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Agricultural Productivity, Demand for Experiment Station Resources and Impacts of Research on Productivity

By

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This bulletin provides a picture of the dramatic growth of U.S. agricultural productivity over the post World War II period, the demand by state legislatures for resources to support state agricultural experiment station (SAES) research, and the impact of public agricultural research on agricultural productivity at the state level. The scientific knowledge base for SAES research has changed dramatically in recent years. Incentives for research by private sector firms, particularly in the biotechnology fields have been greatly strengthened. The structure of U.S. agriculture has changed dramatically. Firm size and specialization changes have occurred. Livestock production has been "industrialized." Crop production has been changed by the introduction of herbicide resistant and insect resistant products. In this bulletin we provide an overview of these changes.

The SAES system has been responding to changes in the scientific underpinnings of applied agriculture research and to changes in the mechanism of support from SAES research. *One proposal is that formula funding of SAES research be reduced in the form of increased competitive grant funding.* We analyze this proposal utilizing new estimates of the demand for public agricultural research by state governments and the impact of public agricultural research on agricultural productivity. We show that shifting of federal formula to

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competitive grant funds would lower agricultural productivity in general and benefit only a few states while harming many.

Aggregate Performance of U.S. Agriculture

Total U.S. agricultural output—consisting of all crop and livestock products—grew at an annual rate of 1.89 percent per year over 1948-1999 (figure 1), and over this long period, livestock output grew slightly faster than crop output by 0.09 percent per year (table 1). Over the sub-period, 1948-70, total output grew at 1.63 percent and this was a period when livestock output was growing faster than crop output by 0.13 percent per year. Over the later sub-period 1948-99, total output grew faster at 2.08 percent per year, but crop output was growing somewhat faster than livestock output at 1.01 percent. About 1970, the reorganization of the livestock industry into factory-type intensive operations started first in beef cattle fattening and finishing and broiler production (Huffman and Evenson 1993). In the mid 1980s, industrialization of pig farrowing and hog finishing started.

From a production function perspective, added output is produced using added inputs and/or technical change. Hence, growth of output is a result of growth of inputs, technical or productivity change or both. Farm inputs consist of capital services (e.g., durable equipment and land), labor, and intermediate inputs—fertilizer, pesticides, energy, feed, seed, and intermediate livestock inputs. Total U.S. agricultural inputs grew at only 0.03 percent per year over 1948-99 (see figure 1). This consisted of a somewhat faster rate of growth over the sub-period 1948-1970 of 0.22 percent per year when rapid mechanization of agriculture was occurring with the introduction of new, more powerful and versatile tractors and introduction of new crop varieties, fertilizers, pesticides, and feed additives (Huffman and Evenson 1993). However, over the later sub-period 1970-99, total input growth was a negative 0.11 percent per year or on average aggregate input use was falling. In the early part off this latter sub-period, U.S. agriculture was adjusting to a rapid rise in energy prices which pushed agriculture to less intensive tillage practices, e.g., no-till farming, and declining real interest rates which contributed to cheap machinery services and mechanization. However, in 1979 U.S. restrictions on interest rates were removed and real interest rates turned dramatically higher. This made machinery services much more expensive and lead to a dramatic reduction in farm machinery and equipment investment. Land prices also fell but given the inelastic supply of cropland, cropland area was not affected by this drop. Government programs have been the main source of variation in cropland area in production over this time period. In the 1990s, a new round of technical change occurred with the aid of the biotechnology revolution that led to the introduction of herbicide tolerant soybeans, cotton, and corn and insect resistant cotton (Huffman 2004).

One of the amazing stories of U.S. agriculture over the post-World War II period has been the rapid rate of output growth and negligible input growth (see figure 1). How could this have happened? Positive technical or productivity change occurred. Total factor productivity (TFP) change captures the growth of total output not accounted for by growth in total production inputs over long periods, which can be viewed as growth in the average product of total production inputs.[1,2] Over the whole period 1948-99, the average annual rate of productivity growth (TFP) was 1.86 percent; it was somewhat lower over the early sub-period 1948-70 being an annual 1.41 percent, but significantly faster, 2.19, percent over the

[1] Productivity growth is a measure of long-term performance and not meant to be presented on an annual basis or over short time periods when weather and business cycles are having transitory effects on productivity.

[2] Total factor productivity for total U.S. agriculture is approximately the share weighted average of total factor productivity of each the 50 states.

later sub-period 1970-99 (see table 1).[3] This latter period is one that was affected by the biotech revolution. Over 1980-90, agricultural productivity was even growing faster than total output Hence, no evidence exists in the aggregate statistics that productivity growth of U.S. agriculture is slowing down.

With growth and productivity change in U.S. agriculture, the composition of inputs has changed. The capital-to-labor ratio grew relatively rapidly over the whole period 1948-99 at 3.2 percent per year (table 1). Over the sub-period 1948-70, the capital-to-labor ratio was growing at an incredibly fast 6.25 percent per year. Much of this growth was due to rising real cost of labor and labor saving technical change. However, the growth of the capital-to-labor ratio slowed to only 0.88 percent per year over the sub-period 1970-99. This latter sub-period was one where the price of capital services relative to the wage was relatively unchanged. The capital-to-materials ratio grew at 0.82 percent over the whole period 1948-99. Most of the increase was over the early sub-period 1948-70 when mechanization was occurring and the capital-to-materials ratio grow at 0.53 percent per year. Over the latter sub-period 1970-99, the capital-to-materials ratio fell at 2.32 percent per year. This was an unusual time period in that disinvestment in farm capital was occurring. Over 1948-99, the materials-to-labor ratio grew at a very fast 4.02 percent. It grew at an incredibly fast rate of 5.72 percent per year over the sub-period 1948-70 and a somewhat slower but still rapid 2.72 percent per year over the 1970-99 sub-period.

What are the implications for the economy of rapid productivity change? An increasing U.S. agricultural productivity lowers real U.S. agricultural output prices. For

[3] The science of total factor productivity measurement has advanced considerable over the past three decades, but there remain some procedures that are subjective or art. This creates some problems when one tries to compare TFP measures across studies or sectors when they are they do not apply the same methods. Jorgenson and Stiroh (2000) disaggregated the U.S. economy into 37 sectors, including the government and household,

example, over 1948-1999, the U.S. price of food (at home) relative to other inputs into household production fell by 1 percent per year (Huffman 2003). This means to U.S. consumers that the real cost of food has been declining which implies rising consumer welfare. Also, a declining U.S. price of agricultural products means increased U.S. competitiveness in the world market for these products, provided trade barriers are not strengthened.[4]

The Funding of SAES Research

U.S. total state agricultural experiment station funding was $1.893 billion (2000 dol.) in 1980, and this total grew at an average of 1.4 percent per year over the next decade (to $2.178 billion constant 2000 dol). See table 2. However, over 1990 to 2000 there was very little growth in real SAES funding, only 0.2 percent per year or to $2.230 billion in 2000. This slow growth over the past decades has caused SAES directors to look widely and intensely for new sources of funding that might re-establish growth. Also, a surprisingly small amount of research has attempted to model the funding of state agricultural experiment stations.

Over the past two decades, the distribution of SAES resources has shifted somewhat. The share of SAES funding from federal-formula funding has decreased from 17 percent in 1980, to 14 percent in 1990 to 12 percent in 2000 (see figure 2). Hence, the drop in the share of federal formula funds occurred during the 1980s rather than the 1990s. However, the composition of regular-federal funds has changed. The share of federal formula funds declined from 15.8 percent in 1980 to 10.3 percent in 1990 and to 9.0 percent in 2000.

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and applied the same methods of TFP measurement in all of them. They reported that over 1958 to 1999, the U.S. agricultural sector ranked third among 37 sectors in TFP growth.

[4] Of course with positive productivity change in U.S. agriculture, this makes it more difficult to manage the U.S. farm program such that inventories of surplus commodities do not occur.

Competitive grant funding has increased from a negligible amount in 1980 to 2 percent in 2000. Hence, from regular-federal sources, federal formula funding remains large relative to competitive grant funding (figure 2).

Other federal-government resources for SAES research has been growing rapidly. It composed 11.4 percent of the SAES system funding in 1980, 12.1 percent in 1990, and 16.2 percent in 2000 (figure 2). The growth in this share has been primarily in non-USDA federal grants and contracts (table 2). State appropriations remain a dominant source of SAES funding, accounting for 55 percent of the total in 1980 and 1990 but declining to 50.1 percent in 2000. Other SAES funds from private industry, commodity group, and foundation funding have also been increasing as a share of the total. It was 9.2 percent of the total in 1980, 13.2 percent in 1990, and 15.3 percent in 2000. Hence, the relative importance of different major sources of funding for the states agricultural experiment stations has been changing over the past two decades.[5]

Khanna et al. (1994) is an exception, and they presented econometric evidence for two public-good formulations of a state legislature's demand for public agricultural research activity: a pure public model and a joint local private and public good model. They found overwhelming support for the joint public-private good model. The interpretation was that SAES research produces some research discoveries that are state-specific and that no other source is available to provide these discoveries and other discoveries are pure public goods for which any state can obtain by free-riding on the research efforts of other state. Also, the income elasticity of demand for SAES research from state legislature's budget was showed

[5] In contrast, the USDA's research agencies—ARS and ERS—show no significant change in funding sources. They are funded almost exclusively by federal government appropriations.

to be between 0.5 and 0.8, which is inelastic, and the demand for SAES research is reduced by higher real prices of research.

Major findings of our new research using a panel of the 48 contiguous states, 1970-1999, and fitting a demand function for state legislatures' resources for SAES research include: The revenue or expenditure elasticity of demand for federal grant funded SAES research is 1.5, of privately funded research is 1.4, of state government funded research is 1.0, and of federal formula funding is only 0.4 (Huffman and Evenson 2003b). *Hence, as agricultural experiment station budgets grow (decline) in real term we predict large growth (decline) in federal grant and private grant and contract funding and a small growth (decline) in federal formula funding.* The share of SAES funds from state appropriations is predicted to remain unchanged. *A larger share of past SAES research invested in basic biological science projects increase current federal grants (contracts and cooperative agreement) funding and reduces state government appropriations.* This result shows the effects of past SAES research efforts on current funding. *If a land-grant university's moves up to be in the top National Research Council (NRC1995) ratings category (Good-to-Excellent) from a lower ranking of the quality of its basic biological science faculty, this increases sizably the demand for federal grants funds and modestly increases state government appropriations.* Hence, higher NRC rankings on average reduce all other types of SAES funding. A higher ranking of land-grant university graduate agricultural science programs (Gourman 1985) increases significantly state appropriations to the SAES but reduces federal grants (contracts, and cooperative agreement) funding.[6]

[6] Gourman's rankings have been criticized for their subjective nature, but this does not prevent state legislature from responding to these ratings. Federal funding agencies, however, may place greater stock in the NRC rankings.

Population demographics and local farm production patterns also affect funding. States that have a larger share of the U.S. farm population obtain more federal grants, federal formula funds, and state government appropriations, other things equal. The positive effect of the U.S. farm population share on the latter two categories is as expected, but the positive and much larger impact of the state's U.S. farm population share on federal competitive grant funding is surprising. Although federal competitive grant programs claim to make awards based on a research proposal's scholarly merits, the latter result suggests that other non-merit factors matter significantly. Maybe federal grants programs are not so strongly based on merit after all.[7] States having a larger farm population share also obtain more SAES funding from state government appropriations and federal formula funds. Federal grants funding is, however, reduced.

States that specialize in livestock and horticultural and greenhouse agriculture are favorable positioned for larger federal grant funding of SAES research but receive less support from state government appropriations.

R&D and Productivity Change in Agriculture

What factors contribute to productivity change? Social scientists have identified the following: public agricultural research, cooperative extension, farmers' schooling, private agricultural research, infrastructure, and government farm programs. Huffman and Evenson (1993, 2001) found that during the pre-1996 period, the government farm program had very little impact on agricultural productivity. Yee et al. (2002) showed that public infrastructure in highways contributed to agricultural TFP growth during 1970-96. The results for public

[7] Given the more than 100 year history of federal formula funding of SAES research and about 25 year history of competitive grant funding, it may not be too surprising that federal grant programs for agricultural research are allocated somewhat on non-merit bases. If too large of a share of total federal public agricultural research

extension have been mixed—sometime a positive impact and sometimes no impact. Huffman and Evenson (1993) have been the only ones to include private agricultural R&D in a productivity decomposition analysis.

Most of the interest, however, has been about the impact of public agricultural research on agricultural productivity at the regional or state level—Griliches (1963), Huffman and Evenson (1993), Alston, et al. (1998), and Yee et al. (2002). All of these studies have shown a positive and significant impact of public agricultural research on agricultural productivity. Huffman and Just (1994) have been the only scholars to pursue the effect of composition of public agricultural research funding on research productivity. The impacts could differ because the research agenda for projects funded by federal formula and state appropriations is set locally, e.g., by the SAES director and scientists, while the research agenda of other types of funds is set outside the university.

Experiment station directors and scientists are engaged in a long term relationship with frequent re-contracting as new information is revealed. Although most contracts are implicit or oral, reputation effects from past performance creates strong incentives for scientists and directors to meet the terms of their contracts. Hence, these contracts are expected to be relatively efficient (Huffman and Just 2001).

For federal competitive grant and contract funds, the research agenda is set in Washington, D.C. RFPs are issued and scientists are encourage to submit written research proposals. Given that the production function for discovery contains a significant random component and scientists' effort cannot effectively be monitored, it is impossible to contract on effort. In fact, contracting is on an abstract research proposal rather than the research

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funding goes to a few states with super science programs the other states can form a coalition to block further increases in federal agricultural research grants programs and pass legislation for increased formula funding.

payoff of the project. Furthermore, it is unusual for federal competitive grant programs to pay for research proposal writing, and hence, all of the risk of federal research grant programs are borne by the competing scientists or their institutions. With infrequent scientist-agency re-contracting on a particular research topic, agency theory has shown that these contracts are not very efficient (see Huffman and Just 2001). Also, federal funding agencies tend to fund less than 100 percent of research project, and hence, these federal competitive grant programs cause misallocation of other research funds. For example, federal formula or state appropriated funds may be diverted from important local research problems to subsidize federal grant proposal writing, but these funds can be expected to come at a high opportunity cost of foregone research discoveries. Local stakeholders can be expected to pick up on this misallocation. In line with these arguments, Huffman and Just found that federal formula funds were more productive than competitive grant funding for impacting state agricultural productivity.

Table 1 shows that the federal formula share of SAES funds has been declining over 1980-2000 from 15.8 to 9.9 percent. CSREES competitive grants, however, increased from zero to 2.0 percent over this time period. Other federal funds, including cooperative agreements have increased from 11.4 to 16.2 percent, and state government appropriations have been about one-half of total SAES funding.

Federal formula and state government appropriations as opposed to federal competitive grants, contracts, and cooperative agreement provide considerable flexibility in how the resources can be used locally by the SAES directors, who are close to the research problems faced by local constituents. Most likely an implicit contract exists between state legislatures and the local land-grant university in which the legislature expects state appropriated funds to be used to support research on local problems. Failure for the SAES director to deliver on discoveries needed locally can be expected to be reflected in future weakening of local state legislative support for funding SAES research.

In the new research funded by ESCOP, we have examined the effects of federal competitive grants, contracts and cooperative agreement fund versus federal formula and state government appropriations on state agricultural productivity for the most recent time period, 1970-2000. Using a panel data set of 48 contiguous U.S. states, we show that complex interactions exist between a state's public agricultural research stocks and state agricultural experiment station funding sources (Huffman and Evenson 2003a). These sources are the share of the SAES funds coming from federal formula and state government appropriations; federal grants, contracts, and cooperative agreements; and other SAES funding sources. *Our results show that a marginal transfer of funds from federal formula to federal competitive grant or contract funds would lower the social rate of return to public agricultural research*. Hence, not only the amount but also the composition of SAES funding matters when it comes to impacting local agricultural productivity.

Our results also provide additional conformational evidence that public agricultural research has a positive and significant effect on state agricultural productivity.[8] *When the benefits are weight against the costs, the implied marginal annual social rate of return is 56 percent.* This is extremely high when viewed against the real rate of return on government Treasury Bills and bonds which has been less than 2 percent over the same period. Hence, the use of public funds to support a portfolio of agricultural research projects managed similar to

[8] Public agricultural extension is shown to have a significant effect on agricultural productivity and public agricultural research and extension are shown to be substitutes. Private agricultural research also has a positive and significant effect on agricultural productivity.

those of past federal formula funded ones can be expected to have a very high rate of return and to be higher than for funds supporting federal grants or contracts.

Simulation of a Counter-Factual Scenario for SAES Funding

The future of federal funding of agricultural research could follow several different scenarios (Committee on Opportunities in Agriculture 2003). For example CSREES has proposed significant increases in federal competitive grant funding. Congress, however, has been unwilling to make dramatic changes. *One possible scenario, is to reduce total federal SAES funding from federal formula funding by 10 percentage points, which would reduce the share of SAES funding from federal formula and state government appropriated funding. These funds then could be re-allocated to the USDA's competitive grant programs, e.g., to the National Research Initiatives, i.e., which would increase the share of the SAES budget from federal grants, contracts, and cooperative agreements.* Let us assume that these funds actually go to the state agricultural experiment stations.[9] Two things are of significant interest, the long run impact on SAES funding (and the stock of public agricultural research) and on state agricultural productivity (TFP).

To implement this policy at the state level, let us assume that each state would have their *baseline federal formula funds rescaled by 13/23* and *their federal grants and contracts funding would increase by a factor of 2.04 times the baseline value*. Following this policy, some states would be positioned well to benefit from these changes. *Twenty-six states would have an increase in their public agricultural research stock, and six states (California, Indiana, Michigan, New York, Oregon, and Wisconsin) would have more than a 10 percent*

[9] Given that the National Research Initiate Program is a national competitive program, some of the funded projects are for individuals who are not at a land grant university and hence not associated with a state agricultural experiment station. In only two cases, a state agricultural experiment station is not directly connect to a land grant university.

increase. However, other states would be poorly positioned to benefit from the new policy. *Twenty-two states would face a decline, and in six states (Kentucky, Massachusetts, New Hampshire, South Carolina, Vermont, and West Virginia), the decline would be by more than 10 percent*. Evaluating the total difference in our TFP equation and funding shares change, we compute the implied change in Pn TFP for each state.[10] This change is not proportional to the change in total public agricultural research capital because the share of the SAES revenue from federal formula and state government appropriations and of federal grants, contracts, and cooperative agreements are also changing. We must include the impact of their changes on Pn TFP, too (see Huffman and Evenson 2003a). *The conclusion is that forty-five (45) states would experience a decline in Pn TFP from this policy scenario. The largest decline—approximately 8 percent would occur in Alabama, Nebraska and West Virginia.*[11]*Only three states would experience an increase—California, Oregon, and Wisconsin.* These latter states have a history of significant reliance on federal grants and contracts for SAES funding.

Conclusion

Overall, we conclude that the social rate of return to public agricultural research remains very high. However, with the increased transactions costs of federal competitive grant funds relative to federal formula funding and the focus on different sets of research issues, shifting federal funds from formula to competitive grants would lower the rate of

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[10] We treat this scenario as a non-marginal change, and hence, apply the difference equation.

[11] We have ignored the impact of the policy change on public agricultural research spillin, RPUBSPILL, because it is difficult to approximate how it would change. In addition to public agricultural research impacting state agricultural productivity, it may have other largely independent effects, including basic scientific discoveries, which are socially valuable but not related to agricultural productivity (Committee on Opportunities in Agriculture, 2003). Hence, our simulation results may not capture all of the social benefits of a re-allocation of federal funds between formula and grants and contracts.

increase in agricultural productivity and most likely lower the rate of return to public agricultural research. We conclude that a combination of funding sources---competitive funds, formula funds, state appropriations, and other funds---provide for more effective SAES programs rather than reliance on a single source. Federal formula funds give SAES directors flexibility and can be combined with state government appropriations to fund research on local problems or basic research needed to solve local agricultural research problems.

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Figure 1. Plot of U.S. total farm output, farm input, and total factor productivity, 1948-1999 (1948=100).

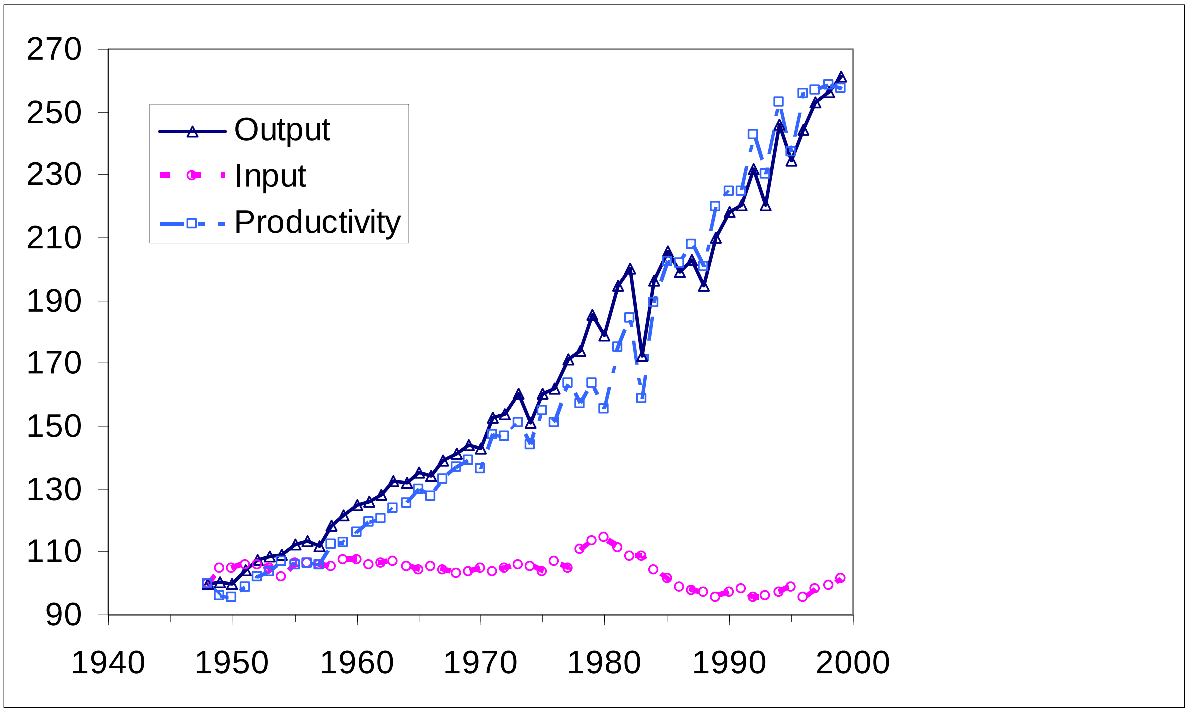

Figure 2. Shares of SAES revenue from major sources, 1980, 1990, and 2000

Chart A: 1980

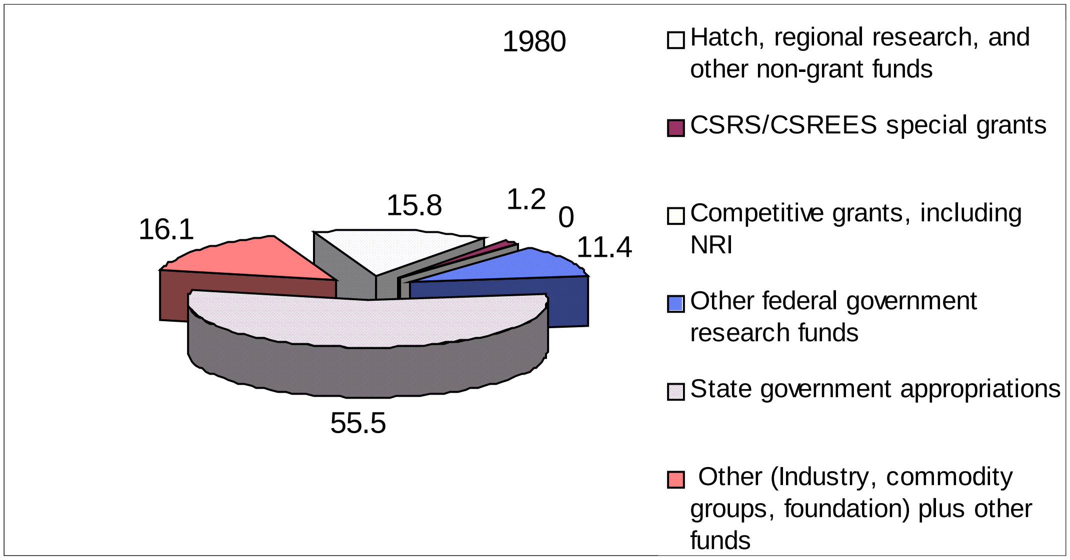

Chart B: 1990

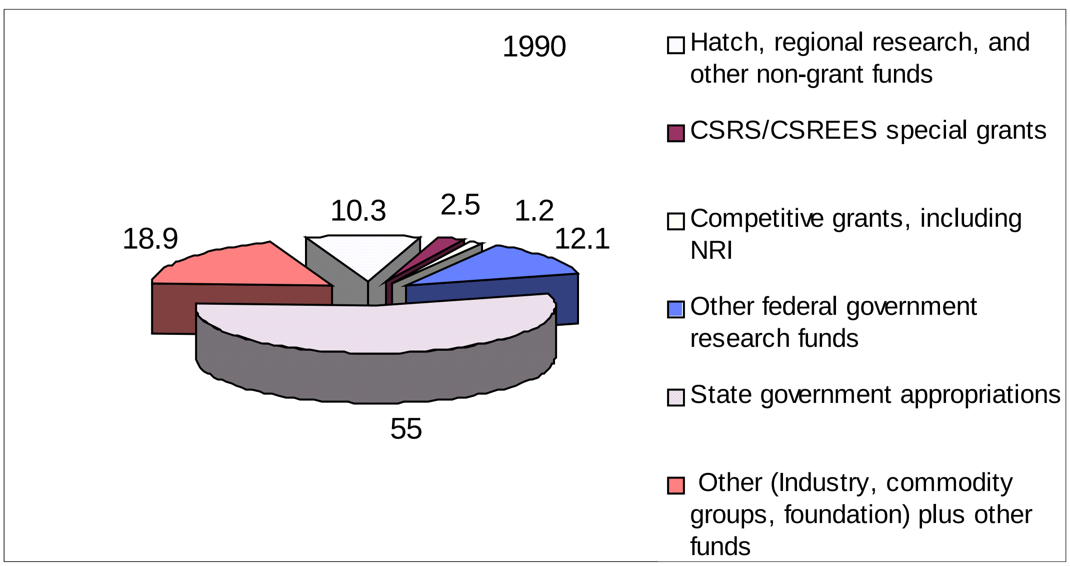

Figure 2, Continued
Chart C: 2000

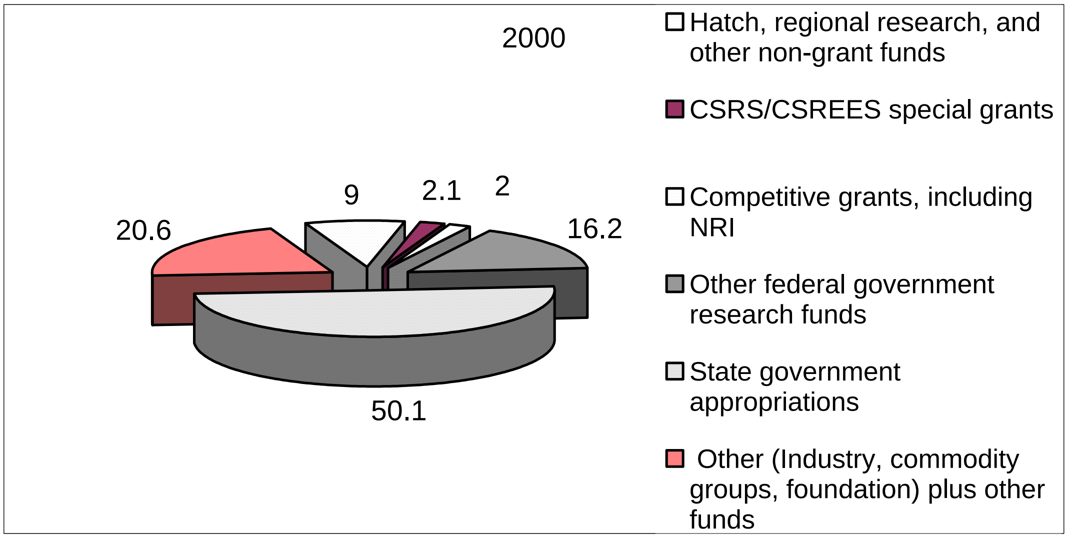

Table 1. Growth of U.S. farm outputs, inputs, and productivity, and factor ratios, 1948-1999 and selected sub periods (annual average percentage change).

Variable	Time Period 1948-99	1948-70	1970-99
Total output	1.89	1.63	2.08
Livestock output	1.69	1.33	1.31
Crop output	1.78	1.20	2.32
Total inputs	0.03	0.22	-0.11
All capital	0.81	2.90	-0.78
Durable equipment	0.69	3.27	-1.26
Land	-0.54	-0.59	-0.50
All labor	-2.39	-3.35	-1.66
Hired labor	-1.79	-3.23	-0.69
Self employed	-2.62	-3.39	2.03
All materials	1.63	2.37	1.06
Farm origin	1.41	2.07	0.90
Energy	0.92	1.59	0.41
Chemicals	3.00	5.29	1.26
Purchased services	1.78	1.26	2.17
Ratios:			
Total factor productivity:	1.86	1.41	2.19
Livestock to crop output	-0.09	0.13	-1.01
Capital to labor input	3.20	6.25	0.88
Capital to materials input	-0.82	0.53	-2.32
Materials to labor input	4.02	5.72	2.72

Source: U.S. Department of Agriculture, Economic Research Service

Table 2. Amount and Distribution of Major Sources of Revenues of U.S. State Agricultural Experiment Stations, 1980-2000.

Sources	Current Dol., Millions			Constant 2000 Dol.[a], Millions			Distribution (%)		
	1980	1990	2000	1980	1990	2000	1980	1990	2000
Regular federal appropriations	136.9	223.6	292.6	322.1	305.0	292.6	17.0	14.0	13.1
Hatch, regional research, and other non-grant funds	127.2	163.9	200.9	298.8	223.6	200.9	[15.8]	[10.3]	[9.0]
CSRS/CSREES special grants	9.6	39.7	47.0	22.6	54.2	47.0	[1.2]	[2.5]	[2.1]
Competitive grants, including NRI	--	20.0	44.7	--	27.3	44.7	--	[1.2]	[2.0]
Other federal government research funds	91.8	193.3	360.4	216.0	263.7	360.4	11.4	12.1	16.2
Contracts, grants, and cooperative agreements with USDA agencies	24.4	49.5	75.0	57.4	67.5	75.0	[3.0]	[3.1]	[3.4]
Contracts, grants, and cooperative agreements with non-USDA federal agencies	67.4	143.9	285.4	158.6	196.3	285.4	[8.4]	[9.0]	[12.8]
State government appropriations	446.9	877.9	1,117.8	1,051.5	1,197.7	1,117.8	55.5	55.0	50.1
Industry, commodity groups, foundations	74.0	210.0	340.9	174.1	286.5	340.9	9.2	13.2	15.3
Other funds (product sales)	55.2	91.6	118.0	129.8	125.0	118.0	6.9	5.7	5.3
Grant total	804.8	1,596.5	2,229.7	1,893.6	2,178.0	2,229.7	100.0	100.0	100.0

Source: U.S. Dept. Agr. 1982, 1991, 2001.

[a]Obtained by deflating data in first three columns using the Huffman and Evenson (1993, p. 95-97 and updated to 2000) agricultural research price index with 2000 being 1.00.

[b]Amount received from industry and "other non-federal sources," excluding state appropriations and product sales or self-generated revenue