato	1	26.00	26.00
*1996	Bofu S.	Global	Potato	1	65.00	65.00
*1996	Khatana V.	Global	Potato	4	10.00	33.20
1991	Dey M.	Bangladesh	Potato	1	129.00	129.00
1994a	Evenson R.	Indonesia	Potato	1	> 100	
1994a	Evenson R.	Indonesia	Potato	1	100.00	100.00
*1996	Bofu S.	China	Potato	1	102.00	102.00
*1996	Uyen N.	Vietnam	Potato	1	70.00	70.00
*1996	Rueda J.	Rwanda Burundi	Potato	1	84.00	84.00
Other commodities						
1978b	Evenson R.	All United States	All crops	1	55.00	55.00
1993	Huffman W.	All United States	All crops	3	41.60	62.60
1996	Evenson R.	All United States	All crops	1	90.00	90.00
1996	Evenson R.	All United States	All crops	3	40.00	57.00
*1990	Macagno L.	U.S. State	Barley	3	62.70	85.20
*1992	Macagno L.	U.S. State	Barley	2	84.80	90.90
1981	Araji A.	All United States	Beans	2	3.91	11.61
1981	Araji A.	All United States	Beans	3	4.30	7.30
1989	Ojemakinde A.	U.S. State	crops & livestock	1	19.61	19.61
1993	Deininger K.	All United States	Crops & livestock	18	27.20	384.40

Year published[a]	First author	Subregion	Commodity	Number of observations	Minimum value	Maximum value
1996	Evenson R.	All United States	Crops & livestock	2	71.00	83.00
1996	Evenson R.	All United States	Crops & livestock	4	43.00	67.00
1981	Araji A.	All United States	Maize	1	59.26	59.26
*1958	Griliches Z.	All United States	Maize	1	37.10	37.10
*1977	Easter K.	U.S. State	Maize	16	320.00	1720.00
*1980	Sundquist W.	All United States	Maize	1	115.00	115.00
1981	Araji A.	All United States	Maize	3	14.63	17.04
*1981	Otto D.	All United States	Maize	3	162.40	177.70
*1981	Otto D.	U.S. State	Maize	2	87.10	291.40
1970	Schmitz A.	All United States	Other crop	2	55.74	76.92
1978	Araji A.	U.S. State	Other crop	6	35.83	47.58
1981	Araji A.	All United States	Other crop	16	1.72	161.20
*1976	Bredahl M.	All United States	Other crop	1	36.00	36.00
*1977	Easter K.	U.S. State	Other crop	16	60.00	470.00
1978	Araji A.	U.S. State	Other crop	6	17.85	32.38
*1980	Sundquist W.	All United States	Other crop	1	118.00	118.00
1981	Araji A.	All United States	Other crop	8	1.20	48.00
*1981	Norton G.	All United States	Other crop	10	31.00	85.00
*1981	Otto D.	All United States	Other crop	3	150.20	176.40
*1981	Otto D.	U.S. State	Other crop	1	233.70	233.70
*1983	Smith B.	All United States	Other crop	2	202.00	307.90
1989	Huffman W.	All United States	Other crop	1	62.00	62.00
1991	Norton G.	All United States	Other crop	3	19.00	34.00
1981	Araji A.	All United States	Pasture	2	36.66	38.51
1981	Araji A.	All United States	Pasture	3	8.07	17.20
1978	Araji A.	U.S. State	Rice	2	33.83	35.59
1978	Araji A.	U.S. State	Rice	2	11.44	21.26
1981	Araji A.	All United States	Sorghum	1	112.90	112.90
*1958	Griliches Z.	All United States	Sorghum	1	19.75	19.75
1981	Araji A.	All United States	Sorghum	1	74.42	74.42
*1981	Otto D.	All United States	Sorghum	3	101.20	134.10
1981	Araji A.	All United States	Wheat	1	191.00	191.00
*1982	Blakeslee L.	U.S. State	Wheat	8	-14.90	26.70
*1980	Sim R.	All United States	Wheat	5	25.23	61.96
*1980	Sim R.	U.S. State	Wheat	9	36.00	57.00
*1980	Sim R.	U.S. State	Wheat	2	27.00	42.00
*1980	Sundquist W.	All United States	Wheat	1	97.00	97.00
1981	Araji A.	All United States	Wheat	1	134.20	134.20
*1981	Otto D.	All United States	Wheat	3	80.60	126.30
*1981	Otto D.	U.S. State	Wheat	3	78.80	148.10
*1989	Araji A.	U.S. State	Wheat	3	29.00	71.00
*1997	Barkley A.	U.S. State	Wheat	1	39.00	39.00

Source: Extracted from Alston et al. (2000).

Note: n.a. indicates not available.