Transactions Costs, Fads, and Politically Motivated Misdirection in Agricultural Research

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Research is a productive activity where the primary outputs are innovations or intellectual property and the major inputs (in most cases) are services of human or intellectual capital. Innovations are primary sources of economic growth (Romer 1990, 1994; Huffman and Evenson 1993; Griliches 1990, 1994) and have large social rates of return (Huffman and Evenson 1993; Adams 1990). Research as a production activity involves output uncertainty. For research in general and pretechnology sciences, the uncertainty is so great that no exact output can be defined. Ex ante output is not contractible. For research in applied sciences, the uncertainty is less because a specific innovation can be identified. For example, a specific drug, machine, or chemical is contractible. However, the quality or specific attributes of the innovation are uncertain.

Most of the innovations from research in the general and pretechnology sciences are pure public goods while a few are impure public goods (see Huffman and Evenson 1993, Chapter 2). In applied scientific research, the proportions of public and private goods are reversed. Impure public goods involve joint products where one is a pure public good and the other is a private good which is excludable and rival. Although modest private incentives for undertaking the production of pure public goods may exist, privately financed general and pretechnology research alone will always be suboptimal from a social or full information perspective. The fact that the demand for pure public goods is difficult to assess and payment is generally infeasible provides the economic rationale for public, especially federal government, provision or subsidization of research.

Research that produces joint public-private goods can be more efficiently produced by involving a mix of public and private financing because the private good component can only be obtained by "local" production. This public-private implication applies at two important levels: (1) where the public level is federal and some benefits are state-specific, and (2) where the public level spans firms or individuals and some benefits are firm specific. If the private benefits are local in the sense of being state specific, state governments will generally provide funding for research. If private benefits are local in the sense of being firm-specific, then the private sector may find it profitable to provide funding or undertake the research. In the latter case, a strong intellectual property right system is required so that the private sector can capture a significant share of the benefits from its R&D activities (see Huffman and Evenson 1993, Chapter 5 and 6).

Given these characteristics of the science economy, we see some disturbing trends in U.S. funding and management of research. They are (i) a growing trend toward rent seeking behavior of constituents of society (and rent receiving behavior of bureaucrats and politicians), and (ii) the prospect of dramatic institutional changes in the funding mechanism and management of research. Funding mechanisms that may play a much greater role include (1) federal competitive grant allocation in lieu of formula funding, (2) federal block-grants to states with minimal guidance about the terms of use, and (3) direct interest-group funding and management of public research (e.g., by commodity groups and private industry).

Our objective in this paper is to examine efficiency implications of national and local policies for funding and management of agricultural research. We examine the possibility that increased rent seeking activities reduce both the real resources allocated to public research and the productivity with which these resources are used.

Disturbing National Trends

From the standpoint of a national science perspective, one of the most disturbing trends is illustrated in the lower chart of Figure 1. Expenditures on R&D as a share of the federal budget allocation trended upward significantly from 1940 to 1965. The budget share increased from well below 1 percent to about 8 percent. Since 1965, however, the federal budget share allocated to R&D has trended sharply downward, although with little change since 1975. Just (1993) provides econometric evidence obtained by fitting a switching-regression model that suggests R&D funding tends to be determined as a residual of major national concerns with defense or transfers to entitlement interests.

Using a bargaining model as a basis for interpreting the econometric results, the results suggest that budget allocations were largely driven by national defense needs from 1940 to 1965 whereas a high priority on entitlements and related expenses included in transfer payments largely drove budget allocation from 1965 to 1990. The econometric results identify the associated negative effect on the share of the federal budget allocated to R&D.

The upper chart in Figure 1 demonstrates that a dominant component of the federal budget since 1940 has been national defense. More than 40 percent was allocated to defense during most of the 1940's, 1950's, and 1960's. With the end of World War II and the Korean War, and finally the end of the Cold War, defense needs have declined not withstanding the Reagan defense buildup. On the other hand, the middle chart of Figure 1 demonstrates that over 30 percent of the federal budget has been allocated to transfer payments since 1975. Federal transfer programs are payments associated with entitlement programs where payments are guaranteed to individuals or entities fitting a particular category, direct subsidy programs, and interest on deficit spending related to these programs. (Figure 1 shows a large federal budget share for transfer payments during 1946-50 due to GI programs that compensated World War II veterans. If these programs are reclassified as defense related spending, then both defense and transfer payments follow long running trends after about 1945.)

Transfer payments represented only about 15 percent of the federal budget in the early 1950's. Transfer payments then rose gradually as a share until the late 1960's when the new welfare programs kicked in. For about a decade, starting in 1967, transfer payments grew very rapidly as a share of the federal budget. Since 1980, the growth in the federal budget share spent on transfer payments has stopped (see figure 1), but not yet declined. This behavior of entitlements as a budget share since the 1970's suggests an explosive growth in rent-seeking activities. If R&D funding indeed is determined as a residual of higher priority entitlement and other transfer interests, then one must conclude that the federal budget share allocated to R&D has paid part of the price of growing entitlements interests in recent years just as it gained from declining defense spending in the 1950's and early 1960's.

From the standpoint of the agricultural science perspective, a second disturbing national trend is illustrated in the lower chart of Figure 2. The agricultural share of federal R&D spending was nearly 40 percent in 1940 but dropped sharply with the buildup of defense R&D during World War II. By 1945, agricultural R&D represented less than 2.5 percent of federal R&D. By comparison, defense R&D exploded to over 60 percent during 1941-43. At the end of the War, the share of federal agricultural R&D expenditures recovered somewhat during the late 1940's, but most of the decline in defense R&D went to R&D in other areas. During the 1950's, the agricultural share of federal R&D declined from about 6 percent to less than 2 percent and has remained low since. The share of federal R&D for other areas (represented roughly by a additive inverse of defense R&D in Figure 2 after 1945) grew rapidly for a short time after 1943, but sustained growth in other R&D occurred from the mid 1950's to the 1960's. From 1980 to 1985, the federal R&D share allocated to other areas was temporarily reduced as Reagan built up defense R&D. While a Reagan effect on the agricultural share of R&D is not obvious from Figure 2, the share dropped from 2 percent to 1.5 percent from 1980 to 1985 so the relative effect was substantial. The relative decline in other R&D was even larger.

In summary, agricultural R&D appears to have taken a back seat in federal budget allocation for over 50 years, first to defense R&D and later to other forms of R&D. Based on accumulated history, substantial growth in agricultural R&D does not appear to be a likely prospect. On the other hand, agricultural R&D has demonstrated substantial staying power over the past 30 years.

Figure 3 reveals a further vulnerability of the federal agricultural R&D budget. This figure shows that, aside from fads, R&D allocation between agricultural and non-defense R&D is largely driven by relative sector sizes (a comparison based on GDP rather than employment reveals similar results). One "fad" related to the war years appears in the 1940's where non-agricultural sectors experiences many spillover effects. Another fad occurred in the 1960's related to space sciences R&D. Finally, a third fad occurs during the 1980's related to the Reagan defense buildup. Aside from these fads, the two lines in Figure 3 roughly coincide throughout the 50 year period. This interpretation of the data suggests a current vulnerability of agricultural R&D compared to other sectors if the two lines in Figure 3 are to again converge in tighter budget times.

Figure 4 begins to examine the effects of federal budget allocation on state agricultural experiment stations and compares to associated developments in other sources of funding. The state agricultural experiment station system is a major producer of agricultural research, especially of the pretechnology and applied types. Figure 4 demonstrates how the composition of the SAES system's revenue has changed over time. At the turn of the century, federal funds accounted for most of SAES support. By 1940, state government appropriations accounted for 44.3 percent, federal funds (CSRS-administered) for 33.1 percent, and all other funds for 22.6 percent. Twenty years later, the state government share had increased to 58.2 percent, but federal funds had declined to 29.2 percent, and other revenue sources were 12.6 percent. In 1990, federal funds were down further to 26.1 percent, and growth in the state funding share had reversed to 55 percent, while other sources has risen to 18.9 percent. Overall, since 1960 both federal and state government funding have been declining as a share of SAES budgets while other sources have begun to increase substantially (although not yet reaching pre-1940's levels).

Figure 5 further demonstrates the change in composition of federal funds toward competitive grants. Not only has the share of federal funds in SAES budgets been declining, but the share of regular (Hatch) funds in federal funds has been declining. The share of regular funds in federal funds allocated to SAES's was virtually 100 percent prior to 1940 but has declined steadily and rapidly to less that 54 percent in 1990. These trends have followed from institution and emphasis of such programs as USDA's Competitive Grants Program which was established in 1977. The Competitive Grants Program has attempted recently to fund projects on the frontiers of science. Most priority areas and funding have been in the biological sciences.

The trend toward competitive allocation of funds if further depicted in Figure 6 which shows the share of CSRS-administered funds that have been allocated through competitive grants. This share was non-existent before 1965 but has grown steadily to over 31 percent by 1990. With current plans for the

National Research Initiative, the share of competitively-allocated funds promises to continue to increase.

A further potentially disturbing trend in SAES funding is represented in Figure 7 which depicts the rising private share of funds obtained from non-government sources. Before 1940, the share of non-government funds obtained from private sources such as private firms and commodity groups was virtually non-existent. But this share has grown rapidly to 70 percent in 1990. This raises a serious question about whether private funds are being used to manipulate and leverage research emphasis. An interesting question is whether the mix of public-private research not undertaken by SAES's is socially optimal and consistent with current scientific potential, or whether SAES research activity is increasingly being captured by private interests in tight budget times due to rent seeking activity.

Commodity group funding of agricultural research has been facilitated by federal marketing orders by federal legislation. Federal marketing order provisions were established in 1937, and federal and/or state marketing orders exist for fluid milk and many fresh fruits and vegetables. Federal orders facilitate agricultural producers banding together to tax themselves in order to fund commodity promotion activities including both advertising and research. In addition, the 1985 Farm Bill enacted provisions for national mandatory commodity check-off program levies at the point of sale by producers. The check-off rate has recently been raised for some commodities. Although a larger share of this revenue has been allocated to advertising historically, the increase in total check-off may lead to significant increases in private funding of agricultural research. This development in the agricultural sector is consistent with a national trend across all colleges and universities whereby the rate of growth of research support was largest from private industry. See Figure 8 and Lee and Mansfield(1995).

Another significant development after 1980 has been the increasing composition of federal funding associated with academic earmarks (U.S. Congress, OTA 1991). In this process, a congressman attaches a provision to a federal agency's research budget that a specified quantity of research funds must be "passed through" to a particular state's research institution. The amount of academic earmarks for particular projects before 1980 was very small. However, in 1980 and 1981, two federal appropriations subcommittees allocated about $10 billion to academic earmarks (Figure 9). This amount grew rapidly to $232 billion in 1988 from nine subcommittees before tailing off to smaller amounts in 1989 and 1990. However, agricultural earmarks have not tailed off as quickly or substantially as have non-agricultural earmarks. Furthermore, the share of agriculture in overall earmarks is much larger than the share of agriculture in federal R&D. To the extent that earmarks manifest rent-seeking activity, these comparisons raise concerns about whether agriculture is more subject to rent-seeking activity and how rent-seeking activity may redirect agricultural R&D.

Figure 10 presents Lorenz curve distributions of real total academic earmarks from 1980 to 1989 with states and by universities as units of analysis. What forms should these distributions follow? If academic earmarks were distributed equally among states or universities, then the cumulative distribution would be a straight line. Any ten percent of the states would receive 10 percent of the earmarked funds. More generally, if academic earmark projects represent independent random variables from a population having a finite mean and limiting average variance, then the academic earmark totals by state or university have the statistical properties of summations of random variables. This means state totals will possess a limiting normal distribution (Greene 1993). In other words, the cumulative distribution over states or universities will have a limiting normal distribution. In this case, the Lorenz curve will be bowed upward above a straight line suggesting inequality.

The information in Figure 10 clearly implies that academic earmarks are not allocated uniformly across states or universities. On the other hand, the evidence in Figure 10 is roughly consistent with academic earmarks being independent draws from a normal distribution. Upon further examination, however, one finds strong positive serial correlation of academic earmarks by state (U.S. Congress, OTA, 1991, Table 3.4, pp. 92). While one could argue that persistent inequalities among states may be due to inertia in technical abilities of scientists or quality of research establishments, this evidence is also consistent with differing rent-seeking behavior by states and universities. We view the mere existence of academic earmarks, given the other options for state research institutions to receive federal subsidies, as an indicator of rent-seeking activity and thus see persistent inequality among states as an indicator of rent-seeking activity.

Our conclusion is that several indicators show increased rent seeking activities in federal budget allocations and in SAES sources of funding. Furthermore, we interpret a greater share of SAES research funding coming from federal competitive grants and earmarks and from private commodity and industry sources as opening up the channels to further rent-seeking activities that may ultimately be detrimental to research productivity.

The Economics of Alternative Public Resource Allocation Mechanisms

This section lays out major conceptual issues focusing on the economics of public good provision, the functioning of political institutions, and implications for public funding of agricultural research.

Efficient Provision of Pure Public Goods. A pure public good such as national defense or weather forecasting provides benefits to many. Public goods are non-rival in use and non-excludable. A good is non-rival if one user does not affect the quantity of the good available to other prospective users. A good is non-excludable if excluding a particular potential user is not economical and perhaps not physically possible. These properties give rise to a free-rider problem where everyone wants the benefits but no one wants to pay the cost. Hence, equilibrium private provision of pure public goods may be zero (Gradstein 1992), but the full-information or social optimum quantity will be positive and perhaps large. Cornes and Sandler (1986) and others summarize the advantages and disadvantages of alternative government funding mechanisms for pure public goods. All such mechanisms involve some type of national government tax collection with proceeds spent on production (and distribution) of public goods.

Efficient Provision of Impure Public Goods. Impure public goods have both public good and private good attributes. For example, a good might provide benefits that are location specific. If a good provides benefits that are state specific but non-rival and non-excludable within state, then it is an impure public good. That is, it is rival or excludable at the national level. In this case, state governments should collect taxes and fund production and distribution of the impure public good locally. See Gradstein

(1992) for other possible options.

Another type of impure public good arises when a good provides location-specific benefits with reduced marginal benefits in surrounding localities. For example, if these imperfect spill-overs go to other states, then a social benefit can be obtained by all affected states forming a single decision-making unit to provide the optimal amount of the impure public good. Other funding mechanisms and their properties are also discussed in Cornes and Sandler(1986). If the size of the benefitting area from one locality's production of an impure public good extends to all areas within national boundaries, then national government involvement in provision of impure public goods will generally be socially optimal (Khanna, Huffman, and Sandler 1994).

Because private sector provision of public goods is suboptimal, economists and others generally argue that government sectors should provide funding for pure public goods. For impure public goods, the free-rider problem, although generally present, is less severe. Sometimes the private good attribute can be used as the metering device for use of the public good and for charging for use of both goods (see Stigler1974; Gradstein 1992). Although a private sector solution may not be fully optimal, it may provide a satisfactory policy. In other cases, local government involvement may be necessary.

Models of Political and Bureaucratic Behavior. In the case of government funding of R&D, political and bureaucratic behavior must be examined. Agents of private industry are motivated by long-run profits, and this limits greatly the type and extent of behavior they can pursue. Households and agents of nonprofit institutions are generally perceived by economists as maximizing utility subject to one or more resource and technology constraints. Because households and nonprofit institutions do not use an objective yardstick such as profit, they can engage in a much wider range of behavior (e.g., various forms of discrimination and nepotism) than agents of private industry.

Bureaucrats and politicians seem to form an intermediate category of agents. They may be motivated by (1) public interest, (2) fads, and (3) interest group pressure, including payoffs and bribes for "favorable" treatment. Their behavior, however, is limited by the need for periodical re-election (directly or indirectly). Voting in democratic societies transmits private information of voters much like market prices transmit private information (Lohman 1994).

Public agents that behave in the public interest behave as socially benevolent public servants. They make decisions on public research and other public goods to correct market failures and provide socially optimal quantities of all public goods. Their public sector decisions will be fully social efficient. Considerable doubt exists, however, about whether public sector agents follow this mode of behavior (e.g., see Peltzman 1976; Huffman and Evenson 1993, Chapter 8).

Public agents can reasonably be assumed to have a utility function that reflects the effect of public sector decisions on their own welfare. They may have preferences about philosophies that underline public programs, their status in the political bureaucracy, their allocation of time on the "job," their amount of leisure time, and their quantity of traditional consumption goods. A utility function containing some or all of these arguments could be used to predict a wide range of political behavior.

Status seeking seems to be an innate trait of most humans, and cultures have developed effective signals for status including fashions leading to fads (Stigler and Becker 1977; Grief 1994; Coelho and McClure 1993). Hence, status is one attribute of the utility function that can be the source of "fads" in political and bureaucratic policies. Suppose status (e.g., prestige, esteem, popularity, or acceptance) is defined as the perception by other politicians or bureaucrats of an individual as distinct from the actions of the individual (see Bernheim 1994). However, because perceptions are unobservable, actions are generally the indicator that signals perceptions and affects status. Bernheim (1994) shows that if status within the bureaucracy is sufficiently important relative to other items entering the utility function, then many individuals will conform to a single, homogenous standard of behavior, despite heterogenous underlying preferences. Within a bureaucracy, individuals may be censured for small deviations from a political or social norm. In equilibrium, any departure from the norm is construed as evidence of extreme preferences, and all status-oriented bureaucrats will shade their choices toward the political norm. This type of agent behavior gives rise to policy "fads" which are transitory, and policy customs which are norms that persist.

The value placed by bureaucrats on fashion most likely depends on the stock held by other bureaucrats. This causes interdependencies among bureaucrats about what is regarded as good or important or at the forefront among policies. Fads or fashion seem to be part of the explanation for resource allocation by bureaucrats as well as agents of nonprofit institutions and consumers. This is especially true when the expected term of politicians or bureaucrats is shorter than the period over which the social costs and benefits of policies are realized. Because many benefits of research stretch over 25 years or more, R&D policy seems to be an area where policy fads could be socially counter-productive.

Whenever governments allocate resources such as revenues or rights to public property, economists frequently see the potential for private-interest pressure groups. Individuals or agents who have relatively homogenous private interests form political interest groups to obtain or prevent income and wealth transfers by public policies (Peltzman 1976; Magee, Brock and Young 1989; Lohman 1994). These groups generally use the resources of their members (votes in public elections, wealth, status) to exert pressure that furthers the primary interests of their members. The target of a political interest group is elected officials and bureaucrats and (directly or indirectly) other interest groups. Thus, interest groups compete for favorable treatment in public policies.

Public policies are usually a compromise and represent a weighted average of the policy positions taken by interested groups, given the institutional structure. The weights are determined by the relative rather than absolute pressure exerted. Relative pressure is not necessarily proportional to the number of members or votes that an interest group controls because small, homogenous, well-funded and organized interest groups can be relatively powerful (see Magee, Brock, and Young 1989). Some of this power can arise by mobilizing other relatively neutral interest groups (Lohman 1994).

Many interest groups operate in the public R&D arena. The implications of the literature on political interest groups has an important lesson that should raise a red flag of warning with respect to an increasingly political process of R&D funding. The lesson is four-fold. First, allocating increased effort to capturing at least a piece of a political process can waste effort better be spent on socially productive activities. Second, because pressure counts only as it is relatively greater that competing pressures, the incentive to increase socially unproductive efforts can become excessive. Third, because of the tendency toward fads caused by status-seeking, an increasingly political process of decision making can lead to a reduced portfolio of activities. Fourth, because fads tend to be temporary, critical time can be lost with excessive redirection.

Implications for Public R&D Allocations

Block Grants. We now turn to implications for the funding of agricultural research. In this discussion, we regard that application of federal block-grant funding to R&D as a policy fad. Although federal block grants to States may make some economic and political sense for certain types of entitlements, block grants are an inappropriate mechanism for funding pure public goods and impure public goods where benefits spill over regionally or nationally.

Public agricultural research has been shown to produce joint products (Huffman and Evenson 1993; Khanna, Huffman, and Sandler 1994) that have benefits that spill over to other states as well as state specific benefits. A significant share of these benefits are from the spillover effects (about 40 percent for the United States as a whole). Furthermore, the social marginal real return is about 40 percent. Clearly, public agricultural research has been a good social investment. However, because of significant interstate spillover effects, state governments cannot be expected to see or internalize the incentives for a socially reasonable allocation of funds to public agricultural research. For example, if the 40 percent of benefits that due to spillover effects is ignored, then agricultural research which would otherwise have a 40 percent rate of return may be viewed myopically as a poor investment. These are strong reasons for federal structure and involvement in the funding and direction of public agricultural research. Once funds currently used for R&D are put in to state's hands with authority for redirection, incentives do not exist to take non-state benefits of R&D into account so under-funding of such R&D can be expected.

Competitive Grants and Private Funding. The environment in which the SAES system has been soliciting funding for research has been changing. The federal sector has generally been moving toward allocating a larger share of funds by competition including competition across fields and competitive grants within fields. Additionally, the private sector has been increasingly willing to enter into joint ventures and provide research grants and contracts. These activities increase access to research funding but provide the opportunity for greater rent seeking activities. Hence, these trends can become increasingly unproductive because they endogenize the share of human capital services allocated to socially unproductive rent-seeking activities and direct resources away from socially productive innovation.

Sturzenegger and Tommasi (1994) present an economic model showing the negative effects of misallocating human capital away from innovation and toward rent-seeking activities. They endogenize the share of scientists' time that is allocated to innovation and to the alternative activity of pursuing public funding of R&D, i.e., rent seeking. Given that public R&D funds can in principle be allocated by an arbitrary formula that does not consume human capital services, any alternative allocation system that absorbs human capital services carries a heavy burden of social waste in the sense of reducing the rate of innovation and economic growth. Opponents of this view would argue that competition is needed to select only the best research projects. However, if research activities are dominated by output uncertainty, then any selection process can become subjective and simply serve to narrow the research portfolio.

Sturzenegger and Tommasi further show that the rate of innovation and economic growth are enhanced by limiting the access points to political power affecting the allocation of federal R&D funds. Consider, for example, redistribution across fields such as agriculture, defense, health, resources, and energy. Sturzenegger and Tommasi show that equal horizontal equity in accessing political power by interest groups interested in affecting reallocation is not socially beneficial. Equal power access causes research agents to perceive that they "have a chance" to get a larger share, and creates stronger incentives to allocate human capital to redistribution. When political power is quite unequally distributed among interest groups or is openly biased (e.g., due to idealogy) in favor of some research agents, more innovation can result. The reason is that when "winners" and "losers" are clearly defined, a larger share of available human capital services is allocated to innovation and less is allocated to socially unproductive redistributional activities. Their model also predicts that random shocks to the political power process that are not due to lobbying groups depreciate political power and increase the returns to innovation. The reason is that these shocks cut the productivity of lobbying efforts while the productivity of innovation is unaffected.

These results imply that efforts to move toward competitive grants for SAES research with equal access to the allocation process will reduce innovation and economic growth over the long term. Empirical evidence supports this conclusion. Chubin and Hackett (1990) show that research activities are affected by politics, including competitive grant and peer review processes. McKenny (1994) has shown that the value of scientists' time spent chasing Canadian forestry research funds amounted to 22 percent of the value of available grant funds. Lindbeck (1995) and Freeman (1995) conclude that social welfare states will ultimately collapse due to the long-term incentives created for socially unproductive rent-seeking activities. Consistent with current trends, a parallel conclusion for agricultural R&D funding implies that research agents will increasingly find a larger share of their time allocated to the transactions costs of research and the rate of innovation will approach zero.

The Value of Diversity

The organization of an activity where the technology of production is dominated by uncertainty and where relative outcomes are strategy-dependent is best decentralized. This conclusion follows from the principle of optimal portfolio theory where agents are at least slightly risk averse. Furthermore, a larger expected outcome can frequently be obtained from a diverse rather than a single-item portfolio of program or projects. This is particularly true when many activities have public good spillover effects. This is the lesson recognized in the current emphasis on biological and genetic diversity. A richness and cross-fertilization of ideas can be just as important as having a diverse gene pool for biological research. Finally, a diversified decision-making strategy increases the cost of political maneuvering by politically powerful and perhaps socially misdirected interest groups. For these reasons, we believe that a significant amount of diversity of approaches to R&D problems promises to be the most productive over the long term.

In this spirit, public agricultural research programs should contain considerable diversity of intellectual pursuits. For research in the general and pretechnology sciences, diversity of intellectual pursuits has value in any specific field. Options need not be "too large" because in most fields closely related research pursuits are substitutes. The winner gets all the credit and later discovers get little credit. More to the point, for research teams pursuing a scientific breakthrough in one area, the marginal productivity of one team is reduced by an increase in productivity of the other team. This type of substitution is associated with the potential for research over investment in the aggregate (see Olson 1993; Lazear and Rosen 1981).

The early scientific discoveries and commercial development of hybrid corn provide clear example of how diversity of intellectual pursuits reduced the time to innovation and commercialization. Significant early research on inbreeding and cross breeding was conducted by Edward East (first at the University of Illinois and later at the New Haven SAES) and George Shull (at the Cold Springs Harbor, NY, laboratory for general sciences). East started as a chemist in 1900 and later worked as a corn breeder at the Illinois Agricultural Experiment Station on a project that attempted to raise the protein and oil content of corn. After reviewing the records of these experiments, he became convinced that inbreeding concentrated particular genetic characteristics into pure lines. A controversy over a proposed experiment to determine the effect of inbreeding on oil and protein content of corn with the director of the Illinois project (C. B. Hopkins) hastened East's exit from Illinois.

East then joined the Connecticut Agricultural Experiment Station in New Haven, to head corn breeding research for the new director, Edward H. Jenkins. East conducted a program of inbred line development and crossed these pure lines to obtain single-cross hybrids. He made his first cross in 1907 and in 1908 obtained fantastic success with one single-cross hybrid that yielded over 200 bushels per acre. East presented his results at breeder's meetings in 1908 and 1909 (East 1908 and 1909).

In 1909, East joined the faculty of Harvard University's Bussey Institute. The director of the New Haven station made a special arrangement to keep the unusually talented East as director of the Connecticut corn breeding program for about 10 more years. In this arrangement, East selected promising graduate students from his classes at Harvard, and they were hired to handle the Connecticut corn breeding research under East's direction. The students were to work at the experimental farm during the summer months while pursuing studies at Harvard during the winter months.

This arrangement proved to be a powerful force for advancing hybrid corn research. East was now able to attract exceptional graduate students and to have the opportunity for the first time to challenge students with his revolutionary principles of plant breeding. East's graduate program during the next 20 years was a leading source of outstanding corn plant breeders. Under his direction, the New Haven Agricultural Experiment Station became the center of hybrid corn research in the United States.

A key factor regarding the practical use of single-cross hybrids by farmers was the high cost of seed production. During the early years, inbreds used in single crosses were generally poor seed producers. Thus, it was impossible to obtain enough seed from these inbred lines to produce single-cross hybrid seed in large enough quantities to make hybrid corn a commercial success. Furthermore, the process of crossing inbred lines was too complex and time-consuming for farmers to produce their own seed.

Donald Jones, a Harvard graduate student, discovered the solution to the problem of high-cost hybrid seed production using the seed of two single-cross hybrids as parents for a double-cross hybrid. From double-cross experiments, Jones obtained insights about hybrid vigor. He saw hybrid vigor as the pooling of favorable dominant genes or Mendelian units of heredity from all parents of a cross (East and Jones 1919). This new explanation for hybrid vigor and the possibilities for creating and controlling it revived some plant breeders' interests in the practical importance of hybrid corn, e.g., Henry Wallace (Crabb 1947; Marcus 1983). Jones' discovery, or rediscovery, of the double cross was of immense importance to making hybrid corn commercially successful in the United States.

It is ironic that the first commercial (double-cross) hybrid corn varieties were produced for New England farmers rather than for Corn Belt farmers. However, the Connecticut Agricultural Experiment Station at New Haven at that time was the intellectual center for science applied to the practical problems of corn varietal improvement because of their ties to the Yale and Harvard Scientific Schools (see Huffman and Evenson 1993).

The agricultural experiment stations in the Corn Belt states and the ARS of the USDA had corn research programs during the first two decades of the 20th century, but scientists in these programs failed to piece together the complex puzzle lying behind commercial hybrid corn. Some stations focused their corn research on improving open pollinated varieties (e.g., Iowa), and others engaged in inbreeding or pure line development (e.g., Illinois and Indiana). Some had tried but were not impressed with single-cross hybrids. When Jones discovered double crosses in 1916-19, C. D. Hartley, director of the USDA's corn breeding programs and several directors of corn research in Corn Belt agricultural experiment stations were convinced that hybrid corn had no practical importance. This attitude significantly delayed hybrid corn research in Minnesota, Indiana, and Illinois.

The interesting exercise is to imagine how the development of hybrid corn would have unfolded if research funds were allocated competitively or if the research portfolio would have been narrowed due to current views (fads). Would East's research have been de-selected by a process controlled by those seeking status in the accepted regimes of belief associated with open-pollinated varieties? Apparently, these forces were sufficient to cause East's departure from Illinois. East's interests were pursued only because of diversity in the decentralized SAES system. On the other hand, because of significant spillover effects, the benefits of hybrid varieties were eventually realized in Corn Belt states where scientists originally rejected such possibilities.

Efficient Organization and Management of Local Research Units

In a final section, we turn to the question of how productive science can be fostered if not through competitive allocation of research funds. The organization and management of research along effective lines is very important and complex in single-goal institutions such as biotechnology firms, but even more difficult in multi-goal institutions such as major universities. Universities are of primary concern in SAES research funding because almost all of the SAES's are part of a major university where instruction (teaching at the undergraduate and graduate levels), research (spanning general, pretechnology, and applied sciences), and extension or outreach activities are major activities. Thus, SAES scientists regularly have appointments requiring allocation of time and effort among the three land-grant functions of research, teaching, and extension.

Incentives for Individual Scientists. One key management issue is whether job descriptions or assigned activity mixes are packaged so that a scientist's major activities are complementary (Holmstrom and Milgrom 1994). The primary instrument that deans and directors have for directing scientists' activities is the marginal incentive plan: (1) performance rewards, (2) worker freedom (to define aspects of the job), and (3) returns from possible full or part ownership of intellectual property produced.

When several activities compete for a scientist's scarce time and attention, incentives can easily be misapplied. For example, if the incentive for one activity, say research, is increased, but incentives for other activities remain unchanged, then the scientist may devote too much effort to research while neglecting other activities. If, however, incentives are increased for all of the scientist's activities, misallocation may be avoided. Hence, when several activities compete for a scientist's effort, the level of incentives for all should be complementary. This generally requires a balancing of the three major incentive instruments available to supervisors (Holmstrom and Milgrom 1994).

Performance incentives can be further strengthened by combining activities in scientist's jobs through job descriptions so that the major activities are complementary. By this we mean, that time and effort allocated to one activity increases the productivity of the scientist's time and effort in other activities. For example, conducting high quality research on any topic and teaching a graduate course on a similar topic where research assistants take the course is an example of highly complementary teaching and research activities. With this mix of activities, a scientist's long-term performance in both activities is likely to be preserved and encouraged.

Alternatively, when a scientist teaches in an area that is unrelated to his research efforts, teaching and research are substitutes. In the latter case, over the long term, serious job performance problems are likely to surface in teaching, research or both. These types of job descriptions or duties should be changed or avoided. Attempting to change a developing problem where teaching and research are substitutes by careful monitoring seems likely to be an unproductive and perhaps counterproductive activity (Frey 1993). Tighter monitoring when a scientist and dean have an implicit contract for performance is likely to be interpreted as distrust and this frequently reduces work effort further (Frey 1993). No other approach appears to substitute for negotiating good job descriptions and using effective reward instruments wisely to induce good performance of scientists who engage in multiple activities.

Incentives for Teams of Scientists. Many research projects, however, require the use of a team (two or more scientists and perhaps other personnel). Setting rewards for team efforts is more difficult than for individual scientists. The nature of the problem can be defined along the following lines. In general and pretechnology scientific research, outputs or innovations are not contractible. Innovations are ill-defined because of overwhelming uncertainty in the innovation production process. Furthermore, problems of adverse selection (each member's ability to solve a research problem is known only to himself) and moral hazard (each team members effort is unobservable and not contractible) are present (see McAfee and McMillan 1991; Aghion and Tirole 1994). Also, ability and effort are frequently not correlated in the same way across (possible) team members. Ex ante all that can be determined is a commitment of effort by team members, the allocation of property rights on any innovation or intellectual property, and the sharing rule for rewards associated with the innovation (e.g., order of authors name on a publication or division of patent/copyright royalties).

A solution to this problem must be attempted ex ante by the principal agent who may be a team leader or dean. The marginal reward scheme for each team member must be constructed such that his reward depends not only on his own (reported) ability but also on the (reported) ability of all team members. This is achieved by getting each team member to make a voluntary ability assessment ex ante which is related to the share of the ex post total reward that he can receive. This then creates an incentive for each team member to reveal his own ability for the project but also to commit a particular amount of effort to the project. The team members are each induced to exert more effort (1) the greater is their own ability and (2) the greater is the ability of their teammates (McAfee and McMillan 1991). Each team member has an incentive to adopt high ability teammates. In this model, monitoring of effort by a supervisor is not a productive activity, so no human resources are allocated to supervision and no risk of causing distrust by supervision is present.

Incentives for Public Private Cooperation. A final issue is how the public (SAES) and private sector (corporation) should share intellectual property resulting from joint ventures. With joint ventures the investor either makes a monetary commitment to the project which is contractible or provides proprietary services (data, technology, equipment, or facilities). Such services are often subject to availability and thus not contractible. A particular innovation is not contractible, but the probability of discovery is positively related to ability and effort of the scientists and the total resources invested. Uniform shares in any intellectual property created (property rights) from a joint venture has advantages because otherwise the research unit or scientists will tend to work too hard on that component where they get the largest share. This effort is generally impossible to monitor. When there are multiple innovations or multiple customers, property rights should be split on the basis of comparative advantage in creating value from the innovations (Aghion and Tirole 1994). Joint ventures are not very conducive to technology transfer (innovation diffusion), however, because added competition is imposed on the joint venture firm when the intellectual property is used by other firms. This is perhaps one of the most difficult problems deserving of further research.

Conclusions

Several current trends in agricultural R&D funding are disturbing. These include (1) a long-term decline in R&D funding as a share of the federal budget, (2) a long-term decline in the agricultural share of federal R&D, (3) a more recent decline in the share of SAES funding borne by states, (4) a temporary disequilibrium that suggest further decline in federal agricultural R&D funding, and (5) a substantial increase in private funding, earmarks, and competitive allocation of agricultural research funding. Many of these trends manifest increasing rent-seeking activity in the budget allocation process.

These developments make agricultural research funding increasingly vulnerable to interest group pressures which will tend toward socially wasteful rent-seeking activity within the scientific community and reduce productivity of innovations accordingly. Increasing departure from formula funding of agricultural experiment stations promises to increase the response of effort to fads at the expense of long-term productivity because typical research cycles are longer than the life of political fads. More centralized competitive allocation of research funds will tend to narrow the diversity of research approaches because of scientific fads and pursuit of intellectual status and reduce productivity accordingly. On the other hand, block grants to states will result in under-investment in agricultural research because spillover returns among states will not be valued.

Research shows that better methods than competitive grants exist to manage scientific research through proper structuring of incentives. By structuring duties to take advantage of complementarities, productive activities of individual scientists can be fostered and maintained. By using the principles forthcoming from principal-agent theory, teams of scientists can be structured to induce appropriate information sharing and self supervision. Several important principles have been developed in the public good literature that appear to have important applications in structuring public-private partnerships between universities and private industry. However, application of those principles appears to remain a fruitful area for further research.

References

Adams, James D. "Fundamental Stocks of Knowledge and Productivity Growth," *J. Pol. Econ.* 98(Aug 1990):673-702.

Aghion, Philippe and J. Tirole. "The Management of Innovation," *Quart J. Econ.* 109(Nov 1994):1185-1209.

Anton, James J. and D.A. Yao. "Expropriation and Incentives; Appropriable Rents in the Absence of Property Rights," *Am. Econ. Rev.* 84(March 1994):190-209.

Baker, George, M. Gibbs, and B. Holmstrom. "The Wage Policy of a Firm," *Quart. J. Econ.* 109(Nov 1994):921-955.

Baker, G., R. Gibbons, and K.J. Murphy. "Subjective Performance Measures in Optimal Incentive Contracts," *Quart. J. Econ.* 109(Nov 1994):1125-1156.

Berkowitz, M.K. and Y. Kotowitz. "Promotions as Work Incentives," *Econ. Inq.* 31(July 1993):342-353.

Bernheim, Douglas B. "A Theory of Conformity," *J. Pol. Econ.* 102(Oct 1994):841-877.

Bolton, Patric and M. Dewatripont. "The Firm as a Communication Network," *Quart. J. Econ.* 109(Nov 1994):809-839.

Chubin, Daryl E. and E.J. Hackett. *Peerless Science*. Albany, NY: State University of New York Press, 1990.

Coelho, Philip R.P. and J.E. McClure. "Toward an Economic Theory of Fashion," *Econ. Inq.* 31(Oct 1993):595-608.

Cornes, Richard and T. Sandler. *The Theory of Externalities, Public Goods, and Club Goods*. New York, NY: Cambridge University Press, 1986.

Demougin, Dominique and A. Siow. "Careers in Ongoing Hierarchies," *Am. Econ. Rev.* 84(Dec 1994):1261-1277.

Freeman, Richard B. "The Large Welfare State as a System," *Am. Econ. Rev.* 85(May 1995 forthcoming).

Frey, Bruno S. "Does Monitoring Increase Work Effort? The Rivalry with Trust and Loyalty," *Econ. Inq.* 31(Oct 1993):663-670.

Gibbons, Robert and Kevin J. Murphy. "Optimal Incentive Contracts in the Presence of Career Concerns: Theory and Evidence," *J. Pol. Econ.* 100(June 1992):468-505.

Gradstein, Mark. "Time Dynamics and Incomplete Information in the Private Provision of Public Goods," *J. Pol. Econ.* 100(June 1992):581-597.

Greef, Avner. "Cultural Beliefs and the Organization of Society: A Historical and Theoretical Deflection on Collectivist and Individualist Societies," *J. Pol. Econ.* 102(Oct 1994):912-950.

Greene, William H. *Econometric Analysis*. New York, NY: Macmillan Publishing Co., 1993.

Griliches, Zvi. "Patent Statistics as Economic Indicators: A Survey," *J. Econ. Lit.* 28(1990):1661-1707.

Griliches, Zvi. "Productivity, R&D, and the Data Constraint," *Am. Econ. Rev.* 84(Mar 1994):1-23.

Hermalin, Benjamin E. "Heterogeneity in Organizational Form: Why Otherwise Identical Firms Choose Different Incentives for Their Managers," *RAND Journal* 25(Winter 1994):518-537.

Holmstrom, Bengt and Paul Milgrom. "The Firm as an Incentive System," *Am. Econ. Rev.* 84(Sept 1994):972-991.

Hirshleifer, Jack. "The Paradox of Power," *Economics and Politics* 3(Nov 1991):177-200.

Huffman, Wallace E. and Robert E. Evenson. *Science for Agriculture: A Long Term Perspective.* Ames, IA: Iowa State University Press, 1993.

Huffman, Wallace E. and Robert E. Evenson. *Agricultural Research and Education: An Economic Perspective*. Ames, IA: Iowa State University Press, 1995.

Huffman, Wallace E. and Richard E. Just. "Funding, Structure, and Management of Public Agricultural Research in the United States," *Am. J. Agr. Econ.*76(Nov 1994):744-759.

Hwang, Hae-Shin, W.R. Reed, and C. Hubbard. "Compensating Wage Differentials and Unobserved Productivity," *J. Pol. Econ.* 100(Aug 1992):835-858.

Jaffe, Adam, M. Trajtenberg, and R. Henderson. "Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quart. J. Econ.* 108(Aug 1993):577-98.

Just, Richard E. "Economic and Political Considerations Affecting Public Research in Agriculture," University of Maryland, Department of Agricultural and Resource Economics, June 1993.

Kandel, Eugene and E.P. Lazear. "Peer Pressure and Partnerships," *J. Pol. Econ.* 100(Aug 1992)801-817.

Khanna, J., W.E. Huffman, and T. Sandler. "Agricultural Research Expenditures in the United States: A Public Goods Perspective," *Rev. Econ. and Statist.* 66(May 1994):267-277.

Krueger, Anne O. "The Political Economy of the Rent-Seeking Society," *Am. Econ. Rev.* 64(1974):291-303.

Lazear, Edward and Sherwin Rosen. "Rank Order Tournament as Optimum Labor Contracts," *J. Pol. Econ.* 89(1981):841-64.

Lee, Jeong-Yeon and Edward Mansfield. "Industrial Support of Academic Research," University of Pennsylvania, Wharton School, Jan. 1995.

Lindbeck, Assar. "Hazardous Welfare-State Dynamics," *Am. Econ. Rev.* 85(May 1995 forthcoming).

Lohmann, Susanne. "Information Aggregation Through Costly Political Action," *Am. Econ. Rev.* 83(June 1994):518-530.

Magee, Stephen P. W.A. Brock, and L. Young. *Black Hole Tariffs and Endogenous Policy Theory*. New York, NY: Cambridge University Press, 1989.

McKenny, Daniel W. "On the Cost of Chasing Research Dollars," *Can. J. Agr. Econ.* 42(1994):105-112.

Meyer, Margaret A. "The Dynamics of Learning with Team Production Implications for Task Assignment," *Quart. J. Econ.* 109(Nov 1994):1157-1184.

Olsen, Trond E. "Regulation of Multiagent Research and Development," *RAND J.* 24(Winter 1993):529-541.

Peltzman, Sam. "Toward a More General Theory of Regulation," *J. Law and Econ.* 19(1976):211-240.

Roguson, William P. "Economic Incentives and the Defense Procurement Process," *J. Econ. Persp.* 8(Fall 1994):65-90.

Romer, Paul. "Endogenous Technological Change," *J. Pol. Econ.* 98(1990):S71-S102.

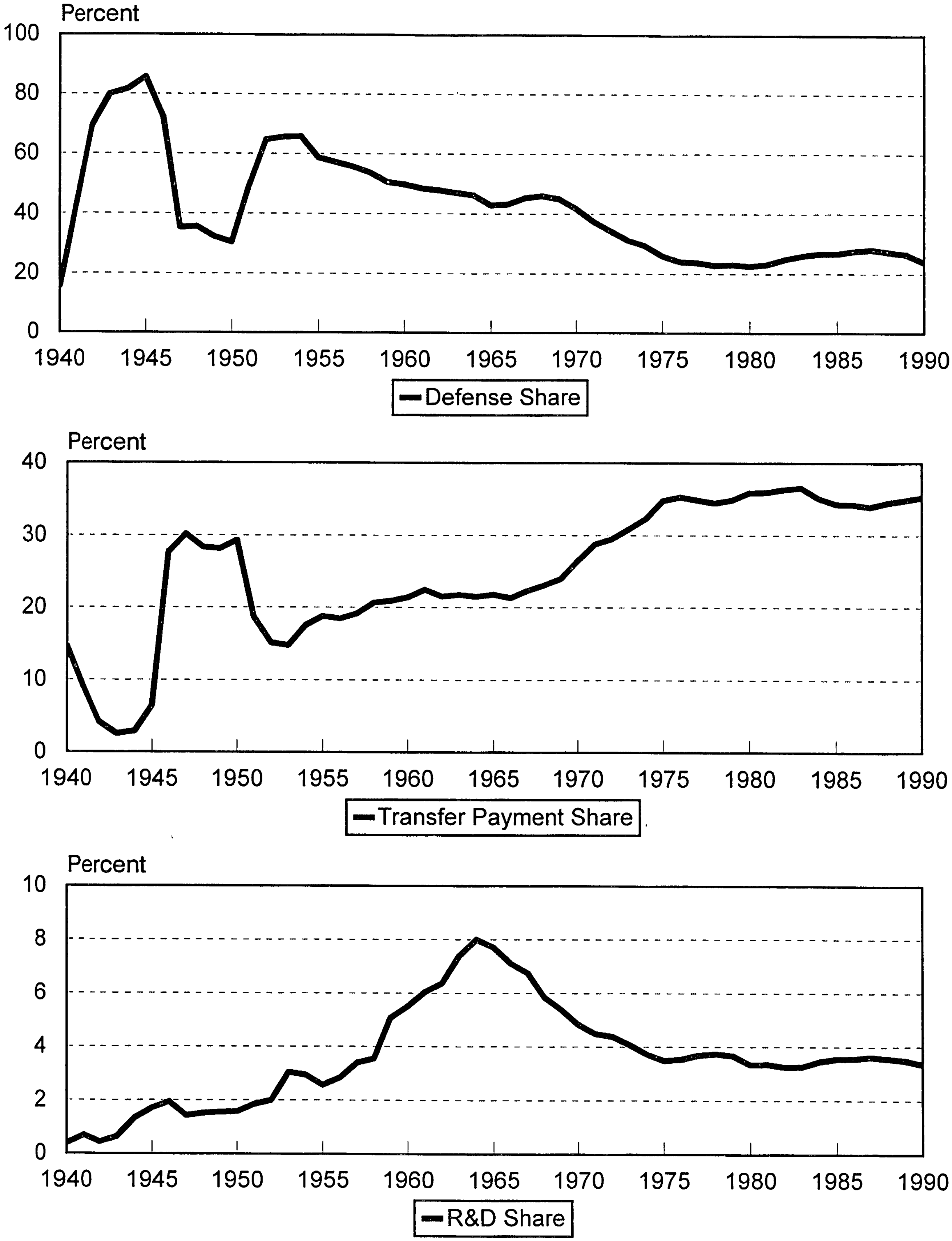
Romer, Paul. "The Origins of Endogenous Growth," *J. Econ. Perspectives* 9(Winter):3-22.

Stigler, George J. "Free Riders and Collective Action: An Appendix to the Theories of Economic Regulation," *The Bell J. Econ. Mgt. Sci.* 5(1974):359-365.

Stigler, George J. and Gary S. Becker. "De Giestubis Non Est Disputandum," *Am. Econ. Rev.* 67(Mar 1977):76-90.

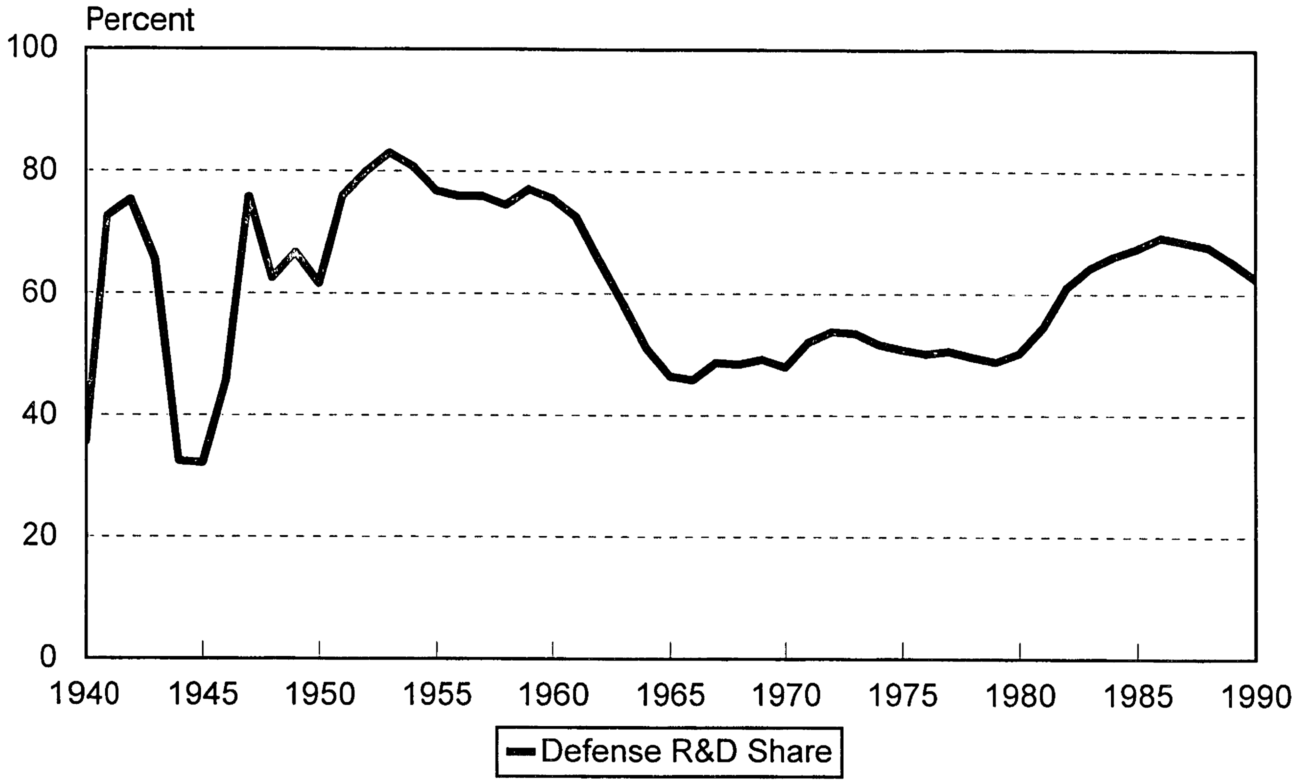
Sturzenegger, Federico and M. Tommasi. "The Distribution of Political Power, The Costs of Rent-Seeking, and Economic Growth," *Econ. Inq.* 32(April 1994):236-248.

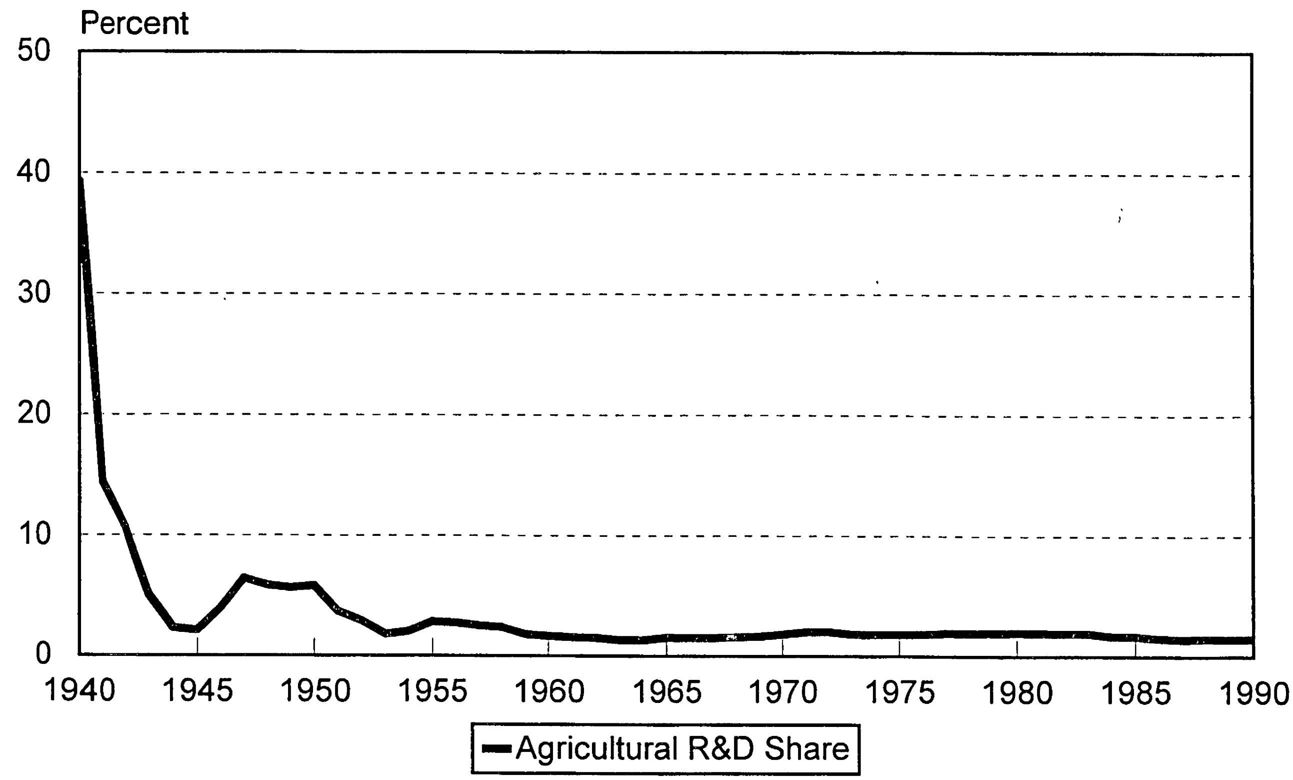
Figure 1. Federal Budget Allocation, 1940-1990



Source: Statistical Abstract of the United States, various issues.

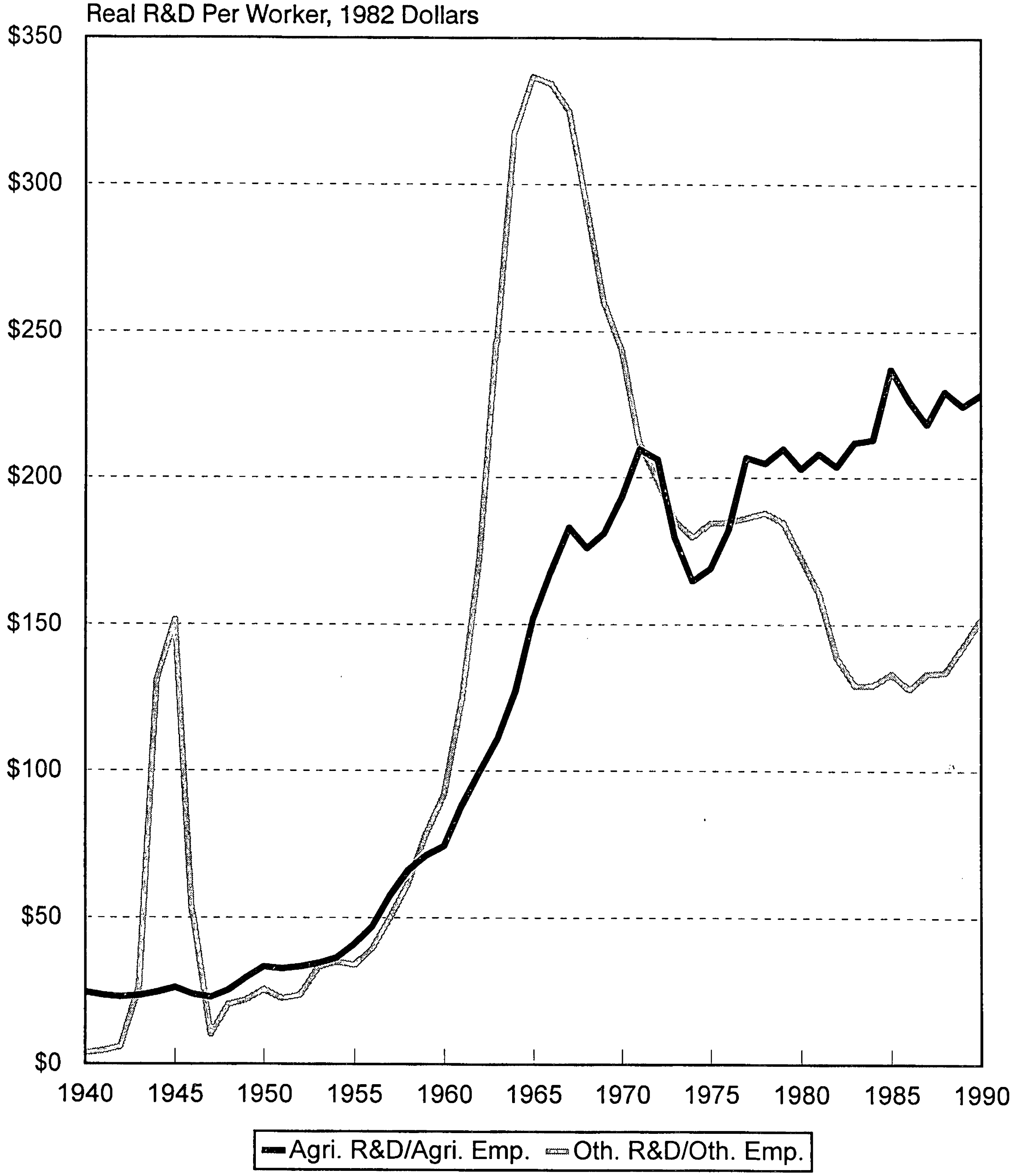
Figure 2. Share of R&D by Sector, 1940-1990





Source: Statistical Abstract of the United States, various issues.

Figure 3. R&D Per Worker by Sector, 1940-1990

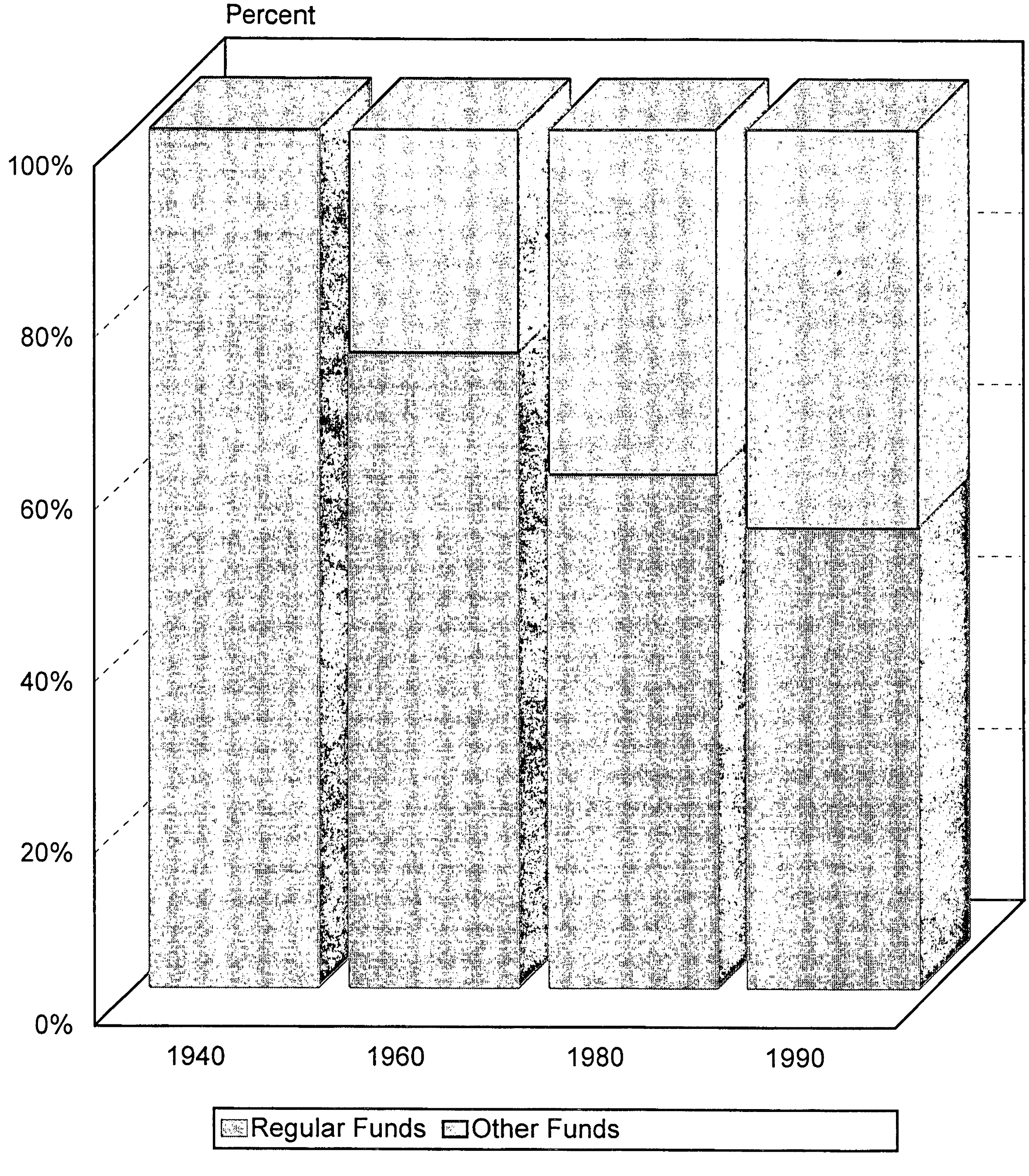


Source: Statistical Abstract of the United States, various issues.

Figure 4. Sources of Revenue for U.S. State Agricultural Experiment Stations, 1900-1990

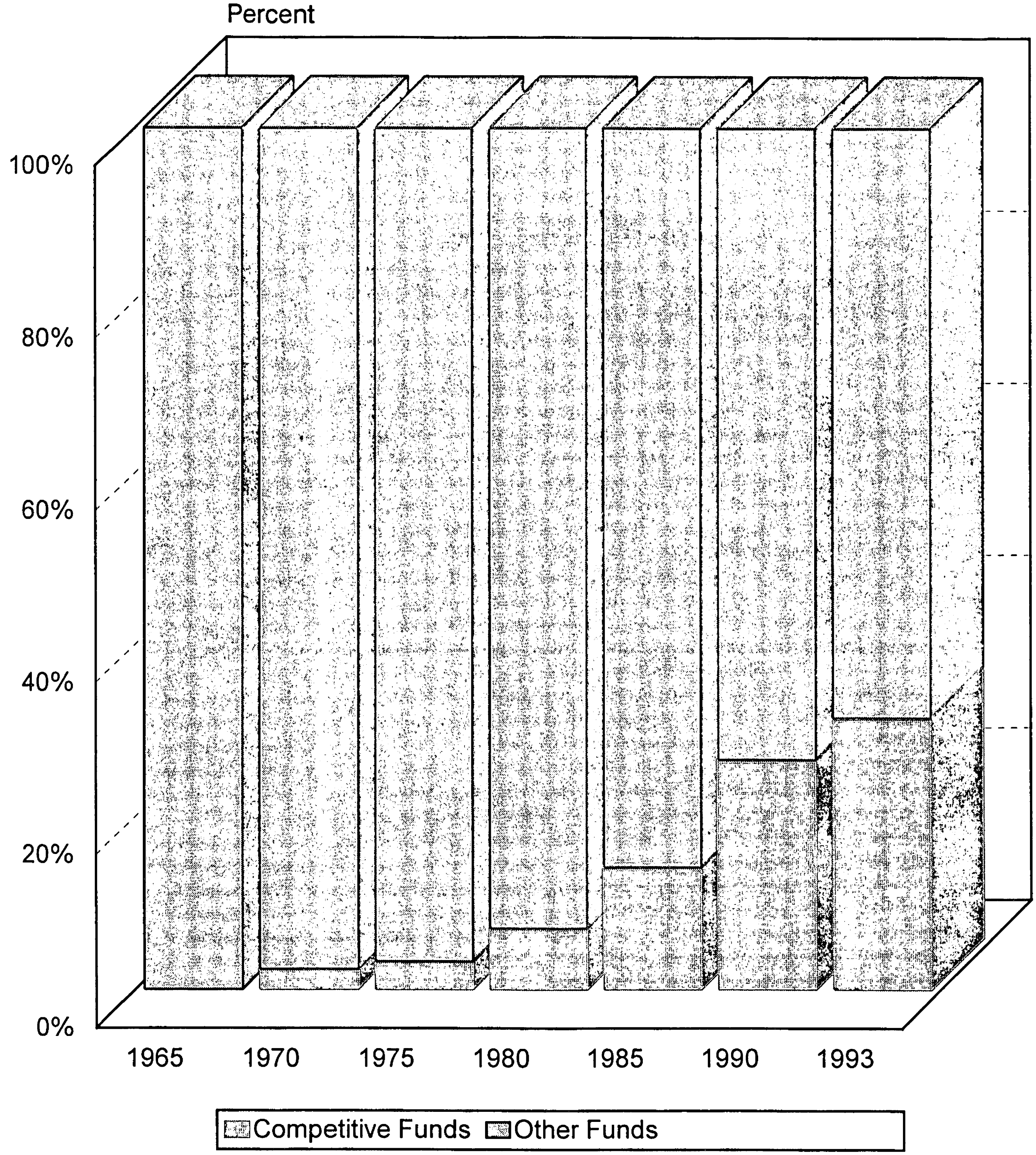
Source: Department of Agriculture, Office of Experiment Stations, 1901, 1921, 1941, 1961. U.S. Department of Agriculture-Cooperative States Research Service, 1981, 1991.

Figure 5. Regular Federal Funds as a Share of Federal Sources for U.S. State Agricultural Experiment Station Revenues, 1940-1990



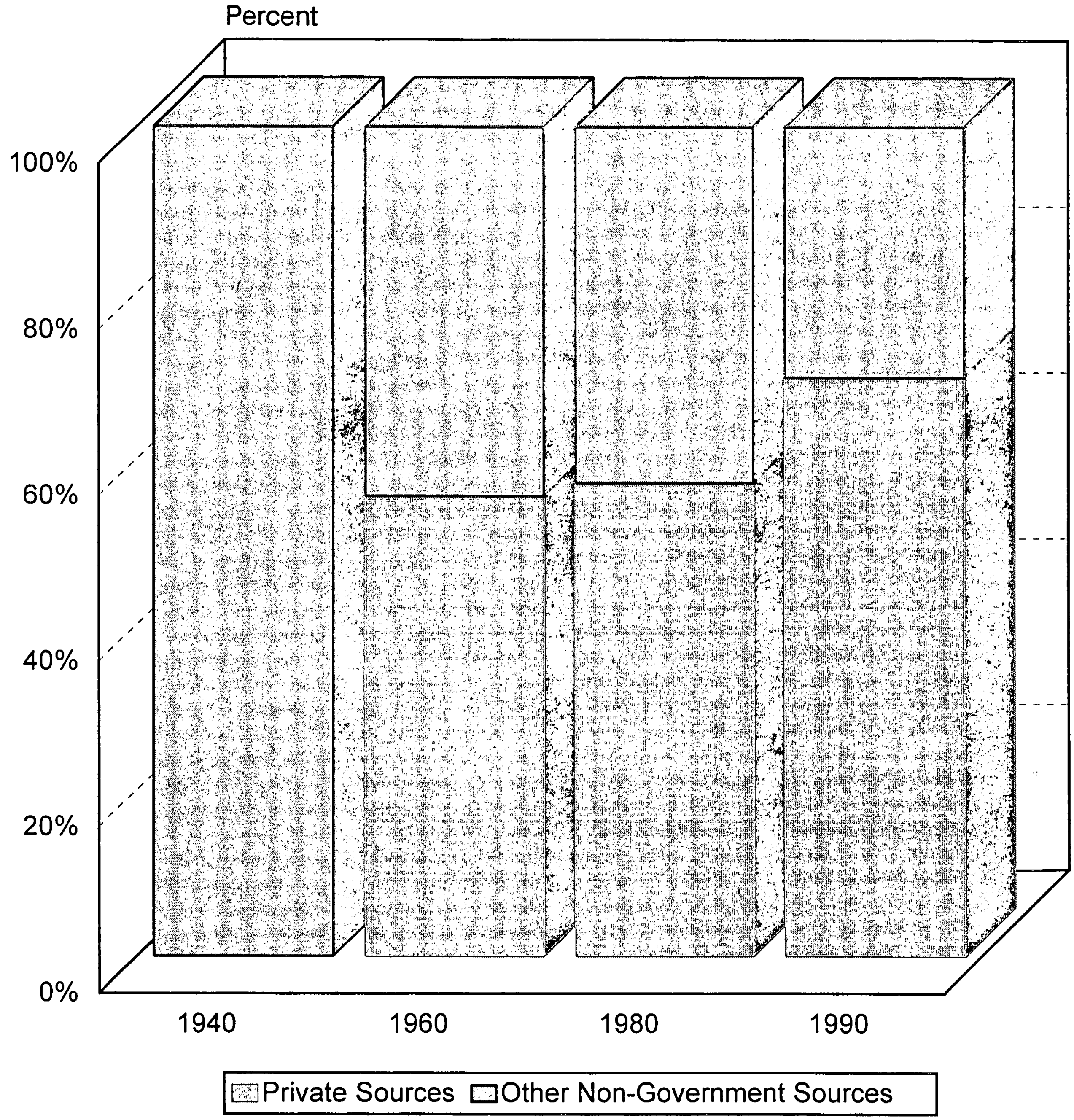
Source: Department of Agriculture, Office of Experiment Stations, 1941, 1961. U.S. Department of Agriculture-Cooperative States Research Service, 1981, 1991.

Figure 6. Competitively Allocated Funds as a Share of CSRS-Administered Funds, 1965-1993



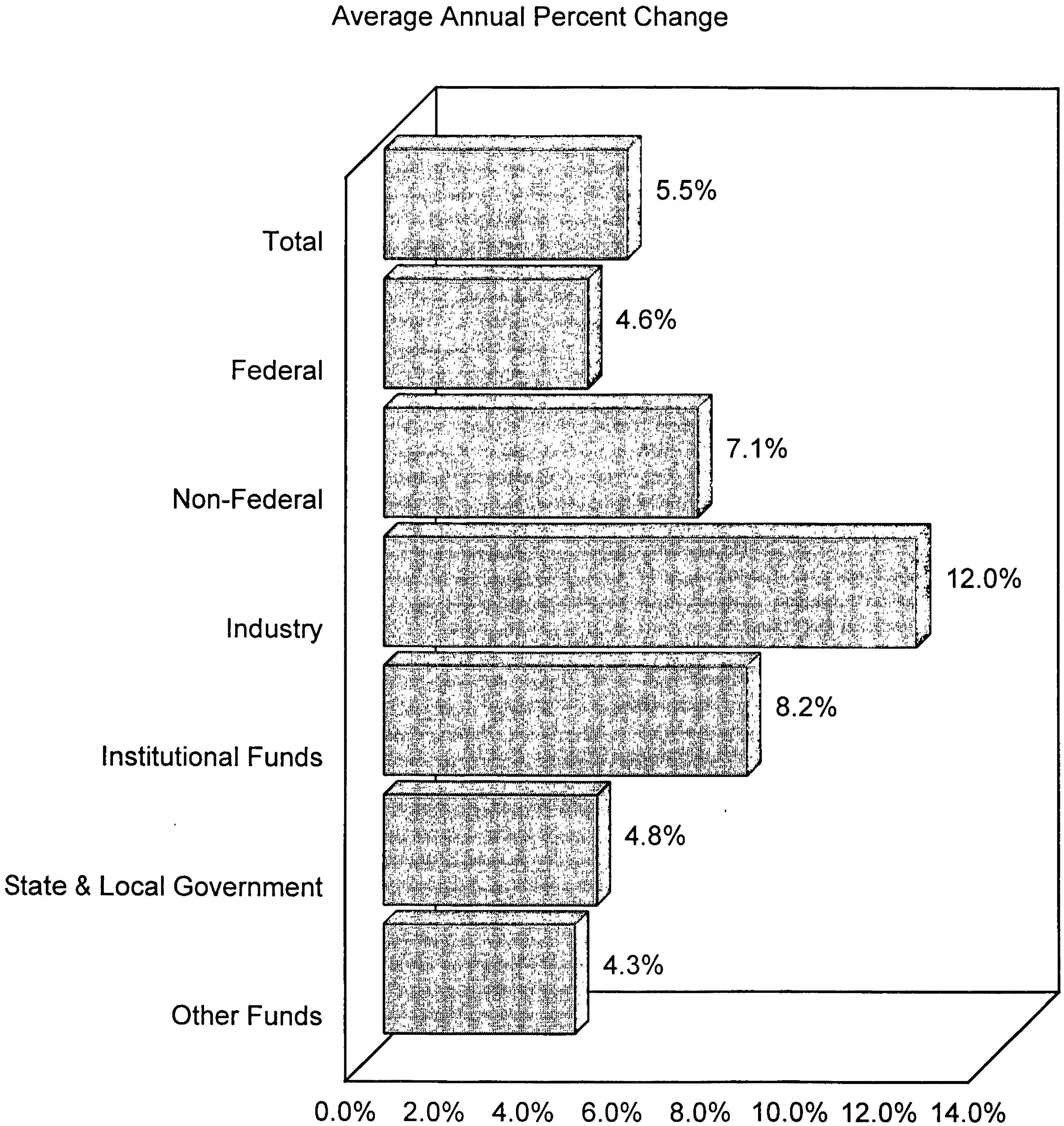
Source: Roland Robinson, U.S. Department of Agriculture, Cooperative States Research Service, revised reports of expenditures of agricultural experiment stations, 1956-68. U.S. Department of Agriculture, Inventory of Agricultural Research 1969-93.

Figure 7. Private Share of Non-Government Sources for U.S. State Agricultural Experiment Station Revenues, 1940-1990



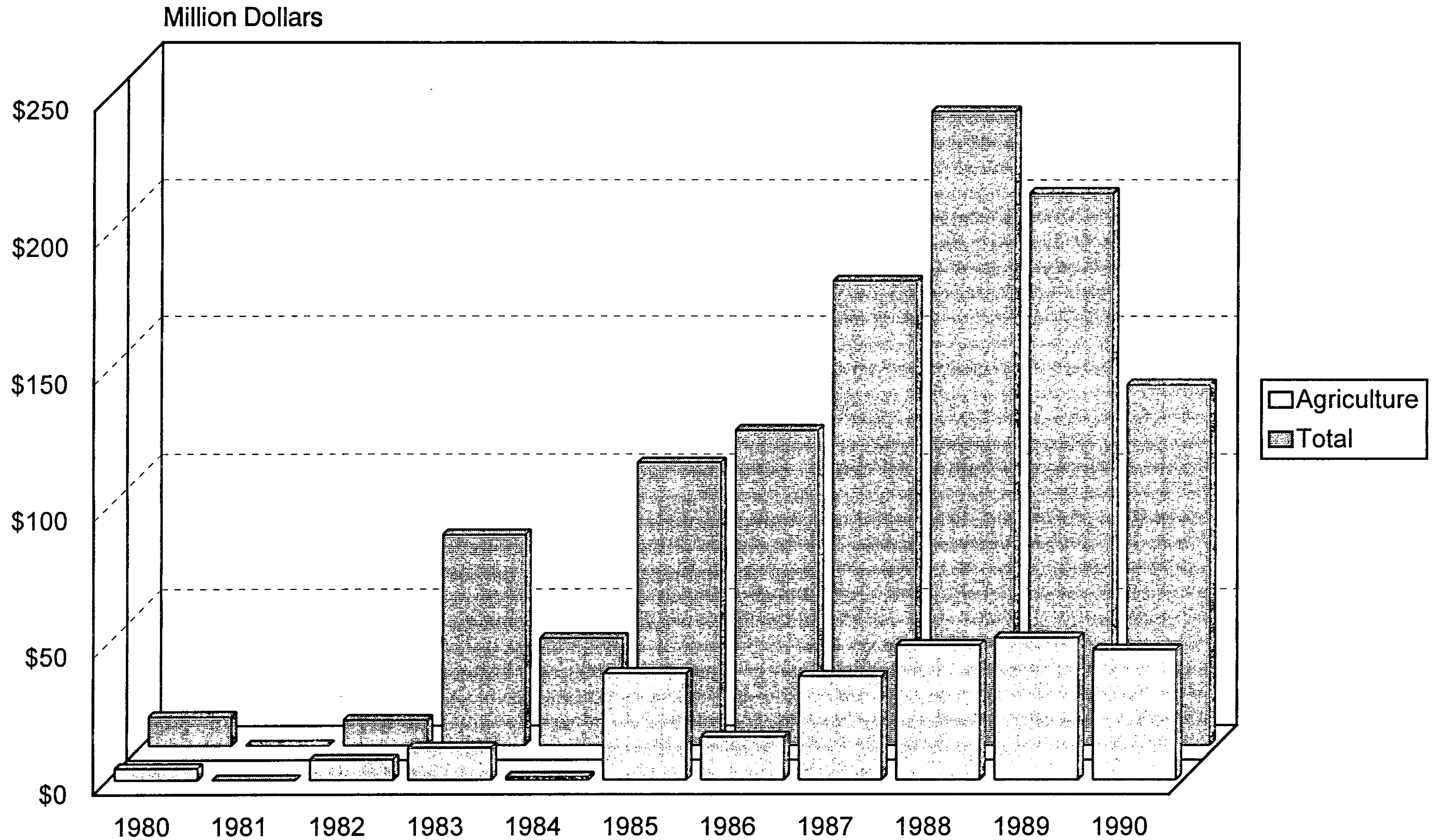
Source: Department of Agriculture, Office of Experiment Stations, 1901, 1921, 1941, 1961. U.S. Department of Agriculture-Cooperative States Research Service, 1981, 1991.

Figure 8. Growth in University and College R&D Performance by Source of Funds, Fiscal 1978-88



Source: National Science Foundation, National Patterns of R&D Resources: 1990, Final Report, NSF 90-316 (Washington, DC: 1990) and Office of Technology Assessment, 1991.

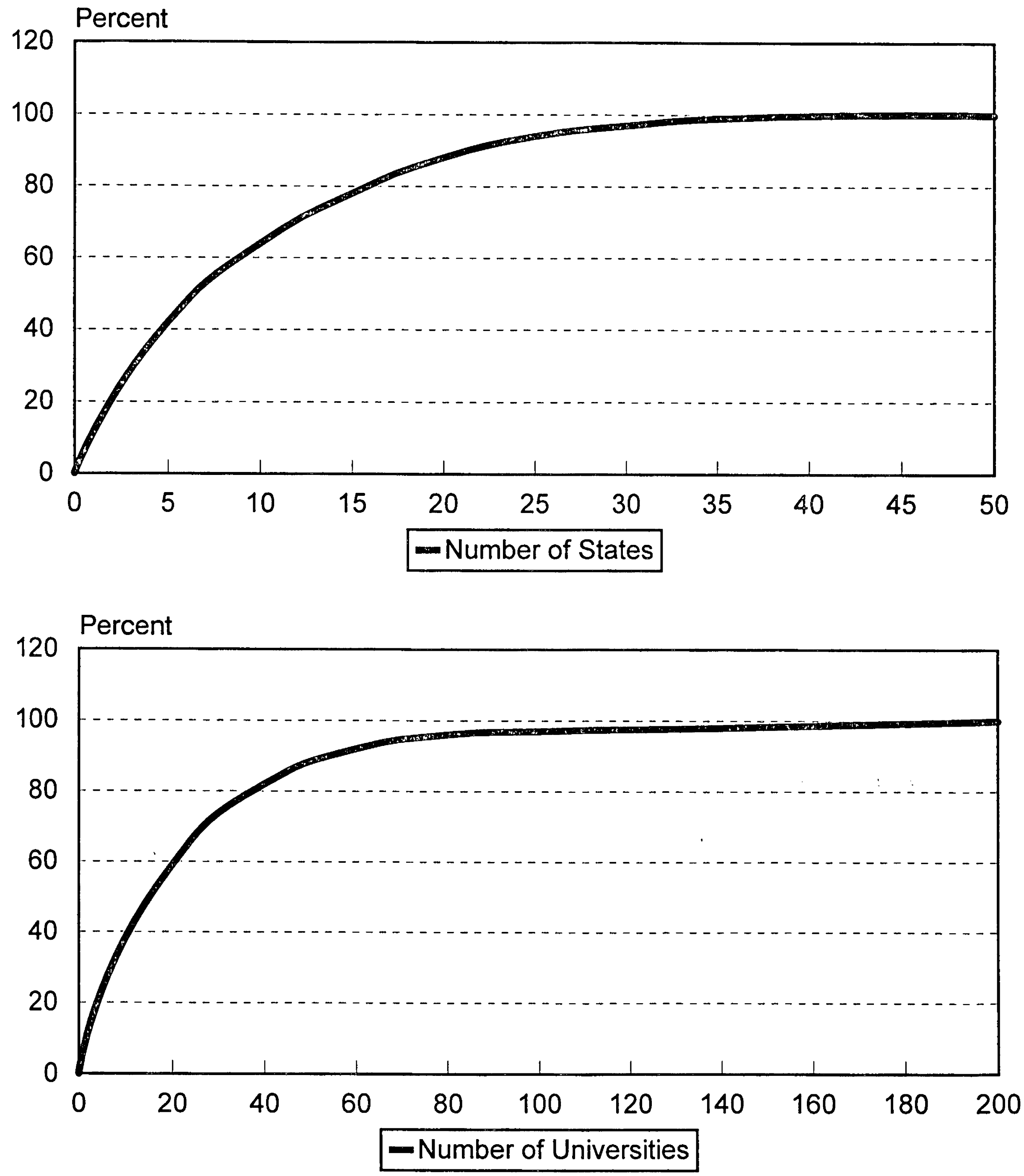
Figure 9. Apparent Academic Earmarks by Appropriations Subcommittee, Fiscal 1980-90



Source: James Savage, Office of the President, University of California, "The Distribution of Academic Earmards in the Federal Government's Appropriations Bills, Fiscal Years 1980-1989, March 7, 1989, and U.S. Congress, Office of Technology Assessment, 1991.

Figure 10. Apparent Academic Earmarks by State and at Universities and Colleges, Fiscal 1980-89

Cumulative Distribution of Academic Earmarks



Source: James Savage, Office of the President, University of California, "The Distribution of Academic Earmards in the Federal Government's Appropriations Bills, Fiscal Years 1980-1989, March 7, 1989, and U.S. Congress, Office of Technology Assessment, 1991.